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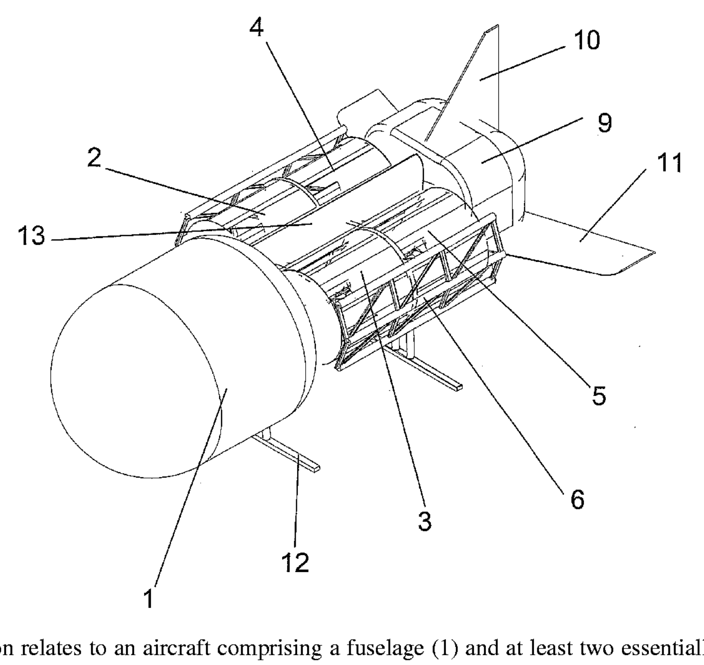
[Fortsetzung auf der nächsten Seite]

(54) Title: AIRCRAFT

(54) Bezeichnung: FLUGGERÄT



(57) Abstract: The invention relates to an aircraft comprising a fuselage (1) and at least two essentially hollow cylindrical lifting bodies (2, 3, 4, 5) which are applied to the fuselage (1) and comprise a plurality of rotor blades (8) which extend over the periphery of the lifting bodies (2, 3, 4, 5), the periphery of the lifting bodies (2, 3, 4, 5) being partially covered by at least one tail surface (49, 50). The aim of the invention is to provide an aircraft with an extremely high degree of manoeuvrability, compact dimensions and economy of fuel. To this end, the lifting bodies (2, 3, 4, 5) are driven by at least one drive unit and respectively comprise a cylindrical axis which is essentially parallel to a longitudinal axis (1a) of the aircraft.

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(57) Zusammenfassung: Die Erfindung betrifft ein Fluggerät mit einem Rumpf (1) und mindestens zwei am Rumpf (1) angebrachten Auftriebskörpern (2, 3, 4, 5), die im Wesentlichen hohlzylindrisch ausgebildet sind und die eine Vielzahl von Rotorblätter (8) aufweisen, die sich über den Umfang des Auftriebskörpers (2, 3, 4, 5) erstrecken, wobei der Umfang des Auftriebskörpers (2, 3, 4, 5) durch mindestens eine Leitfläche (49, 50) teilweise abgedeckt ist. Eine extreme Wendigkeit, kompakte Abmessungen bei gleichzeitiger Treibstoffökonomie werden dadurch erreicht, dass die Auftriebskörper (2, 3, 4, 5) durch mindestens ein Antriebsaggregat angetrieben sind und jeweils eine Zylinderachse aufweisen, die im Wesentlichen parallel zu einer Längsachse (1a) des Fluggerätes ist.

Fluggerät

Die Erfindung betrifft ein Fluggerät mit einem Rumpf und mindestens zwei am Rumpf angebrachten Auftriebskörpern, die im Wesentlichen hohlzylindrisch ausgebildet sind und die eine Vielzahl von Rotorblätter aufweisen, die sich über den Umfang des Auftriebskörpers erstrecken, wobei der Umfang des Auftriebskörpers durch mindestens eine Leitfläche teilweise abgedeckt ist.

Insbesondere ist ein solches Fluggerät mit einem System spezieller Auftriebskörper versehen, die als Rotoren ausgebildet sind, mit einer Drehachse die im Wesentlichen parallel zur Längsachse des Fluggerätes angeordnet ist. Dabei ist jeder Rotor mit einer bestimmten Anzahl tragflügelähnlicher Rotorblätter versehen, die im wesentlichen an zwei scheibenähnlichen Endkörpern derart angeordnet sind, dass während einer vollen Umdrehung des Auftriebskörpers (Rotors) die Mittelachse des Rotorblattes eine Kreisbewegung mit dem Abstand von der Drehachse als Radius ausführt, und das Rotorblatt vorzugsweise während einer vollen Umdrehung individuell in seiner Lage verändert werden kann. Damit kann in jeder augenblicklichen Position des Rotorblattes eine definierte Krafteinwirkung (z. B. Auftriebskraft, Querkraft) auf das Fluggerät erzeugt werden.

Es sind vielfache Anstrengungen unternommen worden, die Vorteile eines Flugzeugs mit denen eines Hubschraubers zu vereinen. Von besonderem Interesse ist dabei die Eigenschaft von Hubschraubern, senkrecht starten und landen zu können, oder auch bei Bedarf in der Luft stillstehen zu können, um beispielsweise Personen zu bergen, bzw. um spezielle Transport- und Montageflugmanöver oder ähnliche Aufgaben zu erfüllen. Nachteilig bei bestehenden Hubschraubern sind, der hohe technische Aufwand, insbesondere im Bereich der Rotorsteuerung, sowie das enorme Absturzrisiko bereits bei geringfügigster Berührung der rotierenden Rotorflügel mit einem Hindernis wie z. B Baumwipfel oder Felswände. Gerade Einsatzbedingungen, wie Alpinbergungen, sind äußerst kritisch, da einerseits eine Position möglichst nahe an z. B. einer Felswand erforderlich wäre, andererseits die geringste Kollision bereits fatale Auswirkungen zur Folge hat; somit kann nur unter Einhaltung entsprechend großer Sicherheitsabstände gearbeitet werden. Ein weiterer Nachteil ist der hohe Treibstoffverbrauch von Hubschraubern, der auch im Reiseflug gegeben ist.

Um diese Nachteile zu vermeiden, sind so genannte VTOL- oder STOL-Flugzeuge entwickelt worden, die vom Aufbau her grundsätzlich Flugzeugen ähneln, jedoch durch verschiedene technische Maßnahmen mit der Fähigkeit ausgestattet sind, senkrecht starten und landen zu können, oder zumindest mit extrem kurzen Start- und Landebahnen auskommen.

Eine solche Lösung ist beispielsweise in der EP 0 918 686 A offenbart. Diese Druckschrift beschreibt ein Flugzeug, das Tragflächen aufweist, die im Wesentlichen durch Querstromrotoren gebildet sind. Auf diese Weise ist es möglich, durch entsprechende Strahlumlenkung einen vertikal nach unten gerichteten Luftstrahl zu erzeugen, um den Senkrechtstart des Fluggerätes zu ermöglichen. Für den Reiseflug kann der Schub entsprechend umgelenkt werden.

Nachteilig bei dieser bekannten Lösung ist zum einen, dass die auf die Auftriebserzeugung optimierten Tragflächen einen hohen Luftwiderstand aufweisen, so dass der Treibstoffverbrauch insbesondere bei höheren Fluggeschwindigkeiten übermäßig groß ist und dass das Fluggerät insgesamt eine relativ große Spannweite aufweist. Es benötigt daher viel Platz und ist auch unter beengten Verhältnissen nicht oder nur schlecht einsetzbar.

Weitere Fluggeräte sind in der US 4,519,562 A beschrieben Die Lösung ist aufwendig und besitzt einen geringen Wirkungsgrad, so dass sich ein solches System nicht durchgesetzt hat. Auch die in der US 6,261,051 B beschriebenen Rotoren sind nicht geeignet, ein senkrecht startendes Fluggerät darzustellen, das praxistauglich ist.

Ein weiteres Fluggerät, das Auftrieb unter Verwendung von abgewandelten Querstromventilatoren erzeugt, ist in der DE 196 34 522 A offenbart. Abgesehen von der Frage der nicht unmittelbar ersichtlichen Funktionsfähigkeit eines solchen Fluggerätes sind auch hier die oben beschriebenen Nachteile gegeben.

Ein weiteres Fluggerät mit einem Querstromrotor als Antriebselement ist aus der US 6,016,992 A bekannt. Auch hier ergibt sich durch den Querstromrotor in Flugrichtung eine sehr große Querschnittsfläche, und der Platzbedarf ist ähnlich hoch wie bei den oben beschriebenen Lösungen.

Ein weiteres bekanntes Fluggerät mit der Möglichkeit des Senkrechtstarts ist in der US 3,361,386 A offenbart. Bei diesem Flugzeug sind extrem variable Tragflächen vorgesehen, die mit Öffnungen zum Gasaustritt versehen sind. Durch den systembedingt schlechten Wirkungsgrad eines solchen Systems ist der Treibstoffverbrauch extrem hoch.

Dem Stand der Technik nahe liegend ist auch jenes Antriebskonzept für Wasserfahrzeuge, welches als Voith - Schneider Antrieb bekannt ist. Dieses seit ca. 75 Jahren bekannte Antriebssystem unterscheidet sich im Wesentlichen dadurch, dass die Schwenkbewegung der einzelnen Schaufeln, während einer vollen Umdrehung des Drehkranzes, in einem festen kinematischen Verhältnis zueinander abläuft. Damit ist eine Vorschubkraft immer nur in eine einzige Richtung möglich. Im Unterschied dazu ist bei dem hier vorgestellten erfinderischen rotierenden Auftriebskörper, unabhängig von einer ersten Kraftkomponente, z. B. gleich bleibende vertikale Auftriebskomponente, eine zweite Kraftkomponente in Querrichtung erzeugbar.

Die gegenständliche Erfindung bezieht sich auf weitere Ausführungsvarianten von VTOL-Fluggeräten, die mit rotierenden Auftriebskörpern ausgerüstet sind, deren Drehachse im Wesentlichen parallel zur Längsachse des Fluggerätes angeordnet ist.

Aufgabe der vorliegenden Erfindung ist es, ein Fluggerät zu schaffen, das einen senkrechten Start und eine senkrechte Landung ermöglicht, das in der Luft einen Schwebezustand einnehmen kann, mit einer Beweglichkeit, die eine langsame Vorwärts-, Rückwärts-, parallele Seitwärtsbewegung nach Backbord oder Steuerbord sowie eine Drehbewegung um die Vertikalachse in bzw. gegen den Uhrzeigersinn ausführen kann, und das gleichzeitig für eine hohe Reisefluggeschwindigkeit geeignet ist. Durch die gewählte Ausbildung der äußeren geometrischen Form des Fluggerätes ist der Übergang von einem Schwebezustand in eine Vorwärtsbewegung mit hoher Reisefluggeschwindigkeit zu gewährleisten. Insbesondere soll dabei eine hohe Treibstoffökonomie erreicht werden, bei vergleichsweise geringem, technischem Aufwand. Ein weiterer Anspruch betrifft die Erfüllung der höchsten Sicherheitstechnischen Standards, die dem Fluggerät selbst bei einem Totalausfall der Antriebsmotore eine sichere Landung ermöglichen. Weiters sollen die rotierenden Auftriebskörper mit einer Verkleidung derart geschützt werden, dass das Fluggerät auch sehr nahe an Hindernisse (z. B. Felswand, Hochhauswand) heran manövriert werden kann und dass selbst bei Berührung des Fluggerätes mit einem Hindernis, bedingt durch die gegen Kollision geschützten rotierenden Elemente des Auftriebskörpers, ein Absturz sicher verhindert werden kann. Ein für den Piloten sicheres und kollisionsfreies Verlassen des Fluggerätes mittels Schleudersitz ist ebenfalls möglich, und stellt einen weiteren Anspruch dar.

Erfindungsgemäß werden diese Aufgaben dadurch gelöst, dass die Auftriebskörper durch mindestens ein Antriebsaggregat angetrieben sind und jeweils eine Zylinderachse aufweisen, die im Wesentlichen parallel zu einer Längsachse des Fluggerätes ist. Dabei ist jeder Rotor mit einer bestimmten Anzahl tragflügelähnlicher Rotorflügel versehen, die im wesentlichen an zwei scheibenähnlichen Endkörpern derart angeordnet sind, dass während einer vollen Umdrehung des Auftriebskörpers (Rotors) die Mittelachse des Rotorblattes eine Kreisbewegung mit dem Abstand von der Drehachse als Radius ausführt, und das Rotorblatt vorzugsweise während einer vollen Umdrehung individuell in seiner Lage verändert werden kann. Damit kann in jeder augenblicklichen Position des Rotorblattes eine definierte Krafteinwirkung (z. B. Auftriebskraft, Querkraft) auf das Fluggerät erzeugt werden. Diese Veränderung der Lage kann als Ganzes erfolgen, es ist aber auch möglich, dass der hintere Abschnitt des Rotorblattes unabhängig vom vorderen Abschnitt schwenkbar ist, um so eine jeweils optimale Tragflügelform zu erreichen.

Durch geeignete Wahl der Anordnung der Auftriebskörper im Fluggerät ist zudem der Raum oberhalb der Pilotenkanzel freigehalten, sodass dem Piloten ein sicheres und kollisionsfreies Verlassen des Fluggerätes mittels Schleudersitz möglich ist (dies ist z. B. bei einem Hubschrauber nicht möglich).

Für den militärischen Einsatzbereich bietet diese Anordnung der Auftriebskörper eine weitere Möglichkeit und zwar können für Aufklärungszwecke Radar- bzw. andere optische Geräte auch oberhalb des Fluggerätes angeordnet werden. Mit diesem Fluggerät ist es nicht notwendig eine schützende Geländeformation zu verlassen, ohne zuvor mit einem flexibel mit dem Fluggerät verbundenen Aufklärungsgerät, welches z. B. vertikal oberhalb des im Schwebezustand verharrenden Fluggerätes in die Höhe verbracht und anschließend wieder eingeholt werden kann, das Geschehen hinter der Geländeformation erfasst und beurteilt zu haben.

Die erfindungsgemäße Lösung erlaubt ein Manövrieren des Fluggeräts auch bei niedrigen Geschwindigkeiten oder im Schwebflug, ohne die Drehzahl des Antriebsaggregats verändern zu müssen, da Richtung und Stärke der Auftriebskräfte durch die Steuerung der Rotorblätter in weiten Grenzen variierbar sind. Dadurch wird eine extrem große Wendigkeit erreicht.

Durch die Anordnung der Auftriebskörper parallel zum Rumpf können mehrere Vorteile gleichzeitig erreicht werden. Zum einen können die Auftriebskörper einen relativ großen Durchmesser aufweisen, ohne die Querschnittsfläche in Fortbewegungsrichtung allzu sehr zu erhöhen, wodurch auch im schnellen Reiseflug ein geringer Treibstoffbedarf gegeben ist. Zum anderen ist das erfindungsgemäße Fluggerät äußerst kompakt aufgebaut und benötigt somit nicht nur wenig Platz in einem Hangar oder dergleichen, sondern ist auch extrem wendig. Dies ermöglicht beispielsweise die Landung auf Waldlichtungen oder im inner städtischen Bereich zwischen Bauwerken, wo die Landung eines Hubschraubers aufgrund des vorgegebenen Rotordurchmessers nicht mehr möglich wäre. Überdies sind die als Rotor ausgebildeten Auftriebskörper besonders robust im Aufbau und umfassen im Allgemeinen außer den Rotorblättern selbst keine weiteren beweglichen Teile, so dass der technische Aufwand vertretbar ist. Durch die Anbringung der Auftriebskörper im unmittelbaren Nahbereich des Rumpfes ist die mechanische Beanspruchung der Rotoraufhängungen sehr gering, so dass eine entsprechende Leichtbauweise möglich ist, die wiederum zur Treibstoffersparnis beiträgt.

Eine besonders raumökonomische Anordnung der einzelnen Bauteile ist gegeben, wenn die Auftriebskörper im oberen Bereich des Rumpfes angeordnet sind. Zusätzlich wird dadurch eine besonders aerodynamisch günstige Ausführung erreicht, da der Ansaugbereich völlig frei und unbehindert durch sonstige Bauteile des Fluggerätes angeströmt werden kann.

Eine weitere besonders begünstigte Ausführungsvariante der Erfindung sieht vor, dass die Auftriebskörper durch Gasturbinen gegenläufig angetrieben sind. Ähnlich wie bei Hubschraubern ist auch hier bei Einsatz von Gasturbinen ein besonders günstiges Verhältnis von Leistung zu Eigengewicht gegeben. Ein zusätzlicher Vorteil gegenüber Hubschraubern besteht bei der vorliegenden Erfindung darin, dass die Drehzahlen der rotierenden Auftriebskörper wesentlich höher liegen als die von üblichen Hubschrauberrotoren, so dass sich der bauliche Aufwand für Getriebe wesentlich verringert. Je nach Baugröße, Einsatzzweck und Sicherheitsvorschriften können die beiden Rotoren von einer gemeinsamen Gasturbine angetrieben werden, oder es kann jedem Auftriebskörper eine eigene Gasturbine zugeordnet werden.

Der Wirkungsgrad der Auftriebskörper kann insbesondere dadurch weiter verbessert werden, dass die im Rotor beweglich angeordneten Rotorblätter aus mindestens einer feststehenden Achse und zwei unabhängig voneinander beweglichen Rotorblattsegmenten bestehen, damit die Rotorblattgeometrie in jedem Augenblick in jeder aktuellen Position optimal an die jeweilige Situation angepasst werden kann; damit können sowohl die Auftriebskräfte und Seitenkräfte optimiert und die Widerstandskräfte minimiert werden.

Besonders hohe Reisegeschwindigkeiten können dadurch erreicht werden, dass zusätzliche Triebwerke zur Erzeugung eines Schubs für den Vortrieb des Fluggerätes vorgesehen sind. An sich ist es möglich und grundsätzlich für geringere Reisegeschwindigkeiten auch ausreichend, dass der Vortrieb durch die verstellbaren Rotorflügel der Auftriebskörper erzeugt wird, in dem das Fluggerät in eine nach vorne abgesenkte Lage gebracht wird und aus der resultierenden Auftriebskraft eine Vorschubkraft abgeleitet wird. Die Reisegeschwindigkeit ist jedoch in diesem Fall begrenzt, so dass für höhere Reisegeschwindigkeiten in vorteilhafter Weise zusätzliche Triebwerke eingesetzt werden. Diese können beispielsweise als Mantelstromtriebwerke ausgebildet werden. Der Start- und Landevorgang kann dadurch unterstützt werden, dass die zusätzlichen Triebwerke schwenkbar angeordnet sind. Einerseits kann dadurch die Auftriebskraft erhöht werden, wenn der Triebwerksstrahl senkrecht nach unten gerichtet ist, und andererseits kann durch entsprechende Steuerung des Schwenkwinkels die Manövrierbarkeit zusätzlich erhöht werden.

Der Treibstoffverbrauch beim Senkrechtstart bzw. bei der Landung und beim Schwebeflug wird maßgeblich von der umgesetzten Luftmenge beeinflusst. Es ist daher insbesondere günstig, wenn sich die Auftriebskörper über mindestens 40%, vorzugsweise über mindestens 70% der Länge des Rumpfes erstrecken.

Auf diese Weise ist es möglich, bei vorgegebener Querschnittsfläche eine größtmögliche Auftriebsleistung der Auftriebskörper zu erzielen.

Die Manövrierfähigkeit, insbesondere im Schwebeflug und beim Start bzw. bei der Landung, kann dadurch verbessert werden, dass im Bereich der Luftauslassöffnungen verstellbare Leitschaufeln vorgesehen sind. Bei niedrigen Fluggeschwindigkeiten ist die Möglichkeit der Steuerung durch das Leitwerk stark eingeschränkt, so dass sich eine ausreichende Manövrierbarkeit durch die individuelle Verstellbarkeit der Rotorblätter ergibt. Um eine Rotation des Fluggerätes auch um eine vertikale Achse zu ermöglichen, ist es in diesem Zusammenhang besonders bevorzugt, wenn die verstellbaren Rotorblätter in zwei paarweise gegenläufigen Auftriebskörpern angeordnet sind und aus jeweils zwei Segmenten bestehen, die unabhängig voneinander betätig bar sind. Weitere verstellbare Leitschaufeln, die um eine Querachse des Fluggerätes schwenkbar sind, ermöglichen eine Vorwärts- und Rückwärtsbewegung im Schwebezustand, die besonders fein steuerbar ist.

Weiters ist es besonders bevorzugt, wenn die Auftriebskörper mit einer äußeren Verkleidung als mechanischen Schutz der Rotorblätter gegen eine Kollision mit einem festen Hindernis ausgebildet sind. Dies bedeutet, dass die Verkleidung nicht nur zur Aufnahme der Lagerung der Rotorwelle, sondern auch in mechanisch entsprechend robuster Weise ausgebildet ist, um die Auftriebskörper gegenüber einer Beschädigung zu schützen, wenn das Fluggerät mir geringer Relativgeschwindigkeit eine Kollision mit einem Hindernis erleidet.

In der Folge wird die vorliegend Erfindung anhand der in den Figuren dargestellten Ausführungsbeispiele näher erläutert.

Es zeigen:

Fig. 1 eine schematische Ansicht eine ersten Ausführungsvariante eines erfindungsgemäßen Fluggerätes in axonometrischer Darstellung;

Fig. 2 eine Seitenansicht des Fluggerätes von Fig. 1;

Fig. 3 einen Schnitt des Fluggerätes von Fig. 1 entlang der Linie A – A in Fig. 2;

Fig. 4 einen Schnitt des Fluggerätes von Fig. 1 entlang der Linie A – A in Fig. 2 mit der Darstellung einer geöffneten bzw. geschlossenen Verkleidung der Auftriebskörper, wie sie für eine hohe Reisegeschwindigkeit vorgesehen sind;

Fig. 5 eine Ansicht des Fluggerätes von Fig. 1 von vorne;

Fig. 6 eine Ansicht des Fluggerätes von Fig. 1 von oben;

Fig. 7 und Fig. 7b schematisch einen Auftriebskörper des Fluggerätes von Fig. 1;

Fig. 8, Fig. 8a und Fig. 8b die Anordnung, Drehrichtung und Wirkungsweise des Auftriebskörpers des Fluggerätes von Fig. 1;

Fig. 9, Fig. 9a und Fig. 9b ein Rotorblatt mit zwei beweglichen Segmenten im Querschnitt in der Stellung Auftriebskräfte neutral, maximaler Auftrieb und negativer Auftrieb des Fluggerätes von Fig. 1;

Fig. 10, Fig. 10a, Fig. 10b, Fig. 10c und Fig. 10d Rotorblätter-Anstellungen in ausgewählten Positionen entlang der Drehrichtung des Auftriebskörpers des Fluggerätes von Fig. 1;

Fig. 11 eine Variante eines Auftriebskörpers mit einteiligen Rotorblättern und mechanischer Anstellung der Rotorblätter eines Auftriebskörpers des Fluggerätes von Fig. 1;

Fig. 12 die einzelnen Auftriebskräfte der Auftriebskörper zur Erzielung eines stabilen Gleichgewichtes in der Luft des Fluggerätes von Fig. 1;

Fig. 12a und Fig. 12b die Lage der Einzel- und Gesamtmassenschwerpunkte des Fluggerätes von Fig. 1;

Fig. 13 die nach vorne geneigte Lage des Fluggerätes von Fig. 1 zur Erzielung einer Vorwärtsantriebskomponente für eine langsame Vorwärtsbewegung;

Fig. 14, Fig. 14a, Fig. 14b, Fig. 14c und Fig. 14d die Auftriebskörperanordnung und die Anstellung der Rotorblätter zur Erzeugung von Seitenkräften für die Querbewegung des Fluggerätes von Fig. 1;

Fig. 15 die Erzeugung einer paarweise gegensinnig wirkenden Kraftkomponente quer zur Längsachse des Fluggerätes zur Erzeugung einer Drehbewegung des Fluggerätes um die Vertikalachse;

Fig. 16, Fig. 16a, Fig. 16b und Fig. 16c eine besondere Variante eines Auftriebskörpers mit "doppelter" Länge und schränk baren Rotorblättern zur Erzeugung unterschiedlicher Auftriebs- bzw. Querkräfte des Fluggerätes von Fig. 1;

Fig. 17 die Anstellung der Rotorblätter während eines Sinkfluges im freien Fall zwecks Autorotation des Auftriebskörpers z. B. nach einem Motorausfall des Fluggerätes von Fig. 1;

Fig. 18 und Fig. 18a bis Fig. 18g eine Ausführungsvariante eines Fluggerätes mit nur zwei Auftriebskörpern, die gegenläufig angetrieben, hintereinander in einer Mittelachse des Fluggerätes angeordnet sind;

Fig. 19, Fig. 19a und Fig. 19b eine Ausführungsvariante eines Fluggerätes mit einem System gegenläufiger Querstromrotore mit einer gemeinsamen Drehachse;

Fig. 20 eine schematische Ansicht eines erfindungsgemäßen Fluggerätes mit der Anordnung eines mit dem Fluggerät flexibel verbundenen Aufklärungsgerätes;

Fig. 21 eine weitere Ausführungsvariante der Erfindung in einer Darstellung von vorne;

Fig. 22 die Ausführungsvariante von Fig. 21 von oben;

Fig. 23 die Ausführungsvariante von Fig. 21 in einer axonometrischen Darstellung;

Fig. 24 eine weitere Ausführungsvariante der Erfindung in einer seitlichen Darstellung;

Fig. 25 die Ausführungsvariante von Fig. 24 von vorne;

Fig. 26 eine schematische Darstellung zur Erklärung der Ansteuerung der Rotorblätter; und

Fig. 27 ein Detail von Fig. 26.

Das Fluggerät gemäß Fig. 1 bis Fig. 6 besteht aus einem Rumpf 1 mit einer Längsachse 1a und aus vier parallel zu dieser Längsachse 1a in bevorzugter Weise oberhalb der Schwerpunktlage angeordneten Auftriebskörpern 2, 3, 4 und 5, die von einem Seitenschutz 6 gegen Kollision mit einem festen Hindernis geschützt sind. Im hinteren Bereich 9 befinden sich in an sich bekannter Weise ein Höhenleitwerk 11 und ein Seitenleitwerk 10, vorzugsweise auch das Antriebsaggregat z. B. eine od. zwei Gasturbine(n) und das Getriebe sowie zusätzliche Antriebsaggregate (hier nicht näher dargestellt), ausgeführt als z. B. Mantelstromtriebwerke, die dem Fluggerät eine hohe Reisefluggeschwindigkeit verleihen bzw. bei entsprechender schwenkbarer Ausführung den Start- und Landevorgang unterstützen können. Kufen bzw. ähnliche Standbeine 12 stützen das Fluggerät am Boden ab. Mittels Längsstreben 13, 14, die eine strömungsgünstige Querschnittsform oder eine gewichtsoptimierte Fachwerkskonstruktion aufweisen können, ist der hintere Bereich des Fluggerätes mit dem vorderen Bereich verbunden, weiters ist mit den Längstreben und dem Seitenschutz eine stabile Konstruktion für eine Lagerung (hier nicht näher dargestellt) der Auftriebskörper 2, 3, 4, 5 im mittleren Bereich vorgesehen.

In Fig. 2 sind die Längenverhältnisse ersichtlich, wonach die Länge der rotierenden Auftriebskörper 2, 3, 4, 5 etwa 50 % der Gesamtlänge, vorzugsweise 30 bis 70 %, des Fluggerätes entspricht. In Fig. 3 sind die gegenläufig um die Drehachsen 7a, 7b rotierenden Auftriebskörper 2, 3, 4, 5 mit den Drehrichtungen 20a, 20b und den zur Erzeugung der Auftriebskraft erforderlichen Rotorblättern 8 ersichtlich. Für eine hohe Reisegeschwindigkeit bei gleichzeitiger Treibstoffökonomie, sind die zusätzlichen Antriebsaggregate, hier nicht näher dargestellt, vorgesehen und zur Reduzierung des Luftwiderstandes, werden die Auftriebskörper 2, 3, 4, 5, die bei einer hohen Reisegeschwindigkeit nicht den erforderlichen Auftrieb erzeugen können, mittels geeigneter Verkleidungsschürzen strömungsgünstig im Fluggerät abgedeckt. Gemäß Fig. 4 können diese Verkleidungsschürzen als kompakte Flächen 40a, 40b ausgebildet sein (wie z. B. in Fig. 4 im geöffneten Zustand, für eine optimale Wirkung der Auftriebskörper, dargestellt), bzw. als ein System von Lamellen 40a', 40b', 41a', 41b', die wahlweise zu einer geschlossenen Verkleidung oder für einen ungehinderten Luftdurchlass angestellt werden können.

Wie in Fig. 7 dargestellt, besteht ein Auftriebskörper 2, 3, 4, 5 im Wesentlichen aus einer Drehachse 7, aus zwei Endscheiben 2a - 2b, 3a – 3b, 4a – 4b, 5a – 5b mit dem Durchmesser D 23b und einer bestimmten Anzahl (vorzugsweise 4 bis 10) von Rotorblättern 8, die beweglich um eine Schwenkachse 8a in den beiden Endscheiben (z. B. 2a – 2b) angeordnet sind, und bei einer vollen Umdrehung eine Kreisbahn 23a mit dem Radius R 23 beschreiben. Die Tiefe des Rotorblattes t 8e ist Abhängig von der Größenordnung der Gesamtkonstruktion und beträgt ca. 30 bis 50% des Kreisbahnradius R 23, die Länge L 8d des Rotorblattes 8 beträgt vorzugsweise ca. 25 bis 35% der Gesamtlänge des Fluggerätes. Im Betriebszustand rotiert der Auftriebskörper mit Nenndrehzahl (vorzugsweise ca. 750 bis 3000 1/min) um die Drehachse 7, und während einer vollen Umdrehung werden die Rotorblätter 8 in jeder augenblicklichen Position individuell in Bezug auf die Tangente 23b der Kreisbahn 23a mit dem Radius R 23 angestellt, sodass im Bereich der oberen und unteren Extremlage maximale Auftriebskräfte erzeugt werden können und in den beiden vertikalen Extrempositionen ausschließlich Strömungswiderstandskräfte auf das Rotorblatt einwirken. Die bevorzugte Anordnung der Drehrichtung 20 der Auftriebskörper im Fluggerät ist gegenläufig.

In Fig. 8 sind die Strömungsverhältnisse näher dargestellt, wobei aufgrund der Rotorblättergeometrie die Tragflügeltheorie maßgeblich ist, der zufolge jeweils unterhalb des angestellten Rotorblattes bei einer definierten Relativgeschwindigkeit eine Druckerhöhung und oberhalb ein Unterdruck erzeugt wird. Die entsprechenden Kraftkomponenten, die auf ein Rotorblatt einwirken, resultieren aus diesen beiden Druckkomponenten. Bei entsprechender Anstellung der Rotorblätter relativ zur Tangente 23b der Kreisbahn 23a während einer vollen Umdrehung der

Auftriebskörper 2, 3, 4, 5 mit Nenndrehzahl wird Umgebungsluft bevorzugt von oben angesaugt 18a, in den rotierenden Auftriebskörper hineingepresst 18b, nach unten angesaugt 19a und hinausgepresst 19b. Eine optimale Ausführungsvariante ist in den Fig. 9, Fig. 9a und Fig. 9b dargestellt. Bei dieser Ausführungsvariante besteht das Rotorblatt 8 aus mindestens drei Elementen und zwar einer stabilen Schwenkachse 8a, einer beweglichen Rotorblattnase 8b und einer beweglichen Rotorblattspitze 8c. Für den Normalbetrieb sind die Rotorblattnase 8b um den Winkel α 21a, vorzugsweise um +/- 3° - 10° relativ zur Tangente der Kreisbahn 23a schwenkbar und die Rotorblattspitze 8c um den Winkel β 21b, vorzugsweise um +/- 3° bis 10° relativ zur Tangente der Kreisbahn 23a schwenkbar. Für den Sonderfall "Autorotation" sind Rotorblattspitze und Rotorblattnase um > 90°, vorzugsweise ca. 105° aus schwenkbar. Gemäß Fig. 9a ist eine vertikale Kraftkomponente Fa 22 in Richtung Drehachse 7 des Auftriebskörpers erzeugbar, wenn bei Nenndrehzahl in der oberen Extremposition die Rotorblattnase 8b mit dem Winkel $\alpha < 0°$ und die Rotorblattspitze mit dem Winkel $\beta > 0°$, jeweils bezogen auf die Tangentenrichtung 23b der Umlaufkreisbahn 23a, angestellt werden und vice versa gemäß Fig. 9b ist eine vertikale Kraftkomponente Fa 22 entgegen Richtung Drehachse 7 des Auftriebskörpers erzeugbar, wenn bei Nenndrehzahl in der oberen Extremposition die Rotorblattnase 8b mit dem Winkel $\alpha > 0°$ und die Rotorblattspitze mit dem Winkel $\beta < 0°$, jeweils bezogen auf die Tangentenrichtung 23b der Umlaufkreisbahn 23a, angestellt werden. In Fig. 10 sind die beiden gegenläufig angetriebenen Auftriebskörper mit den zur Erzeugung einer maximalen Auftriebskraft bei Nenndrehzahl optimalen Anstellungen der Rotorblätter in den unterschiedlichen Positionen im Detail dargestellt. Fig. 10a (Detail W von Fig. 10) zeigt die Winkelverhältnisse der Rotorblattnase und Rotorblattspitze beim Eintritt in die obere Umlaufbahn nach dem Verlassen der neutralen Vertikalposition, Fig. 10b (Detail X von Fig. 10) zeigt die Winkelverhältnisse der Rotorblattnase und Rotorblattspitze in der oberen Extremposition der Umlaufbahn, Fig. 10c (Detail Y von Fig. 10) zeigt die Winkelverhältnisse der Rotorblattnase und Rotorblattspitze in der oberen Umlaufbahn vor dem Eintritt in die neutrale Vertikalposition, Fig. 10d (Detail Z von Fig. 10) zeigt die Winkelverhältnisse der Rotorblattnase und Rotorblattspitze in der unteren Extremposition der Umlaufbahn.

Eine vereinfachte Variante eines Auftriebskörpers ist in Fig. 11 dargestellt. Diese Variante unterscheidet sich von der zuvor beschriebenen dadurch, dass die Rotorblätter 8 einteilig um eine Schwenkachse schwenkbar ausgeführt sind und mechanisch mit Hilfe eines Kopplungsgliedes 28, welches als Gestänge oder einer sonstigen Konstruktion, zur Übertragung von Zug- und Druckkräften, ausgeführt sein kann, angesteuert werden können. In einer bevorzugten Ausführungsvariante wird das Kopplungsglied in einer speziellen Kulisse 29, 30, die in den beiden

Endscheiben 2a-2b, ... 5a-5b untergebracht ist, derart geführt, dass, zur Erzeugung einer optimalen Auftriebskraft bei Nenndrehzahl, während einer vollen Umdrehung des Auftriebskörpers 2, 3, 4, 5 um die Drehachse 7 mit der Drehrichtung 20 und dem jeweils aktuellen Drehwinkel δ 31 das Rotorblatt 8 in der oberen Extremlage mit dem Winkel α' 21c, in der unteren Extremlage mit dem Winkel α'' 21d > α' 21c und in den beiden seitlichen Extremlagen jeweils vertikal, d. h. parallel zur Tangentenrichtung der Umlaufkreisbahn 23a, angestellt werden kann. Seitenkräfte zur Erzeugung einer Seitwärtsbewegung bzw. einer Drehbewegung um die Vertikalachse des Fluggerätes werden durch eine entsprechende Verstellung der Kulisse 29, 30 in Querrichtung 27x erreicht, wobei unter Beibehaltung der Drehzahl des Auftriebskörpers die Auftriebskräfte unverändert bleiben. Eine Beeinflussung der Auftriebskräfte ist durch Verstellung der Kulisse 29, 30 durch Veränderung der Mittelpunktslage 27 in Vertikalrichtung 27z vorgesehen. Die Mittelachse 27y liegt parallel zur Drehachse 7. Ein Fluggerät, ausgerüstet mit einem Auftriebskörper gemäß dieser Ausführungsvariante wäre sogar vollständig mechanisch steuerbar.

Eine stabile Gleichgewichtslage in Fig. 12 bis Fig. 12b in der Luft ist dadurch gegeben, dass jeder einzelne Auftriebskörper 2, 3, 4, 5 individuelle Auftriebskräfte A_1 bis A_4 35a, 35b, 35c und 35d erzeugen kann und damit ein Gleichgewichtszustand zum Gesamtmassenschwerpunkt S 32 der Gesamtmasse m 33 bzw. zu den Hauptteilmassenschwerpunkten 32a der Teilmasse aus Pilotenkanzel m_1 33a, mit dem Teilschwerpunktsabstand s_1 34a, und 32b der Teilmasse aus dem rückwärtigen Bereich des Fluggerätes m_2 33b, mit dem Teilschwerpunktsabstand s_2 34b, und dem seitlichen Schwerpunktsabstand s_3 34c des Gesamtmassenschwerpunkt S 32 der Gesamtmasse m 33 zu jeder Situation hergestellt werden kann. Damit kann jederzeit auch auf sich verändernde Gleichgewichtslagen reagiert werden.

Nach Erreichen einer definierten Höhenposition, die mittels der rotierenden Auftriebskörper 2, 3, 4, 5 eingenommen werden kann, ist ein Übergang von einem Schwebezustand in eine langsame Vorwärtsbewegung bzw. Rückwärtsbewegung dadurch möglich, dass das Fluggerät eine Neigungslage (Fig. 13) einnimmt und aus der resultierenden Auftriebskraft 35a, 35b der Auftriebskörper eine Kraftkomponente 35a', 35b' abgeleitet werden kann, die eine Vorwärts- bzw. Rückwärtsbeschleunigung ermöglicht, während die vertikale Kraftkomponente 35a'', 35b'' das Fluggerät weiterhin vertikal im Gleichgewicht hält.

Eine Bewegung des Fluggerätes quer zur Längsachse ist im Schwebezustand durch eine spezielle Anstellung der Rotorblätter zur Tangentenrichtung 23b der Bewegungsbahn 23a der Rotorblätter möglich. In Fig. 14 ist eine Querbewegung mit der Geschwindigkeit v_x 36 dargestellt, die dadurch erreicht wird, dass gemäß Fig. 14a die Rotorblätter in der Position der Vertikalen Extremlage in eine entsprechende Neigungslage 21 gebracht werden, sodass von einer Richtung Luft angesaugt 18a und quasi quer durch das Fluggerät ausgepresst 19b wird; auch hier ist die Tragflügeltheorie anzuwenden. In Fig. 14b ist die Rotorblattstellung in einer neutralen Lage dargestellt, während gemäß Rotorblattanstellung nach Fig. 14c auf das Fluggerät eine Kraftkomponente Fq 22 von der Drehachse weg ausgeübt werden würde und eine Bewegung mit der Geschwindigkeit v_x 36 von rechts nach links zur Folge hätte und gem. Darstellung nach Fig. 14d auf das Fluggerät eine Kraftkomponente Fq 22 in entgegen gesetzter Richtung, in Richtung der Drehachse ausgeübt werden würde und eine Bewegung mit der Geschwindigkeit v_x 36 von links nach rechts zur Folge hätte. Durch paarweise gegensinnige Erzeugung der Kraftkomponenten Fq 22 im vorderen und rückwärtigen Bereich des Auftriebskörpers gemäß Fig. 15, kann eine Drehbewegung 36a im Schwebezustand um die Vertikalachse 1b des Fluggerätes im bzw. gegen den Uhrzeigersinn erreicht werden.

Die gleichen wie zuvor beschriebenen Effekte und Manöver lassen sich auch dann erreichen, wenn anstatt vier nur zwei paarweise gegenläufig angeordnete Auftriebskörper 2, 3 eingesetzt werden, die jedoch mit einer doppelten Länge 2L 8d ausgeführt werden (Fig. 16). Bei dieser Ausführungsvariante sind die Rotorblätter elastisch um die Schwenkachse 8a deformierbar. Die Rotorblattnase 8b und die Rotorblattspitze 8c können parallel an beiden Enden verschoben werden oder unterschiedlich. In Fig. 16a ist eine neutrale Lage des Rotorblattes (Schnitt II - II von Fig. 16) dargestellt, wie sie bei einer gegensinnigen Verschiebung der beiden Enden des Rotorblattes gem. Fig. 16b (Schnitt I - I von Fig. 16) und Fig. 16c (Schnitt III - III von Fig. 16) entsteht. Damit ist es möglich, bei einer Ausführungsvariante mit nur zwei gegensinnig rotierenden Auftriebskörpern, unterschiedliche Schwerpunktslagen im Flug zu korrigieren, Vorwärts- und Rückwärtsbewegungen mit geringer Fluggeschwindigkeit auszuführen und Drehbewegungen um die Vertikalachse ausführen zu können.

Bei genügend großer Verstellmöglichkeit der Schwenkbewegung des Rotorblattes ist im Sinkflug nach einem z. B. Ausfall eines Antriebsaggregates oberhalb einer kritischen Flughöhe eine Autorotation der Auftriebskörper und dadurch ein sicherer Landevorgang möglich. Fig. 17 zeigt die entsprechenden Anstellungswinkel α 21 der Rotorblätter und den Relativluftstrom 41 sowie die Rotationsrichtung 20 der Auftriebskörper, wenn das Fluggerät mit der Sinkgeschwindigkeit 40 im freien Fall in vertikaler Richtung nach unten fällt.

Eine weitere Ausführungsvariante eines Fluggerätes mit zwei gegensinnig rotierenden Auftriebskörpern 2, 3 ist in Fig. 18 dargestellt, wobei Fig. 18a eine Seitenansicht und Fig. 18b eine Frontansicht zeigt. Die beiden gegensinnig rotierenden Auftriebskörper sind entlang der Mittelachse des Fluggerätes entlang einer gemeinsamen Drehachse hintereinander angeordnet. Fig. 18c zeigt einen Schnitt I - I von Fig. 18a, worin die Lagerung der Drehachse der Auftriebskörper 2, 3 und die Seitenschutzverkleidung dargestellt sind. Fig. 18d zeigt den Schnitt II - II von Fig. 18a und Fig. 18e den Schnitt III - III von Fig. 18a woraus die Anordnung und Drehrichtung der beiden hintereinander liegenden Auftriebskörper ersichtlich sind, in der Darstellung für einen üblichen Schwebezustand bzw. Steigflug. Fig. 18f zeigt den Schnitt II - II von Fig. 18a und Fig. 18g zeigt den Schnitt III - III von Fig. 18a in der Stellung der Rotorblätter zur Erreichung der Autorotation im freien Sinkflug nach z. B. Ausfall eines Antriebsaggregates.

Fig. 19 zeigt eine weitere Ausführungsvariante eines Fluggerätes, geeignet für den vertikalen Start- und Landevorgang, ausgeführt jedoch mit Auftriebskörpern 36, 37, 38, 39, die als Querstromrotoren ausgebildet sind. Fig. 19a zeigt die Draufsicht eines derartigen Fluggerätes und Fig. 19b eine Darstellung gemäß Schnitt I - I von Fig. 19. Bei dieser Ausführungsvariante sind so genannte Querstromrotoren im Einsatz, die mit äußeren Strömungsleiteinrichtungen 6 versehen sind, die entsprechend verstellbar angeordnet sind und damit wiederum eine schier unbegrenzte Manövrierbarkeit (Vorwärtsbewegung, Rückwärtsbewegung, Querbewegung, Drehbewegung um die Vertikalachse) erreichen lassen. Diese Auftriebskörper 36, 37, 38, 39, ausgeführt als Querstromrotoren, bestehen aus jeweils zwei runden Endscheiben, die eine Vielzahl von Rotorflügeln 36a, 37a tragen und um eine Drehachse rotieren. In einer bevorzugten Ausführungsvariante sind zur Erhöhung von strömungstechnischen Wirkungsgraden, in jeweils einen äußeren Querstromrotor 36 ein innerer kleinerer Querstromrotor 37, mit gegenläufiger Drehrichtung, eingefügt.

Bedingt durch die Tatsache, dass oberhalb des Fluggerätes keine rotierenden Aggregate vorhanden sind, ist dem Piloten im Bedarfsfall auch ein gefahrloses und sicheres Verlassen des Fluggerätes auch mittels Schleudersitz möglich. Weiters kann gemäß Fig. 20 oberhalb des Fluggerätes auch ein als Aufklärungsgerät 43 bezeichnetes Aggregat (Radar, optischer Sensor, ...) vorgesehen sein, welches bei Bedarf, im Schwebezustand des Fluggerätes, mittels einer flexiblen Verbindung 44 vertikal in die Höhe verbracht und anschließend wieder eingezogen werden kann. Dies ist u. a. dann sinnvoll, wenn mit dem Fluggerät im militärischen Einsatz ein Unterfliegen feindlicher Radarstrahlen hinter schützender Deckungen im Gelände oder in Gebäudefluchten erreicht werden soll, und zur Erfassung der militärischen Situation z. B. hinter einer schützenden Geländeformation, anstatt eines kurzfristigen gefahrvollen "Auftauchens" nur das Aufklärungsgerät 43 vertikal in die Höhe geschossen, die militärische Situation erfasst und anschließend das Aufklärungsgerät mit der flexiblen Verbindung wieder sicher in den Rumpf des Fluggerätes eingebracht wird.

Das Fluggerät der Fig. 21 besteht aus einem Rumpf 1 mit einer Längsachse 1a und zwei oberhalb dieser Längsachse 1a angeordneten Querstromrotoren 2 und 3. Im hinteren Bereich des Rumpfes sind in an sich üblicher Weise ein Höhenleitwerk 11 und ein Seitenleitwerk 10 vorgesehen. Kufen 46 stützen das Fluggerät am Boden ab. Hinter den Querstromrotoren 2, 3 sind im Bereich der Leitwerke 4, 5 zwei Mantelstromtriebwerke 47 vorgesehen, um den nötigen Vortrieb zu erzeugen.

Aus Fig. 22 ist ersichtlich, dass die Länge L1 der Querstromrotoren 2, 3 etwa 50% der Länge L des gesamten Fluggerätes entspricht.

In Fig. 25 ist der Aufbau des Fluggerätes in größerer Detaillierung im Schnitt dargestellt. Die Rotoren 2, 3 besitzen eine Vielzahl von Schaufeln 8, die entlang des Umfanges angeordnet sind. Am Umfang sind die Rotoren 2, 3 jeweils durch eine erste Leitfläche 49 und eine zweite Leitfläche 50 abgedeckt. Dabei ist die erste Leitfläche 49 als Teil der Außenfläche des Rumpfes 1 ausgebildet, während die zweite Leitfläche 50 jeweils als Strömungsleitblech ausgebildet ist. Durch die Drehung der Querstromrotoren 2, 3 im Sinne der Pfeile 51 wird eine Luftströmung induziert, so dass Luft entlang der Pfeile 52 angesaugt wird und in Richtung der Pfeile 53 ausgestoßen wird. Der obere offene Bereich der Rotoren 2, 3 dient somit als Lufteinlassöffnung 54, und der untere offene Bereich als Luftauslassöffnung 55. Durch den Impuls der nach unten ausgestoßenen Luftmengen ergibt sich insgesamt eine Auftriebskraft auf das Fluggerät, die durch den Pfeil 56 dargestellt ist und die bei entsprechender Auslegung ausreicht, das Fluggerät vom Boden abzuheben.

Unterhalb der Rotoren 2, 3 sind verstellbare Leitschaufeln 17 vorgesehen, die bei den Ausführungsvarianten der Fig. 24 aus mehreren Segmenten 17a, 17b, 17c bestehen, die unabhängig voneinander um eine zur Längsachse des Fluggerätes parallelen Achse schwenkbar sind. Dadurch kann durch die Leitschaufeln 17 auch eine Drehung des Fluggerätes um eine Vertikalachse 1b bewirkt werden. Es ist gezeigt, dass die unterhalb der Luftausstoßöffnungen 55 angeordneten Leitschaufeln 17 die Richtung der Luftstrahlen im Sinne der Pfeile 53 entsprechend abgeändert werden kann. In der in Fig. 6 gezeigten Stellung wird durch Verschwenkung der beweglichen Leitschaufeln 17 eine Kraftkomponente nach Backbord erzeugt, was durch den Pfeil 56 angedeutet ist. Innerhalb der Querstromrotoren können Leitschaufeln 58 zur verbesserten Luftströmungsführung vorgesehen sein. Die Leitschaufeln 58 können beweglich ausgeführt sein, was die Manövrierfähigkeit bei hohem Wirkungsgrad verbessert.

Der Antrieb der Querstromrotoren 2, 3 kann im Prinzip durch Kolbenmotoren erfolgen, wird jedoch bevorzugt über Gasturbinen durchgeführt, was in den Zeichnungen nicht dargestellt ist.

Aus Fig. 26 ist ersichtlich, dass die einzelnen Rotorblätter 8 über eine Zugstange 60 um einen Drehpunkt 61 schwenkbar angeordnet sind. Die Zugstangen 60 sind in einem gemeinsamen Sternpunkt 62 gelagert, der beliebig gegenüber der

Achse 63 verschoben werden kann. Dadurch kann eine Gesamtströmung in beliebiger Richtung eingestellt werden. Die Rotorblätter 8 sind über Zapfen 64 in Kulissen 65 geführt, um die entsprechende Stabilität zu gewährleisten.

Aus Fig. 27 ist erkennbar, dass ein Endbereich 66 des Rotorblatts 8 separat verstellbar ist. Ein mit dem Endbereich 66 verbundener Hebel 67 besitzt einen Zapfen 68, der in einer zweiten Kulisse 69 geführt ist, so dass das Rotorblatt 8 ein asymmetrisches Tragflügelprofil annimmt, was die Förderleistung und den Wirkungsgrad verbessert. Je stärker das Rotorblatt 8 insgesamt angestellt wird, um so stärker ist auch die zusätzliche Anstellung des Endbereichs 66 und damit die Gesamtprofilierung des Rotorblatts 8.

Die vorliegende Erfindung beschreibt ein Fluggerät, welches die Möglichkeit eines senkrechten Starts und einer senkrechten Landung aufweist, eine fast unbegrenzte Manövrierbarkeit im Schwebezustand erlaubt, eine hohe Reisegeschwindigkeit bei gleichzeitiger Treibstoffökonomie bietet, dem Piloten im Bedarfsfall ein sicheres Verlassen des Fluggerätes ermöglicht und ein flexibel angeordnetes Aufklärungsgerät oberhalb des Fluggerätes unterbringt.

PATENTANSPRÜCHE

1. Fluggerät mit einem Rumpf (1) und mindestens zwei am Rumpf (1) angebrachten Auftriebskörpern (2, 3, 4, 5), die im Wesentlichen hohlzylindrisch ausgebildet sind und die eine Vielzahl von Rotorblätter (8) aufweisen, die sich über den Umfang des Auftriebskörpers (2, 3, 4, 5) erstrecken, wobei der Umfang des Auftriebskörpers (2, 3, 4, 5) durch mindestens eine Leitfläche (49, 50) teilweise abgedeckt ist, **dadurch gekennzeichnet**, dass die Auftriebskörper (2, 3, 4, 5) durch mindestens ein Antriebsaggregat angetrieben sind und jeweils eine Zylinderachse aufweisen, die im Wesentlichen parallel zu einer Längsachse (1a) des Fluggerätes ist.

2. Fluggerät nach Anspruch 1, **dadurch gekennzeichnet**, dass eine Leitfläche (49, 50) zumindest teilweise von einer Außenfläche des Rumpfes (1) gebildet ist.

3. Fluggerät nach Anspruch 1 oder 2, **dadurch gekennzeichnet**, dass der Umfang des Rotors durch eine erste Leitfläche (49) und eine zweite Leitfläche (50) teilweise abgedeckt ist, so dass zwischen diesen Leitflächen (49, 50) eine Lufteinlassöffnung (14) und eine Luftauslassöffnung (15) gebildet werden.

4. Fluggerät nach einem der Ansprüche 1 bis 3, **dadurch gekennzeichnet,** dass die Rotorblätter (8) beweglich ausgeführt sind und vorzugsweise um ihre Längsachse schwenkbar angeordnet sind.

5. Fluggerät nach einem der Ansprüche 1 bis 4, **dadurch gekennzeichnet,** dass die Auftriebskörper (2, 3, 4, 5) oberhalb der Schwerpunktslage des Fluggerätes angeordnet sind.

6. Fluggerät nach einem der Ansprüche 1 bis 5, **dadurch gekennzeichnet,** dass die Auftriebskörper (2, 3, 4, 5) hohlzylindrisch ausgebildet sind und gegenläufig rotieren.

7. Fluggerät nach einem der Ansprüche 1 bis 6, **dadurch gekennzeichnet,** dass die Auftriebskörper (2, 3, 4, 5) durch Gasturbinen gegenläufig angetrieben sind.

8. Fluggerät nach einem der Ansprüche 1 bis 7, **dadurch gekennzeichnet,** dass für eine hohe Reisegeschwindigkeit zusätzliche Triebwerke (47) vorgesehen sind.

9. Fluggerät nach Anspruch 8, **dadurch gekennzeichnet**, dass die zusätzlichen Triebwerke schwenkbar ausgeführt sind, um eine zusätzliche Unterstützung beim Start, bei der Landung oder bei sonstigen Manövern zu ermöglichen.

10. Fluggerät nach einem der Ansprüche 1 bis 9, **dadurch gekennzeichnet,** dass das Fluggerät mit zwei Auftriebskörpern (2, 3) ausgeführt ist, die entlang der Längsachse (1a) des Fluggerätes hintereinander liegend, gegenläufig rotierend angeordnet sind.

11. Fluggerät nach einem der Ansprüche 1 bis 9, **dadurch gekennzeichnet,** dass das Fluggerät mit zwei Auftriebskörpern (2, 3) ausgeführt ist, deren Mittelachsen parallel nebeneinander liegen.

12. Fluggerät nach einem der Ansprüche 1 bis 9, **dadurch gekennzeichnet,** dass das Fluggerät mit vier Auftriebskörper (2, 3, 4, 5) ausgeführt ist, wobei jeweils zwei Auftriebskörper (2, 3, 4, 5) gegenläufig rotieren und parallel zueinander angeordnet sind.

13. Fluggerät nach einem der Ansprüche 1 bis 12, **dadurch gekennzeichnet**, dass im Inneren der Auftriebskörper (2, 3, 4, 5) jeweils mindestens eine Leitschaufel (18) vorgesehen ist.

14. Fluggerät nach Anspruch 13, **dadurch gekennzeichnet**, dass die Leitschaufel (18) im Inneren der Rotoren (2, 3) verstellbar ausgebildet ist.

15. Fluggerät nach einem der Ansprüche 1 bis 14, **dadurch gekennzeichnet**, dass im Bereich von Luftauslassöffnungen (15) verstellbare Leitschaufeln (17) vorgesehen sind.

16. Fluggerät nach Anspruch 15, **dadurch gekennzeichnet**, dass die verstellbaren Leitschaufeln (17) aus zwei, vorzugsweise aus drei Segmenten (17a, 17b, 17c) bestehen, um eine Rotation um eine Vertikalachse (1b) zu ermöglichen.

17. Fluggerät nach einem der Ansprüche 1 bis 16, **dadurch gekennzeichnet**, dass sich die Auftriebskörper (2, 3, 4, 5) über mindestens 40%, vorzugsweise über mindestens 70% der Länge des Rumpfes (1) erstrecken.

18. Fluggerät nach einem der Ansprüche 1 bis 17, **dadurch gekennzeichnet**, dass weitere verstellbare Leitschaufeln (19) vorgesehen sind, die eine Vorwärts- bzw. eine Rückwärtsbewegung im Schwebezustand erlauben.

19. Fluggerät nach einem der Ansprüche 1 bis 18, **dadurch gekennzeichnet**, dass eine zweite Leitfläche (50) der Auftriebskörper (2, 3, 4, 5) als mechanischer Schutz der Rotorblätter (8) gegen eine Kollision mit einem festen Hindernis ausgebildet ist.

20. Fluggerät nach einem der Ansprüche 1 bis 19, **dadurch gekennzeichnet**, dass die Rotorblätter (8) der einzelnen Auftriebskörper (2, 3, 4, 5) individuell verstellbar sind, um Auftriebskräfte und Seitenkräfte erzeugen zu können, sowie um unterschiedliche Schwerpunktlagen ausgleichen zu können.

21. Fluggerät nach einem der Ansprüche 1 bis 20, **dadurch gekennzeichnet**, dass die Auftriebskörper (2, 3, 4, 5) mit Abdeckungen (40, 41) versehen sind, ausgeführt als kompakte Abdeckungen oder als ein System von Lamellen, die einerseits einen ungehinderten Luftdurchlass gewährleisten und für eine hohe Reisegeschwindigkeit, wo der Wirkungsgrad der Auftriebskörper (2, 3, 4, 5) begrenzt ist, die Strömungsverluste reduzieren.

22. Fluggerät nach einem der Ansprüche 1 bis 20, **dadurch gekennzeichnet**, dass die Auftriebskörper (2, 3, 4, 5) seitlich eine Schutzverkleidung (6) aufweisen, die einen ungehinderten Luftdurchlass gewährleisten, im Bedarfsfall jedoch den rotierenden Auftriebskörper (2, 3, 4, 5) gegen Kollision mit einem festen Hindernis schützen.

23. Fluggerät nach einem der Ansprüche 1 bis 22, **dadurch gekennzeichnet**, dass der Auftriebskörper (2, 3, 4, 5) mit Rotorblättern (8) versehen ist, die tragflügelähnlich ausgebildet sind und als Ganzes um eine Schwenkachse (8a) beweglich sind.

24. Fluggerät nach einem der Ansprüche 1 bis 22, **dadurch gekennzeichnet**, dass der Auftriebskörper (2, 3, 4, 5) mit Rotorblättern (8) versehen ist, die tragflügelähnlich ausgebildet sind und deren hintere Teile unabhängig von der vorderen Teilen um eine Schwenkachse (8a) beweglich sind.

25. Fluggerät nach einem der Ansprüche 23 oder 24, **dadurch gekennzeichnet**, dass eine gemeinsame Verstelleinrichtung für die Rotorblätter (8) eines Auftriebskörpers (2, 3, 4, 5) vorgesehen ist.

26. Fluggerät nach einem der Ansprüche 23 bis 25, **dadurch gekennzeichnet**, dass die Rotorblätter (8) der Auftriebskörper (2, 3, 4, 5) ein im wesentlichen symmetrisches Profil aufweisen.

27. Fluggerät nach einem der Ansprüche 1 bis 26, **dadurch gekennzeichnet**, dass der Auftriebskörper (2, 3, 4, 5) im Wesentlichen aus einer Drehachse (7), zwei Endscheiben (2a, 2b) und Rotorblättern (8) besteht.

28. Fluggerät nach einem der Ansprüche 1 bis 27, **dadurch gekennzeichnet**, dass oberhalb des Fluggerätes keinerlei rotierende Aggregate vorhanden sind, so dass im Bedarfsfall der Pilot das Fluggerät mittels Schleudersitz sicher verlassen kann oder ein spezielles Aufklärungsgerät (43) vertikal in die Höhe geschossen und wieder eingebracht werden kann.

29. Fluggerät nach einem der Ansprüche 1 bis 28, **dadurch gekennzeichnet**, dass mindestens ein Auftriebskörper (2, 3, 4, 5) als Querstromrotor ausgeführt ist.

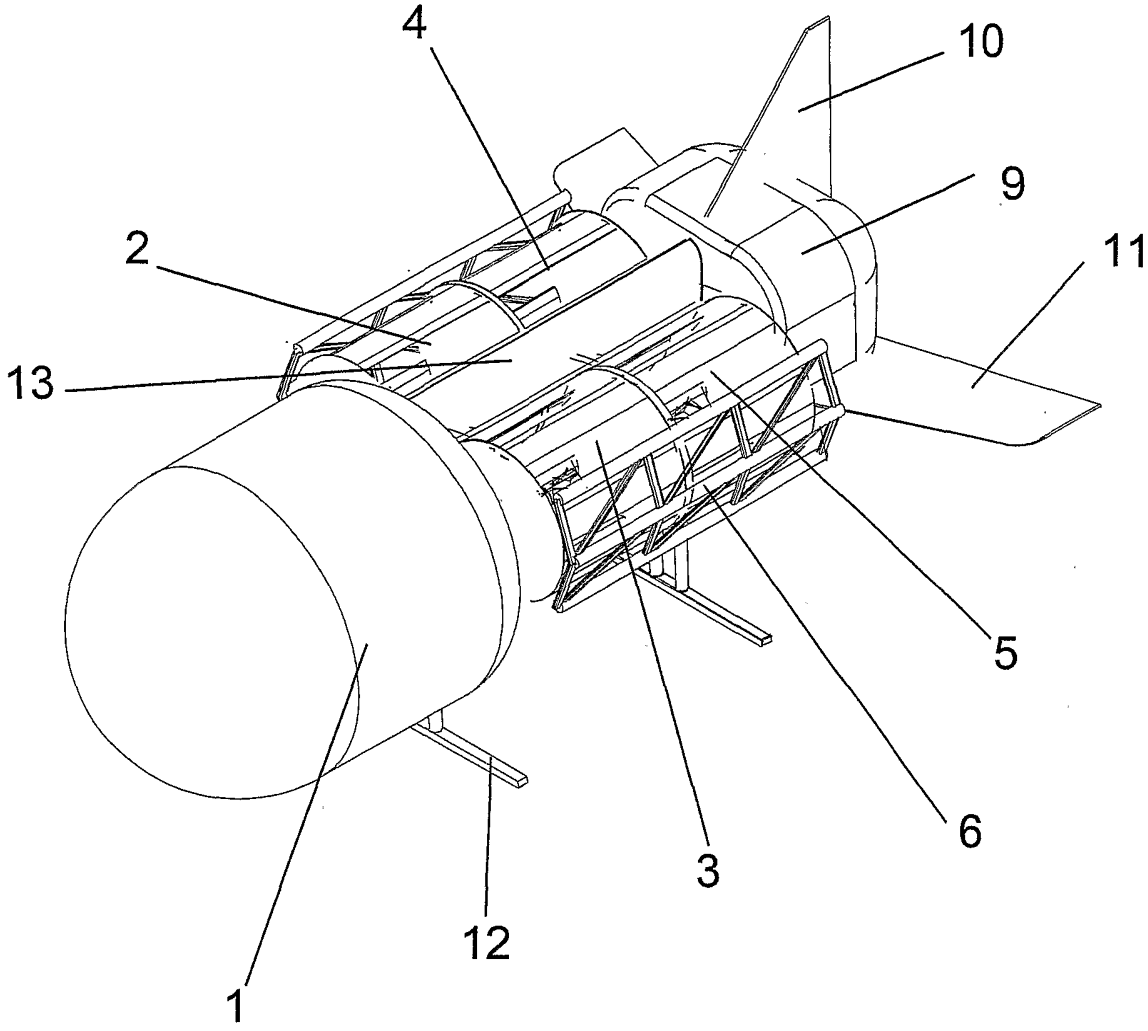


Fig. 1

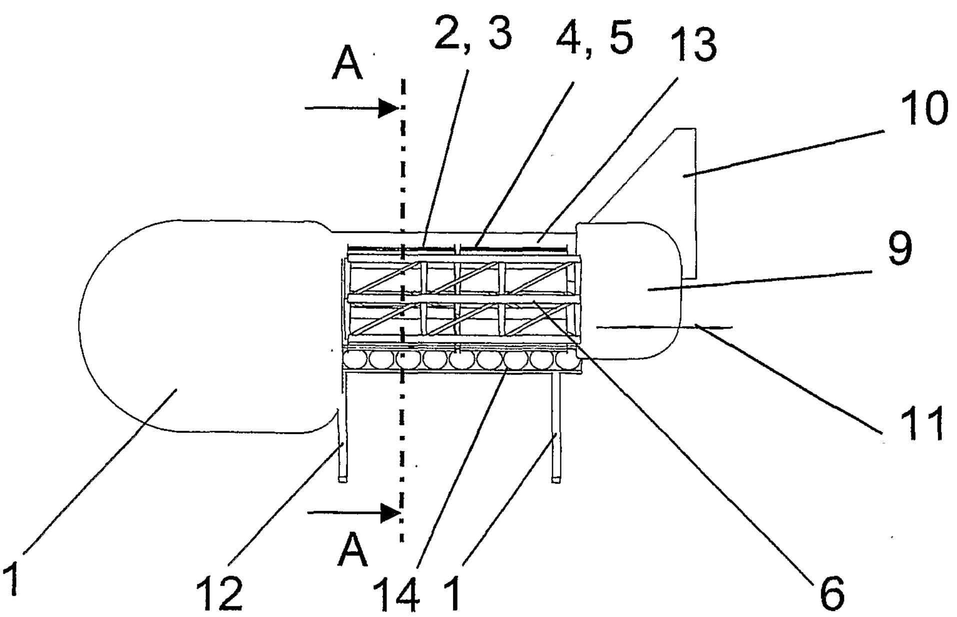


Fig. 2

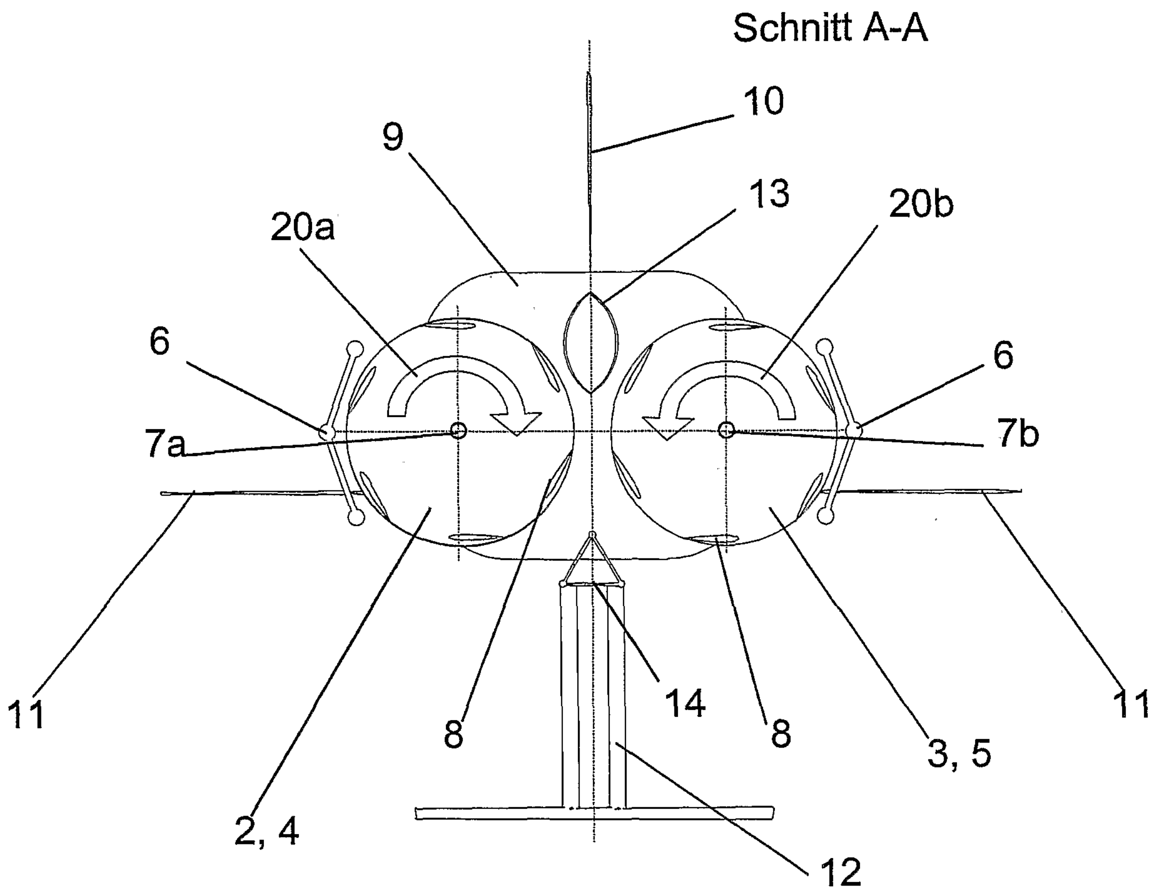


Fig. 3

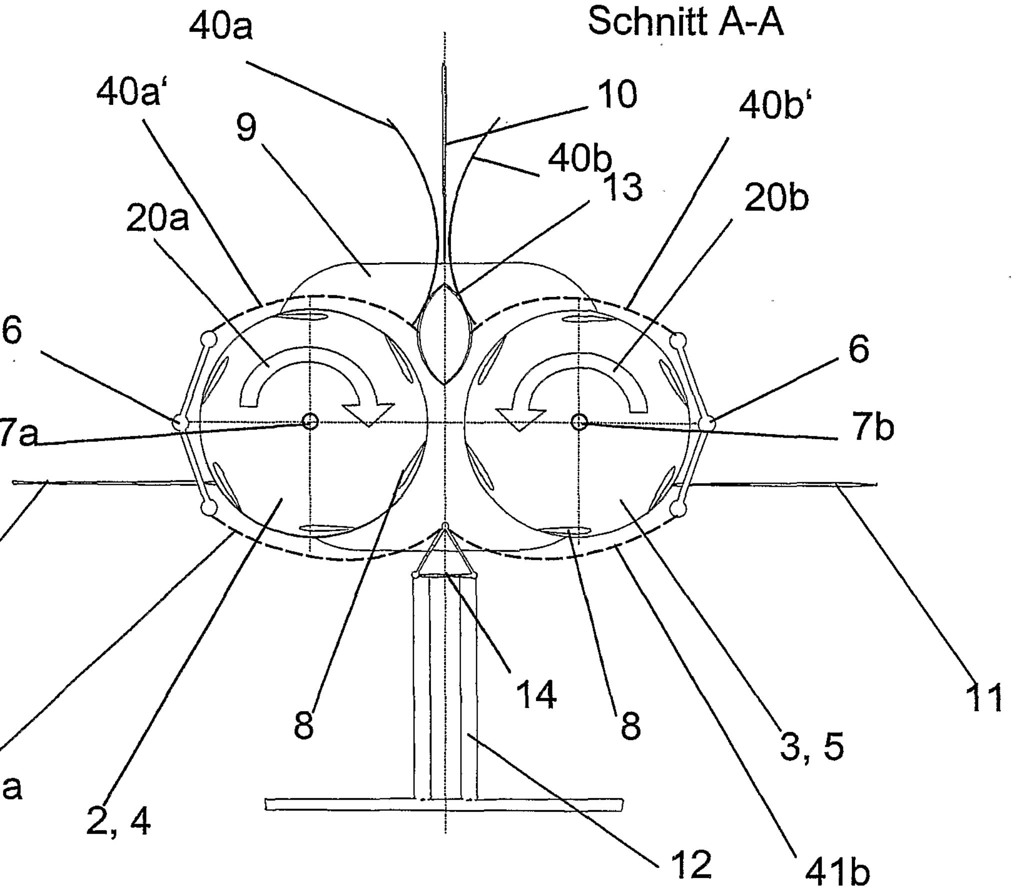

Schnitt A-A
40a
40a'
10
40b'
9
40b
13
20a
20b
6
6
7a
7b
11
11
14
8
8
3, 5
41a
2, 4
12
41b

Fig. 4

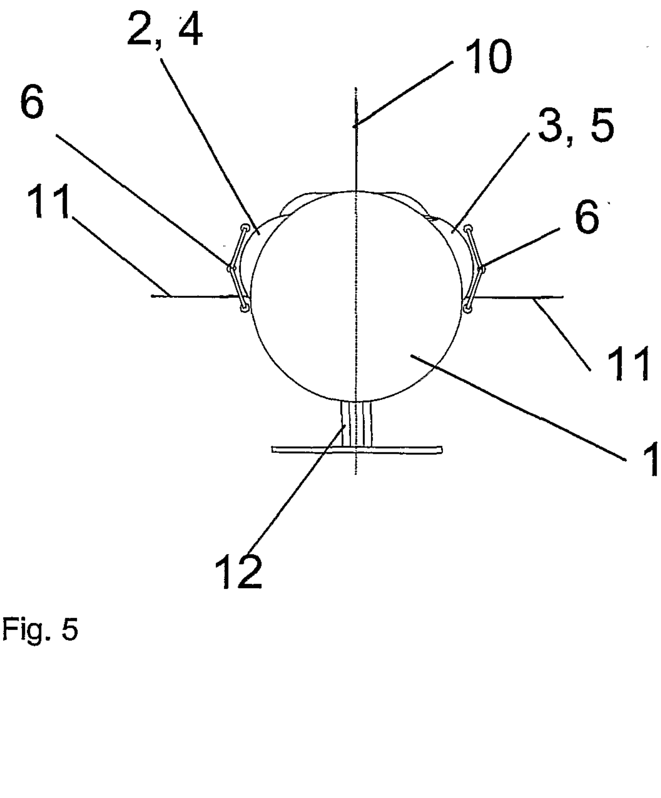

2, 4
10
6
3, 5
11
6
11
1
12

Fig. 5

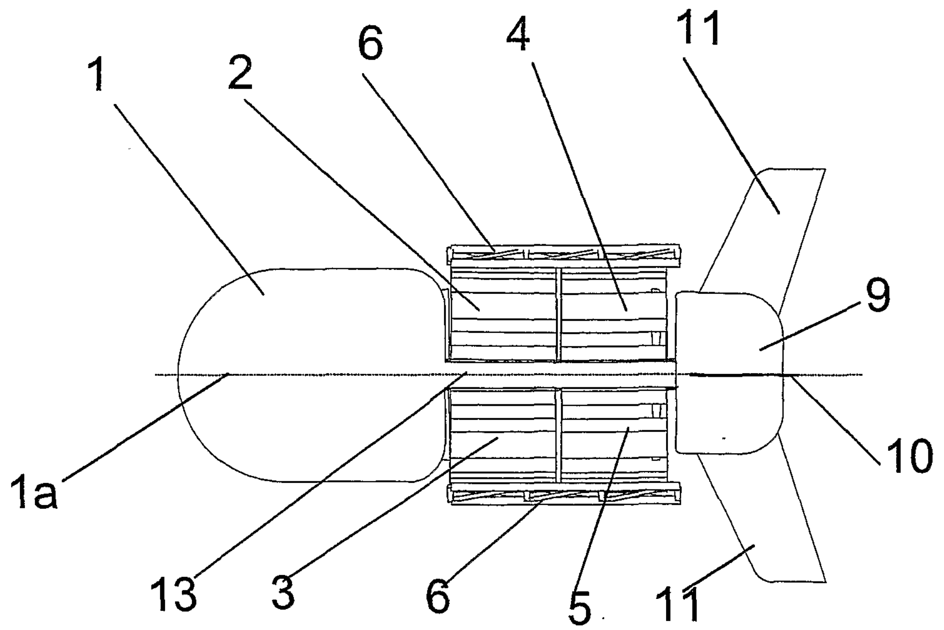


Fig. 6

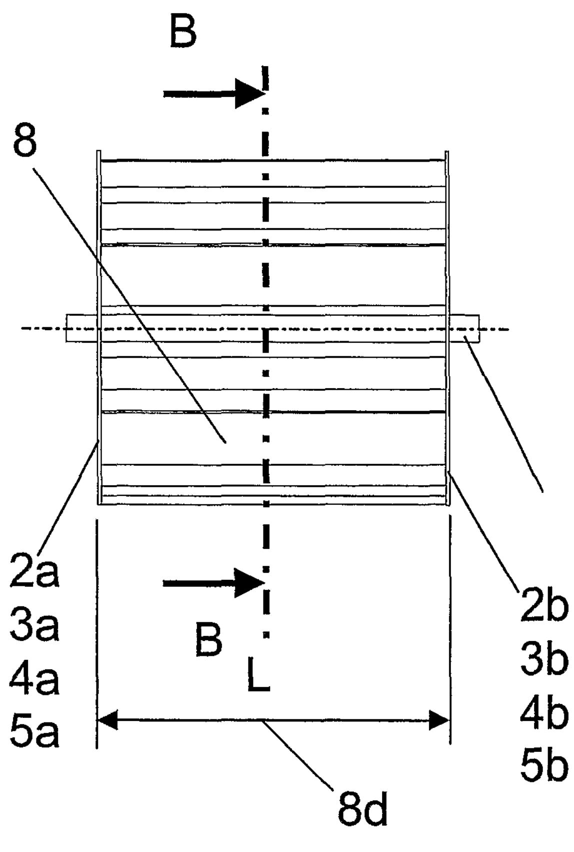


Fig. 7

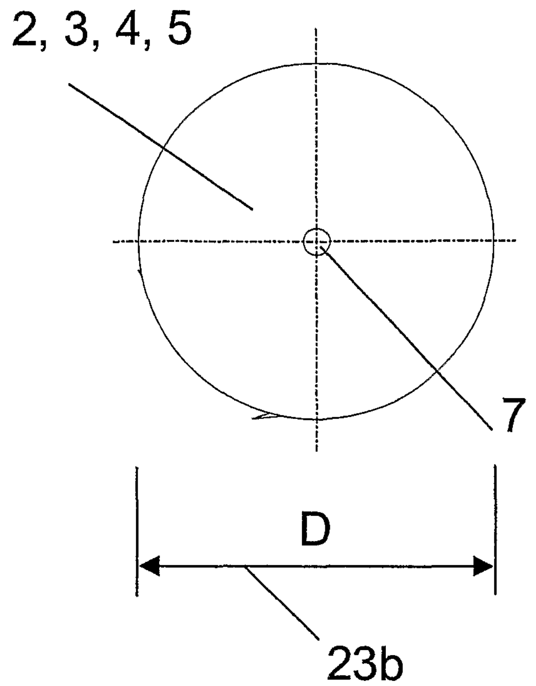


Fig. 7a

Schnitt B-B

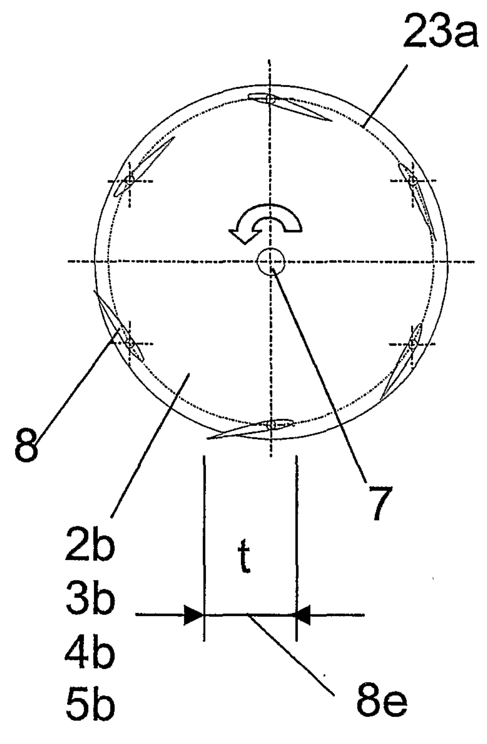


Fig. 7b

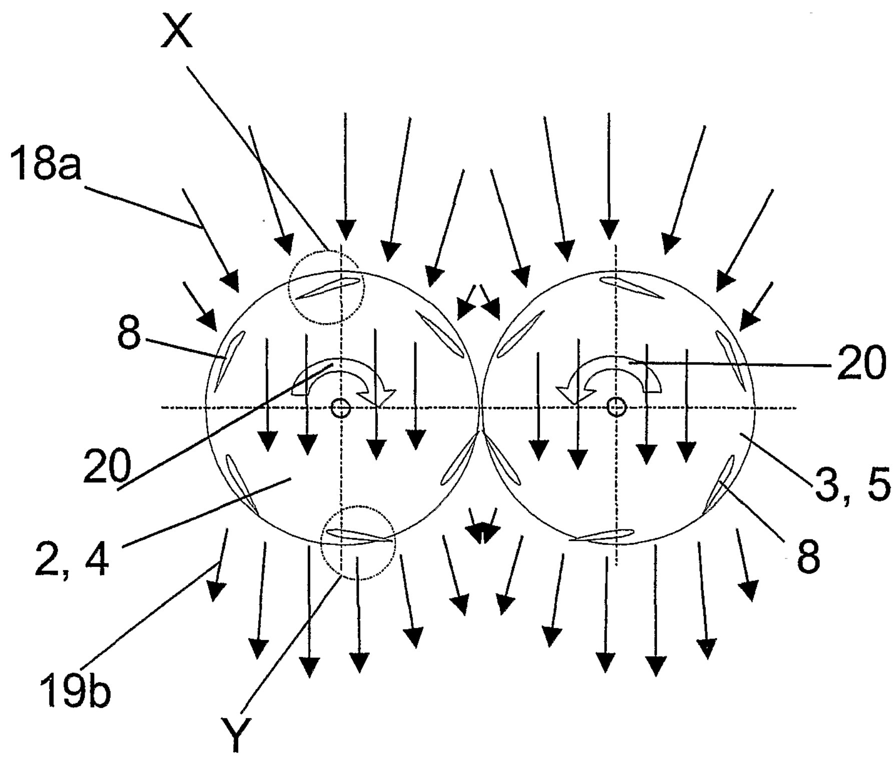


Fig. 8

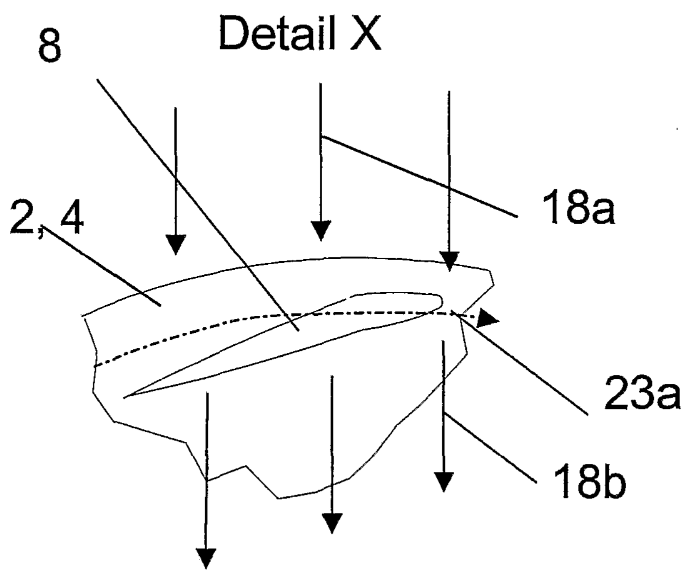


Fig. 8a

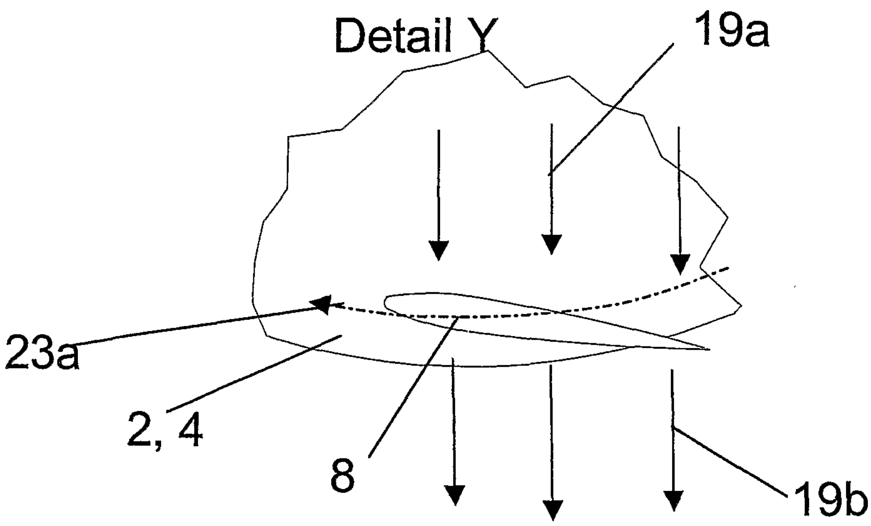


Fig. 8b

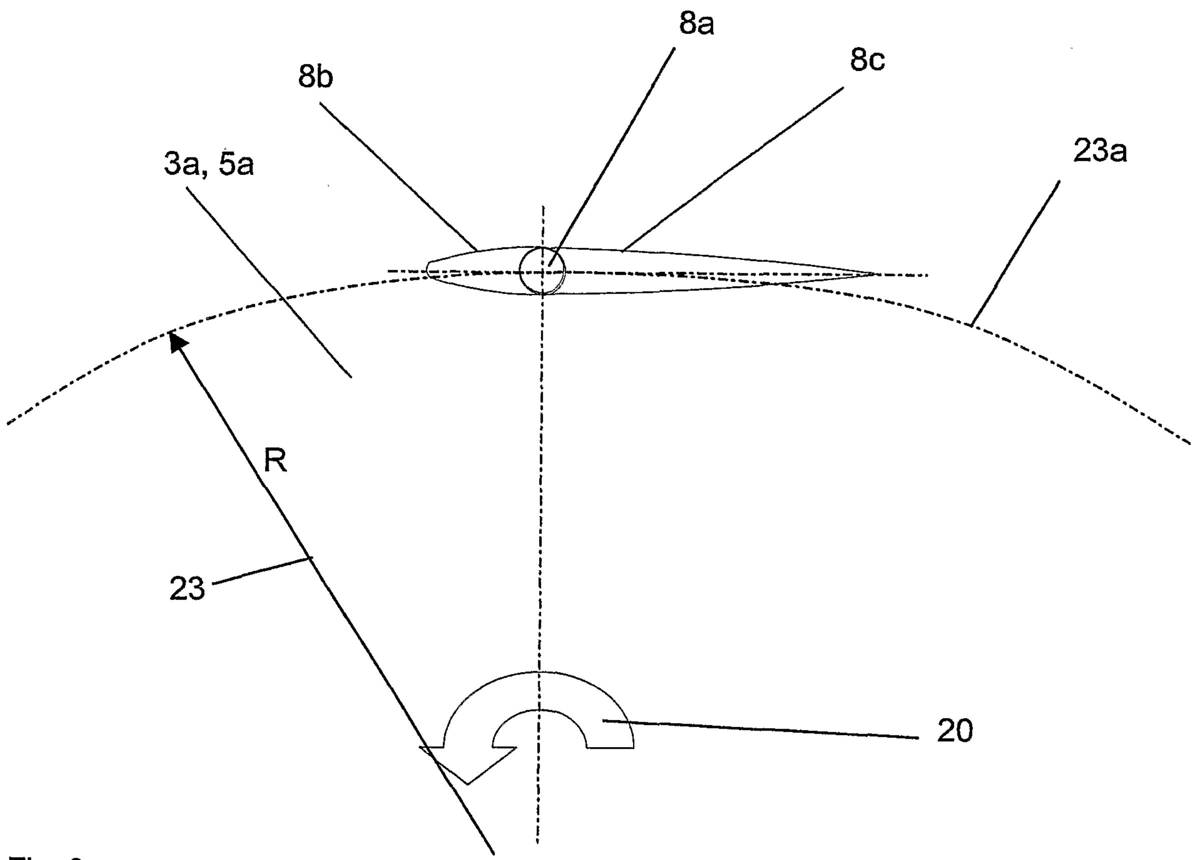


Fig. 9

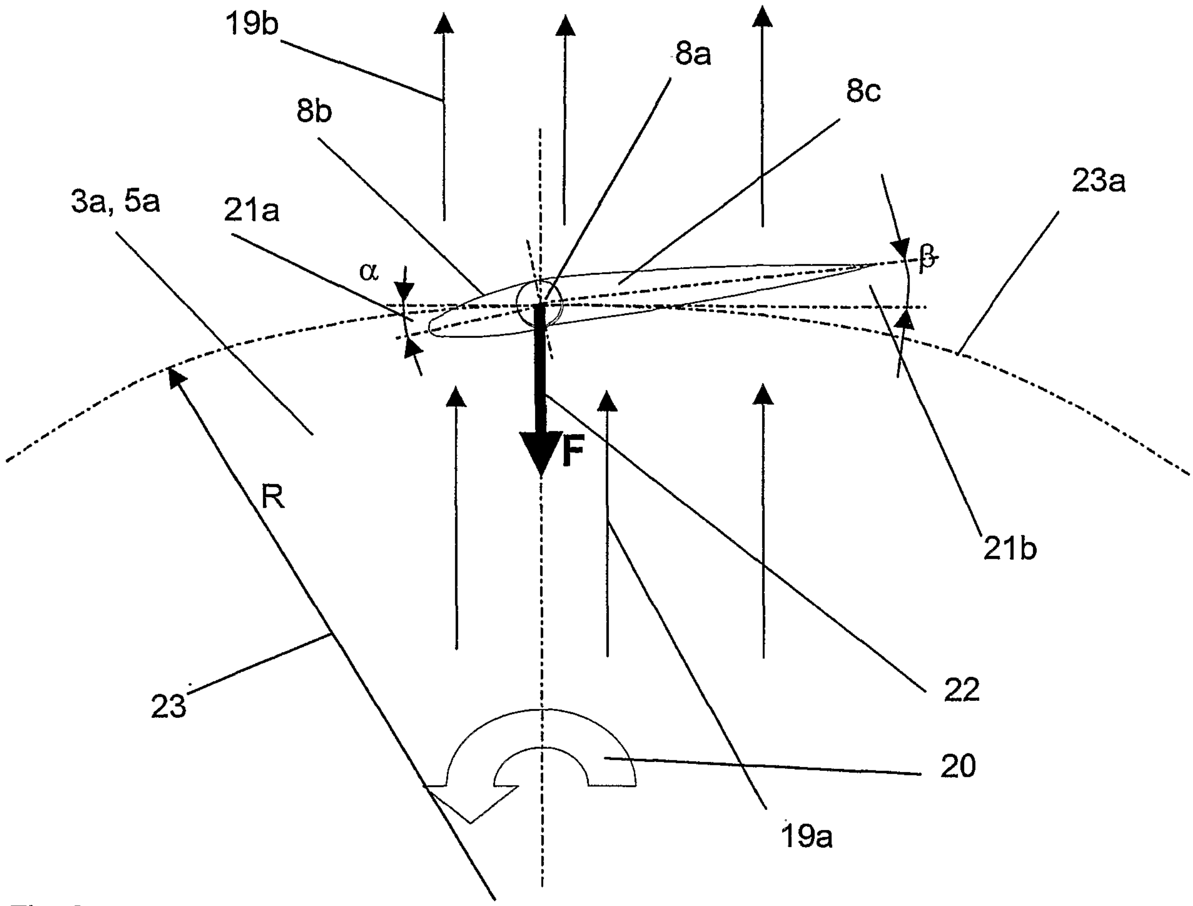

19b
8a
8b
8c
23a
3a, 5a
21a
α
β
F
R
21b
23
22
20
19a

Fig. 9a

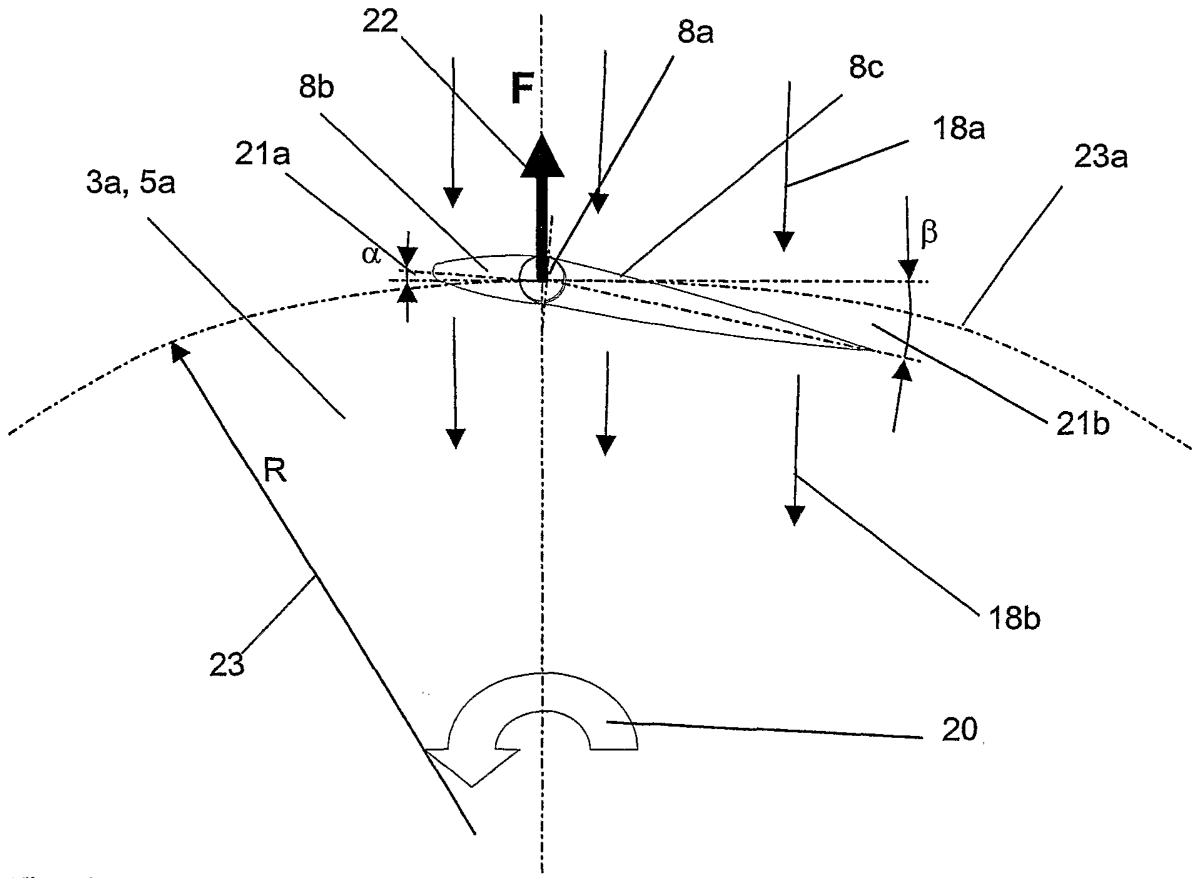

22
8a
F
8b
8c
18a
21a
23a
3a, 5a
α
β
21b
R
18b
23
20

Fig. 9b

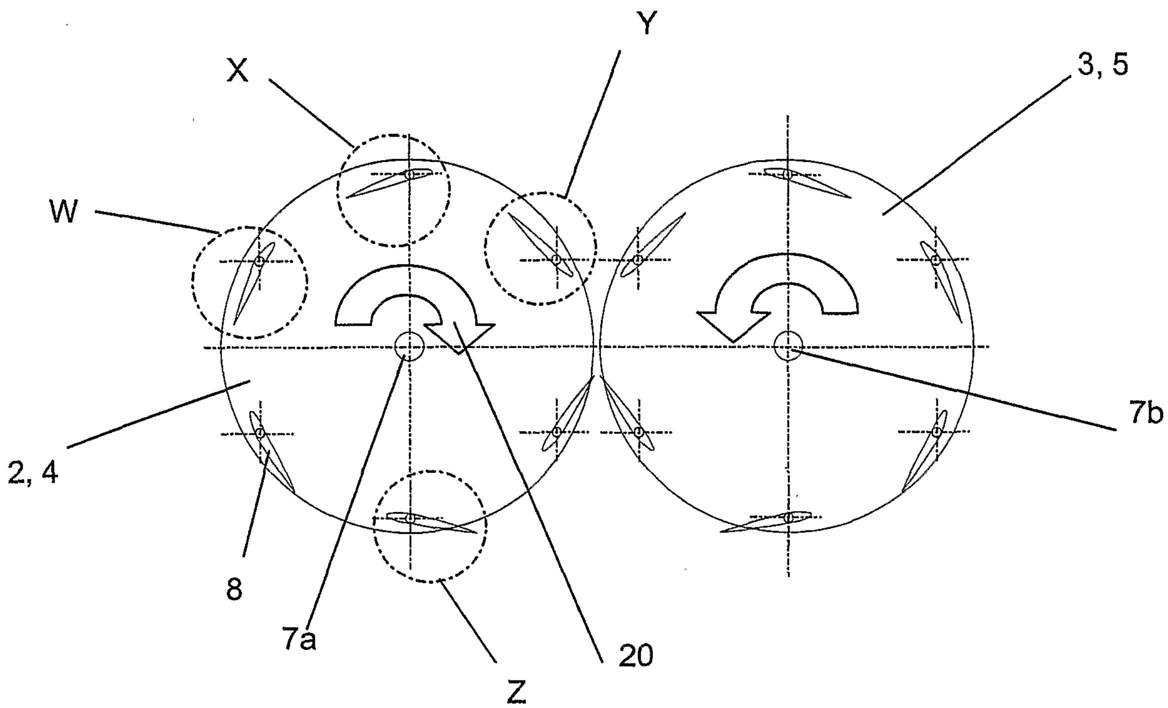


Fig. 10

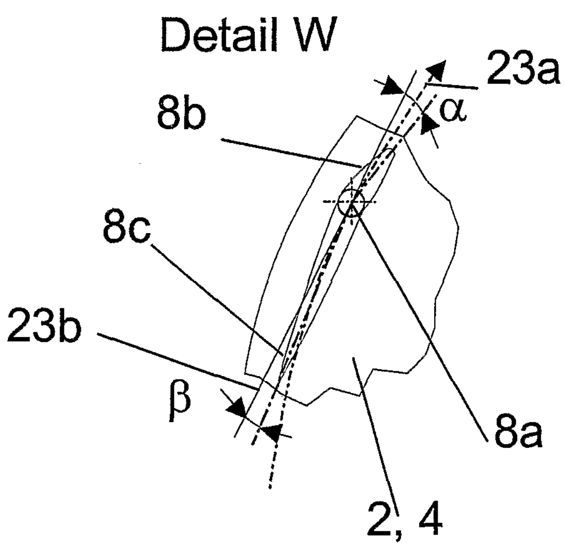


Fig. 10a

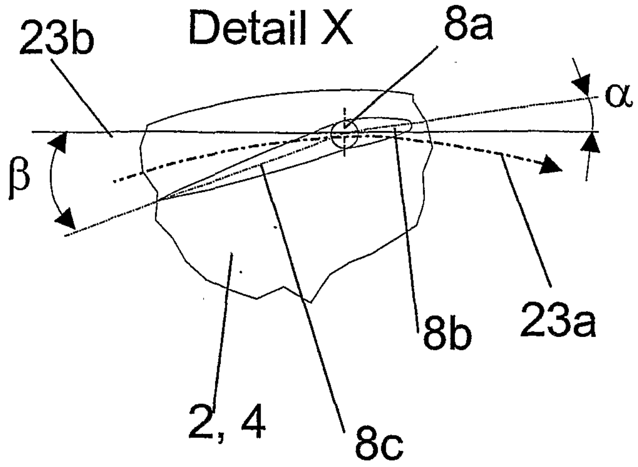


Fig. 10b

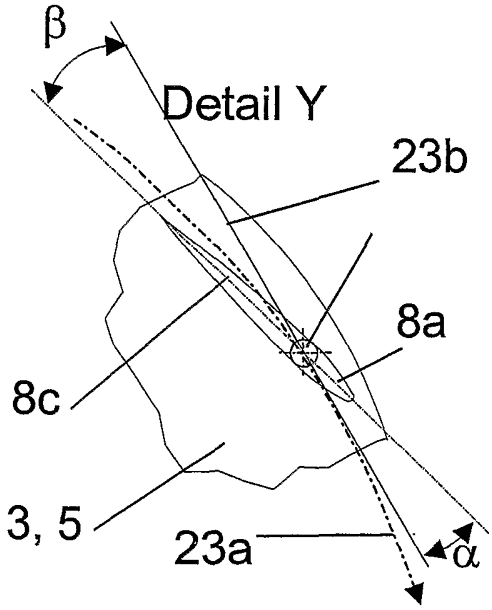


Fig. 10c

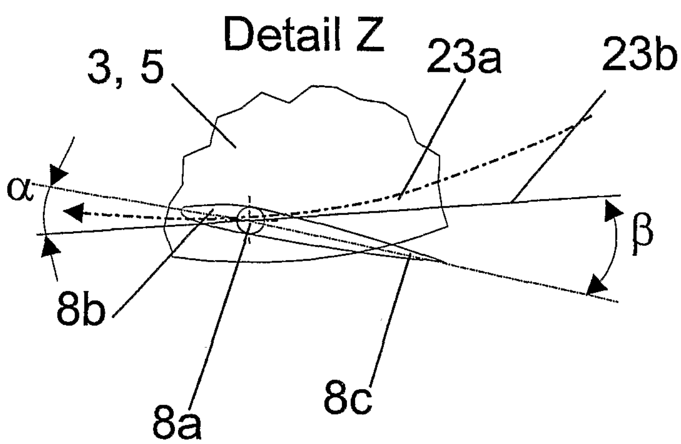


Fig. 10d

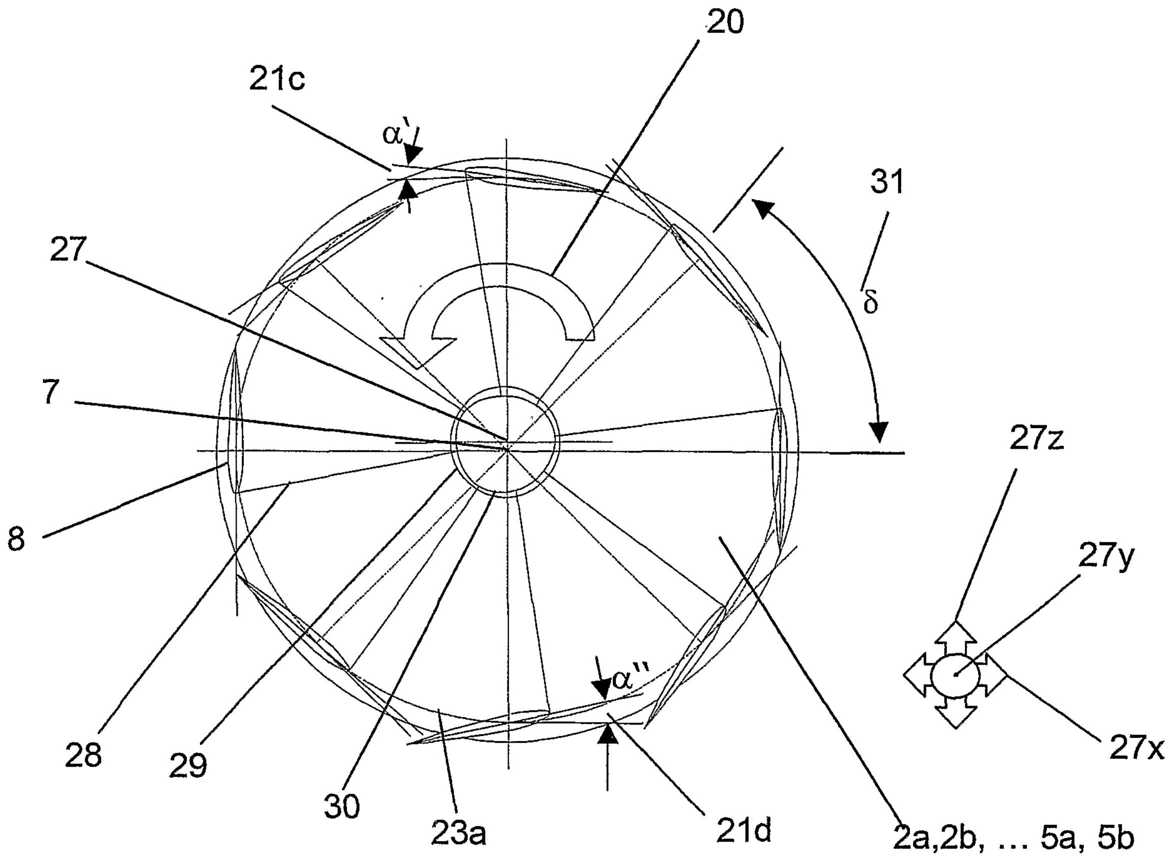


Fig. 11

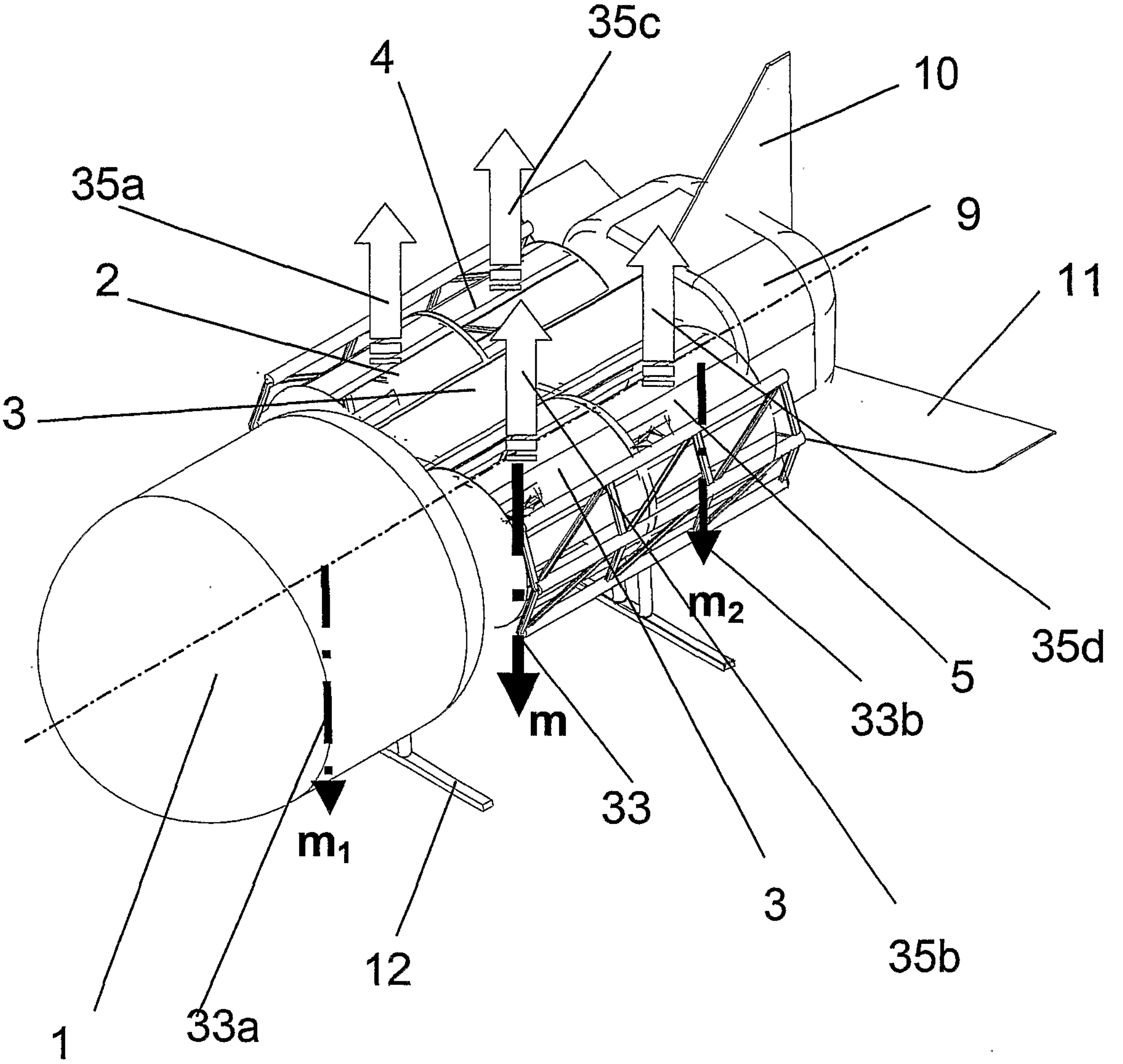


Fig. 12

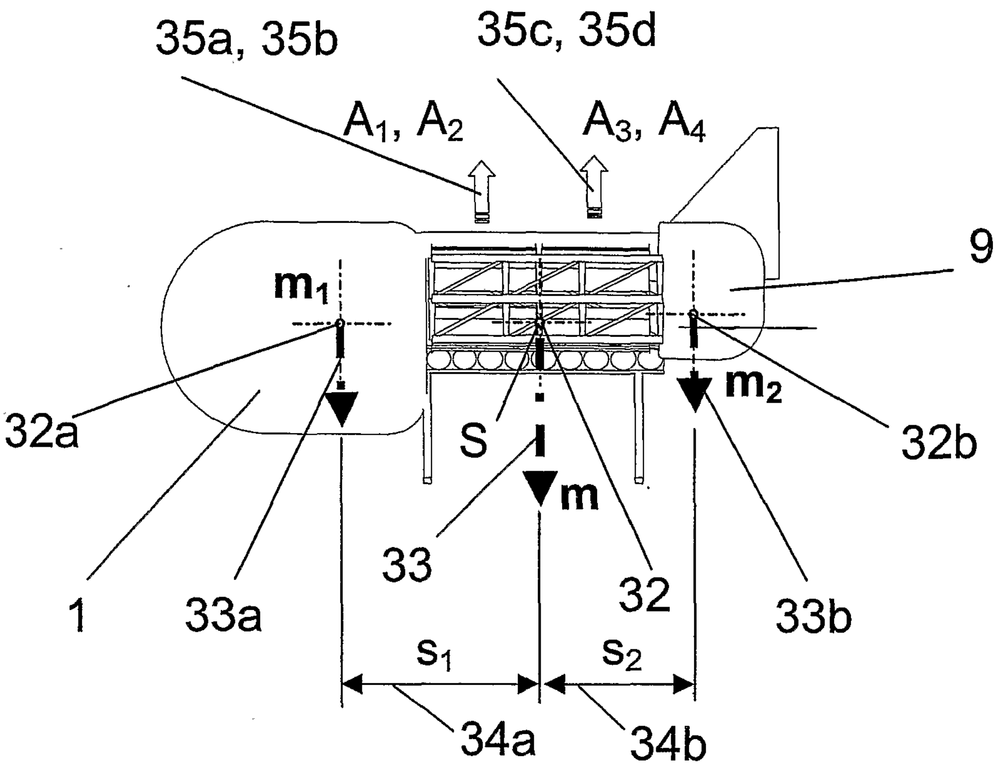


Fig. 12a

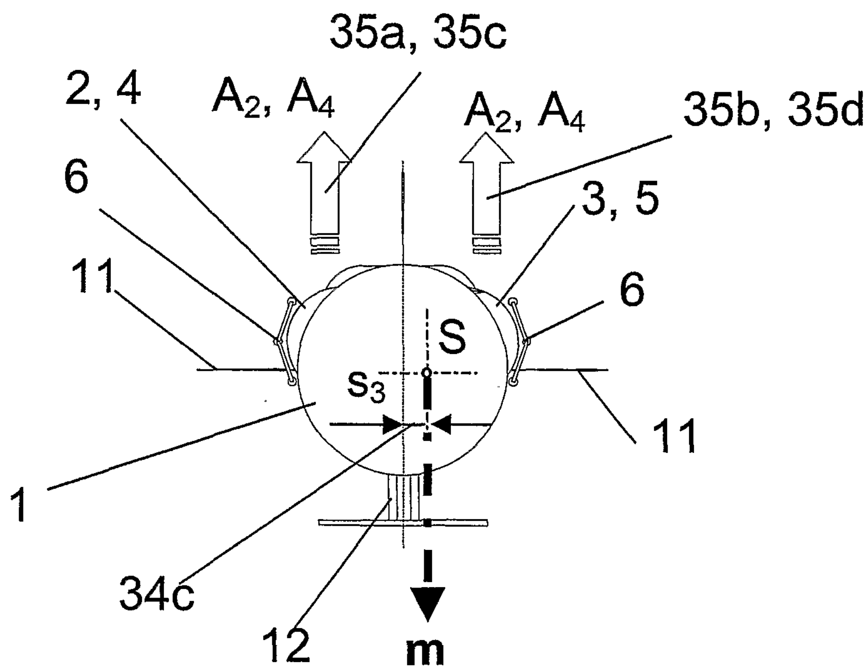


Fig. 12b

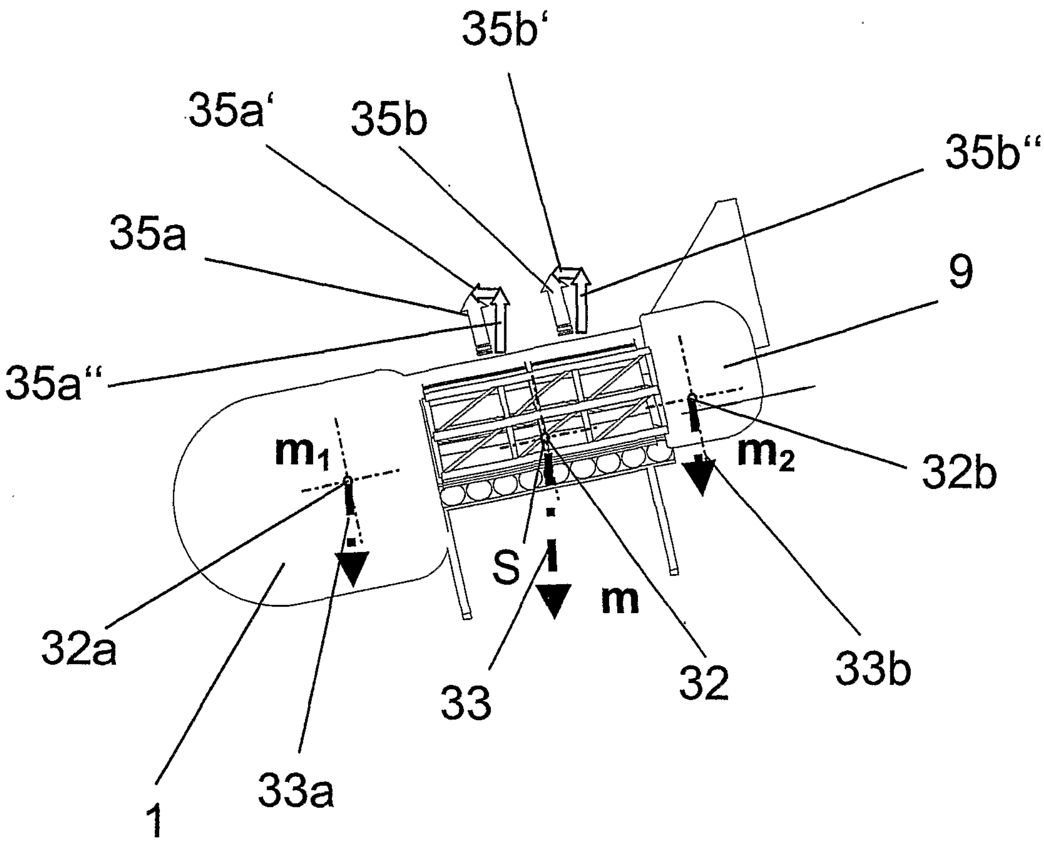


Fig. 13

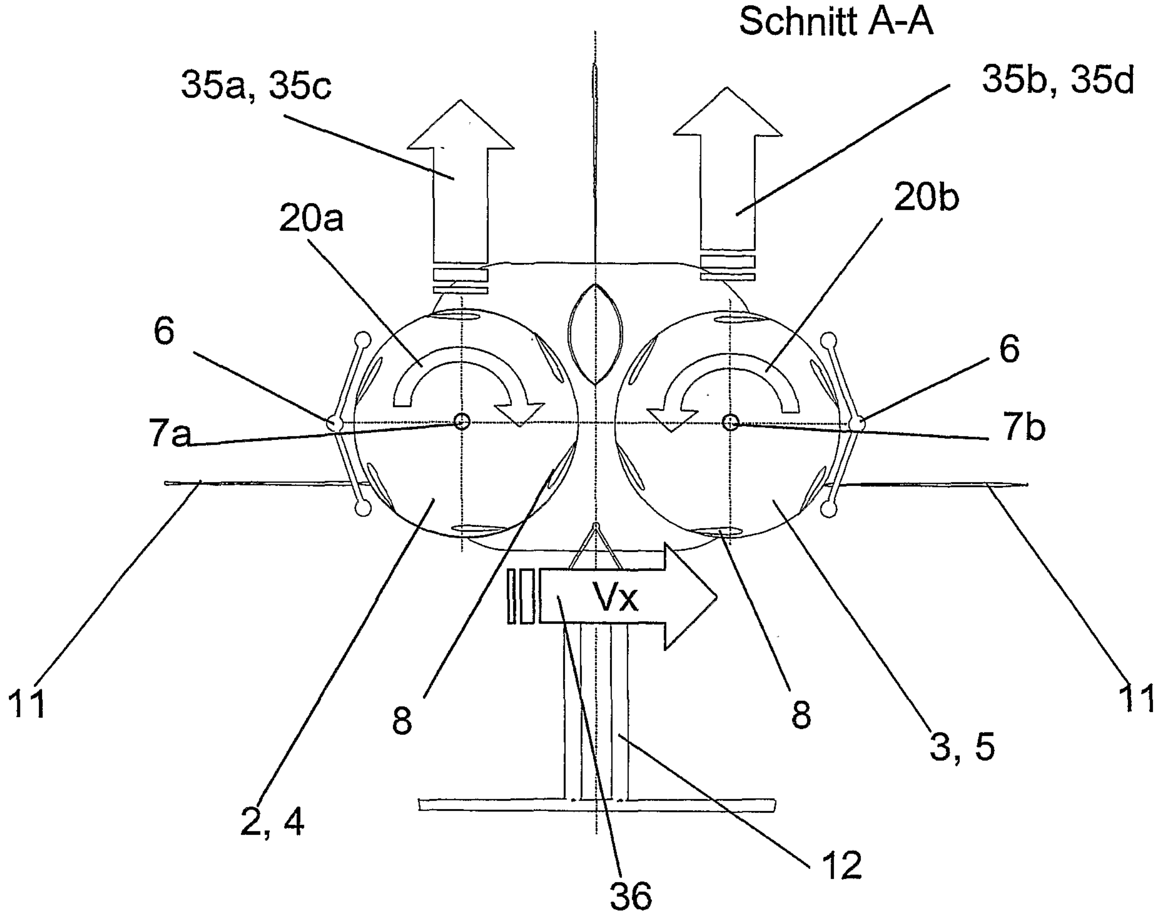


Fig. 14

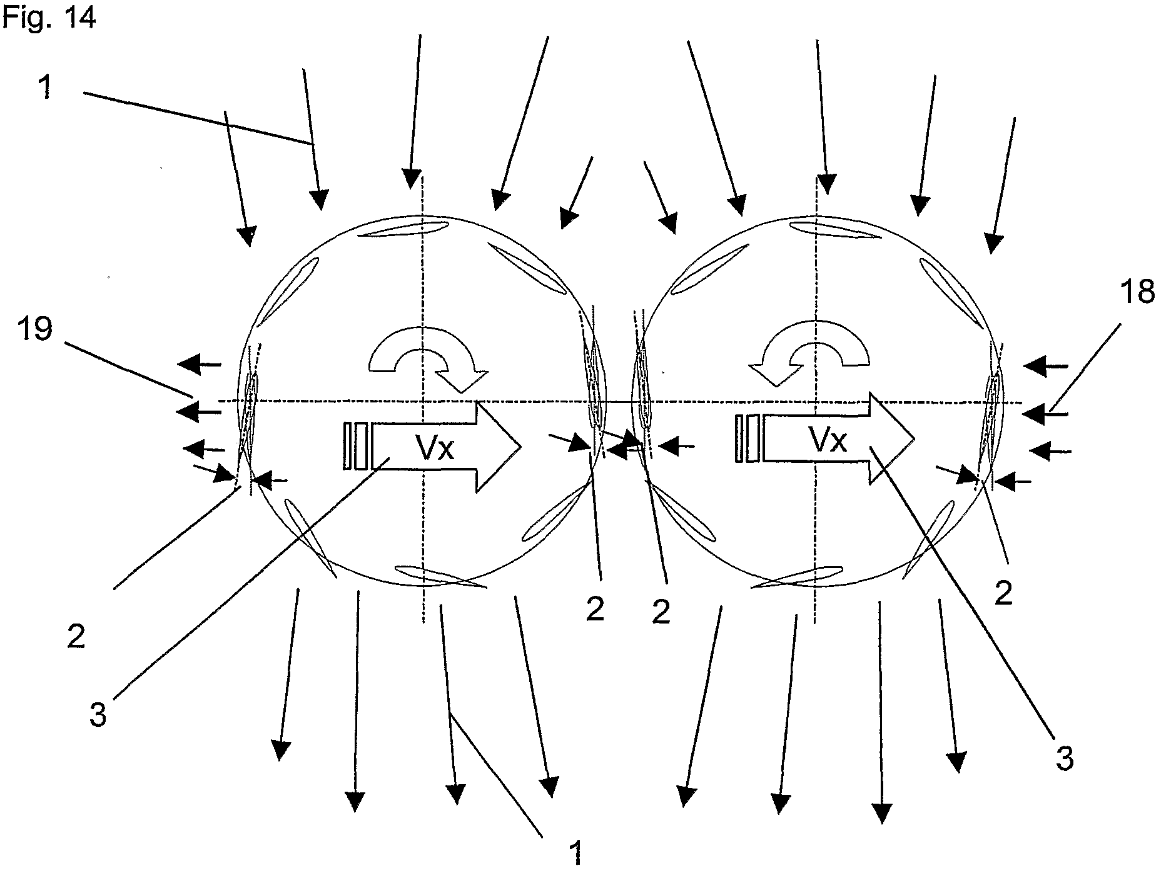


Fig. 14a

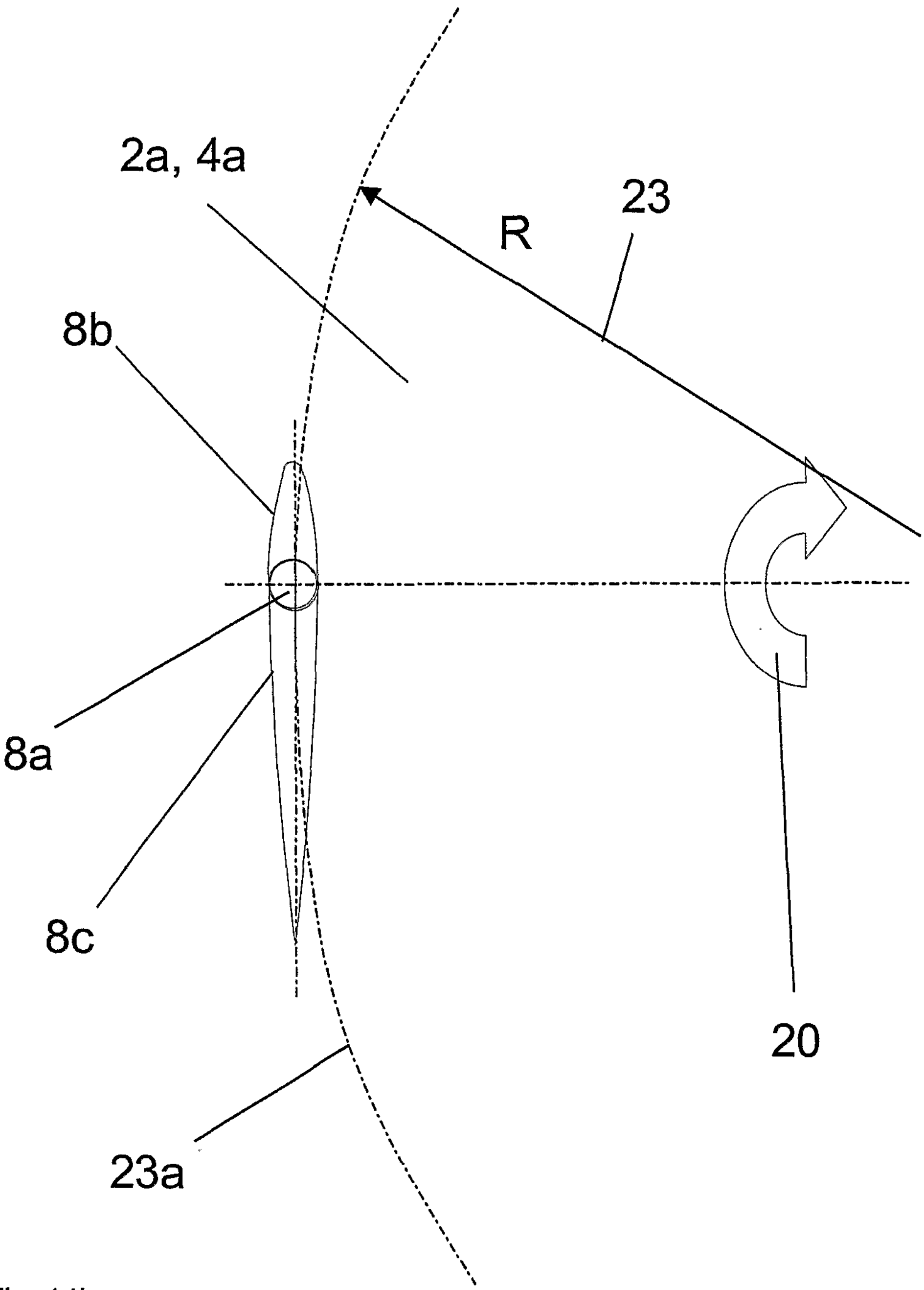


Fig. 14b

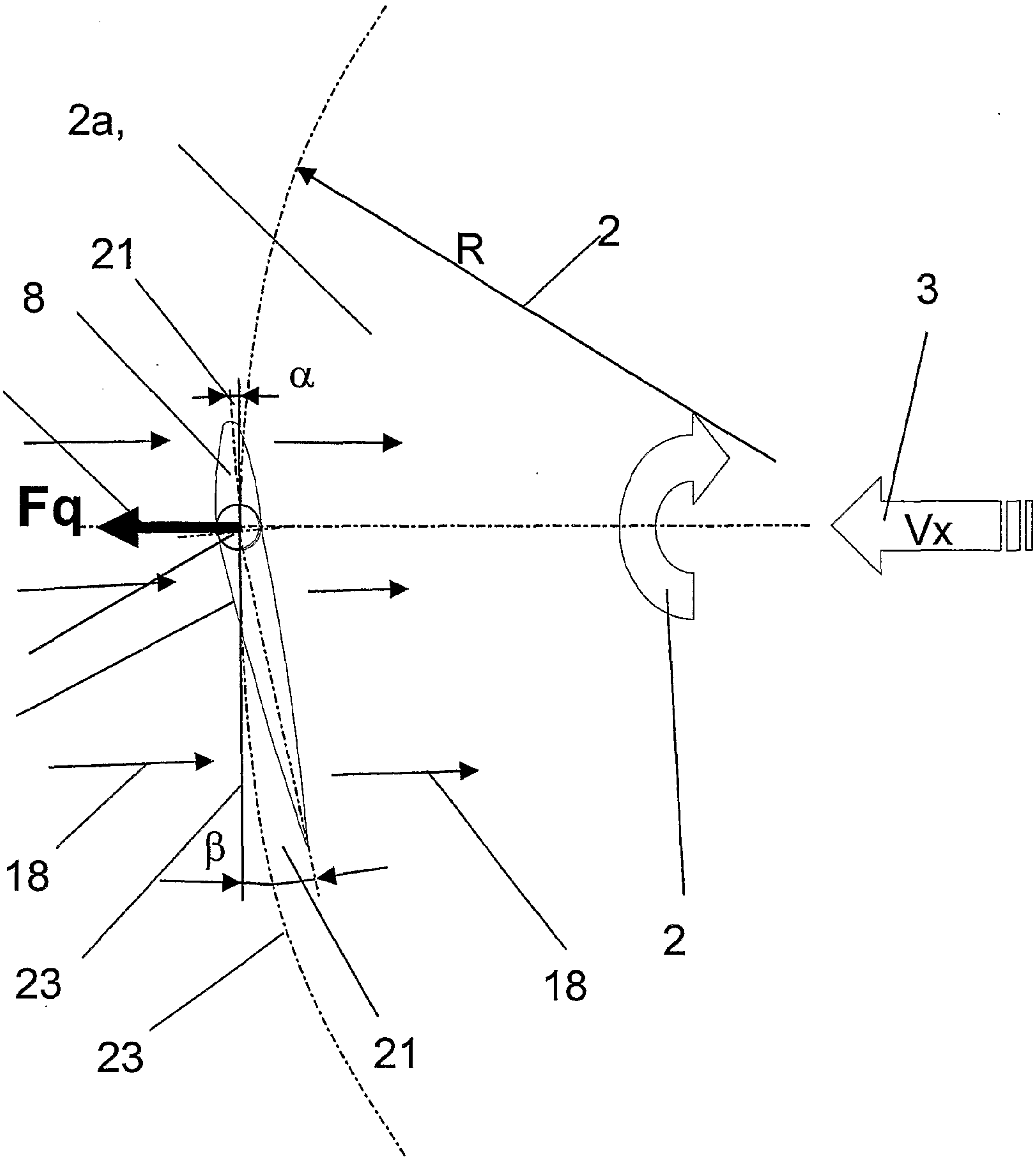


Fig. 14c

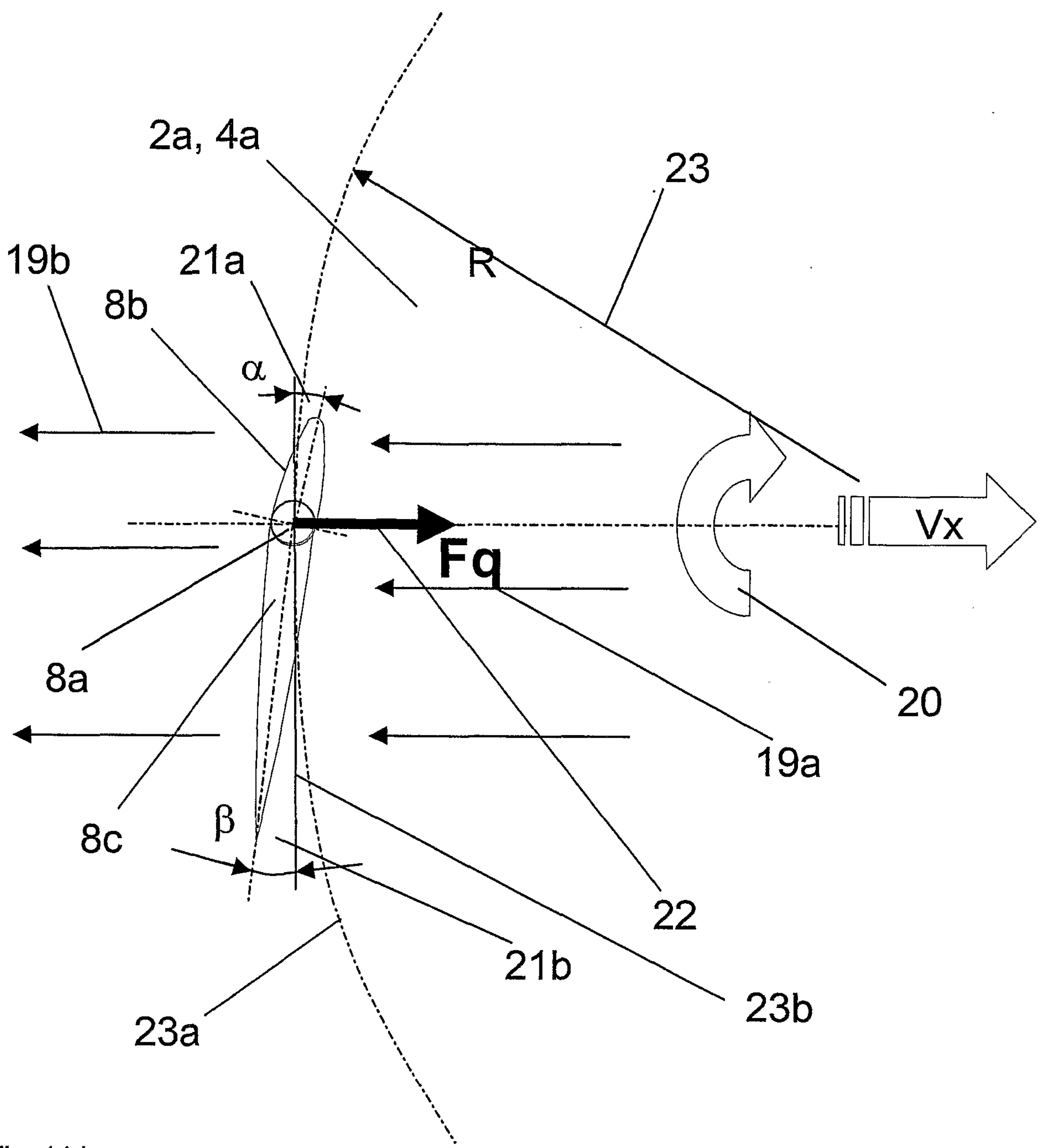


Fig. 14d

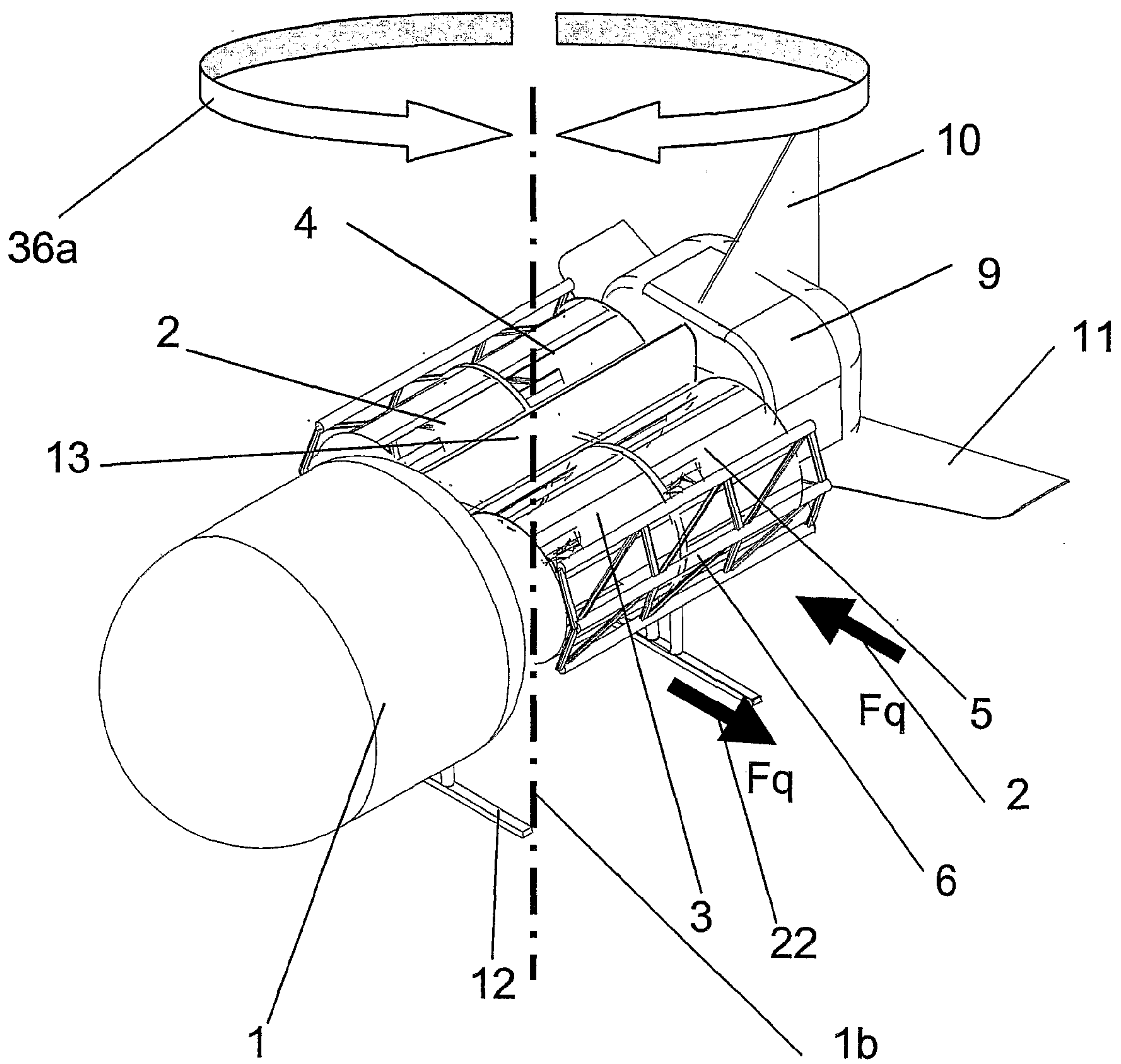


Fig. 15

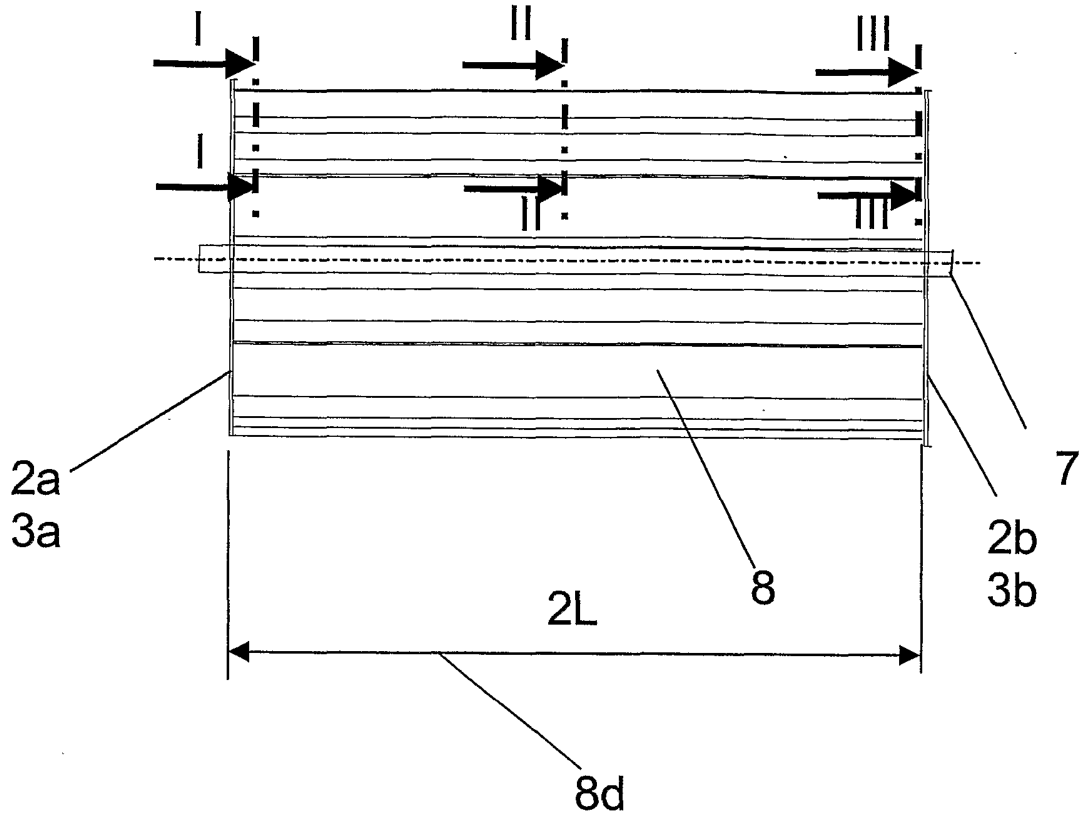


Fig. 16

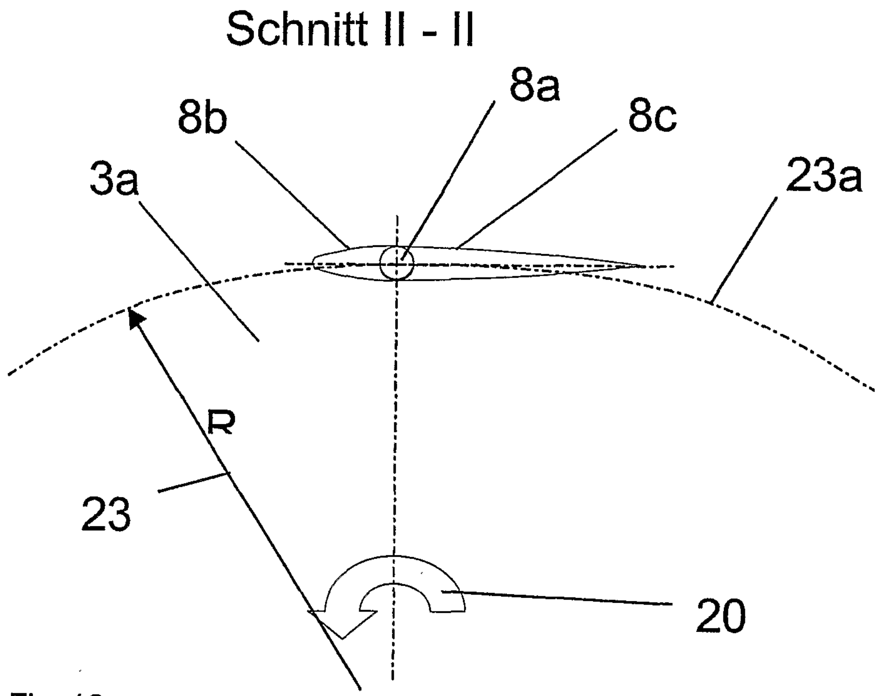


Fig. 16a

Schnitt I - I

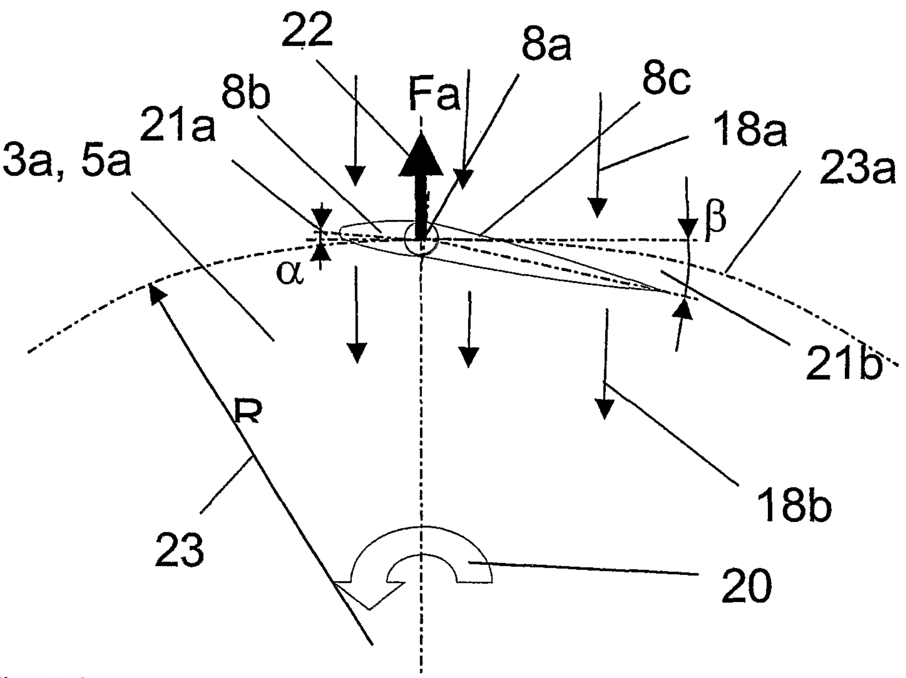


Fig. 16b

Schnitt III - III

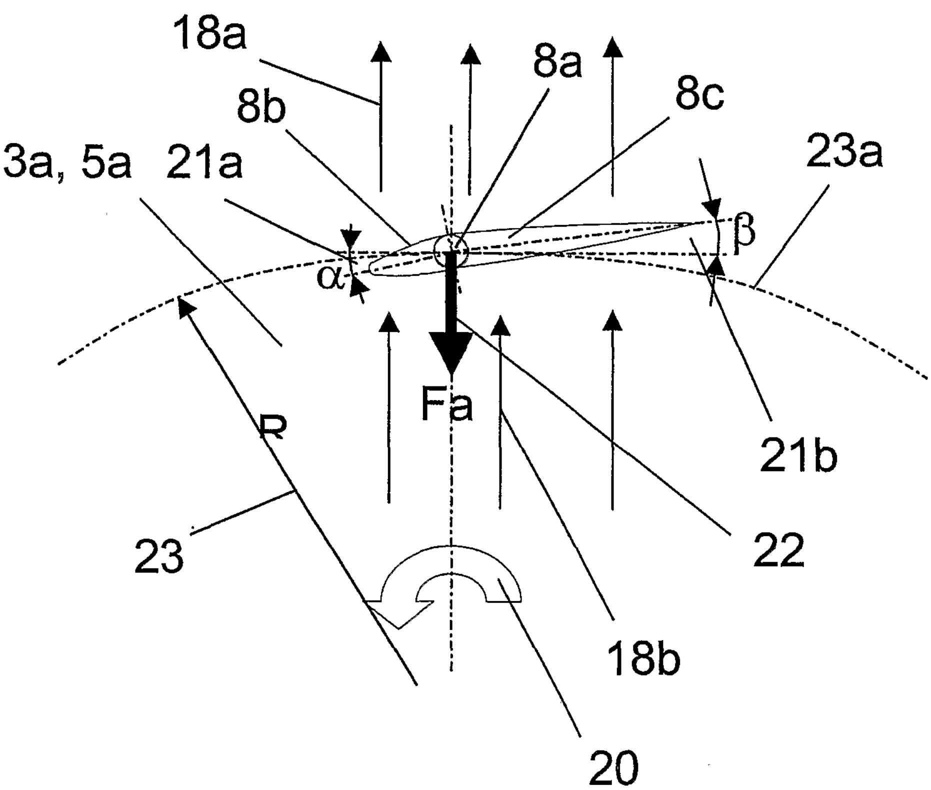


Fig. 16c

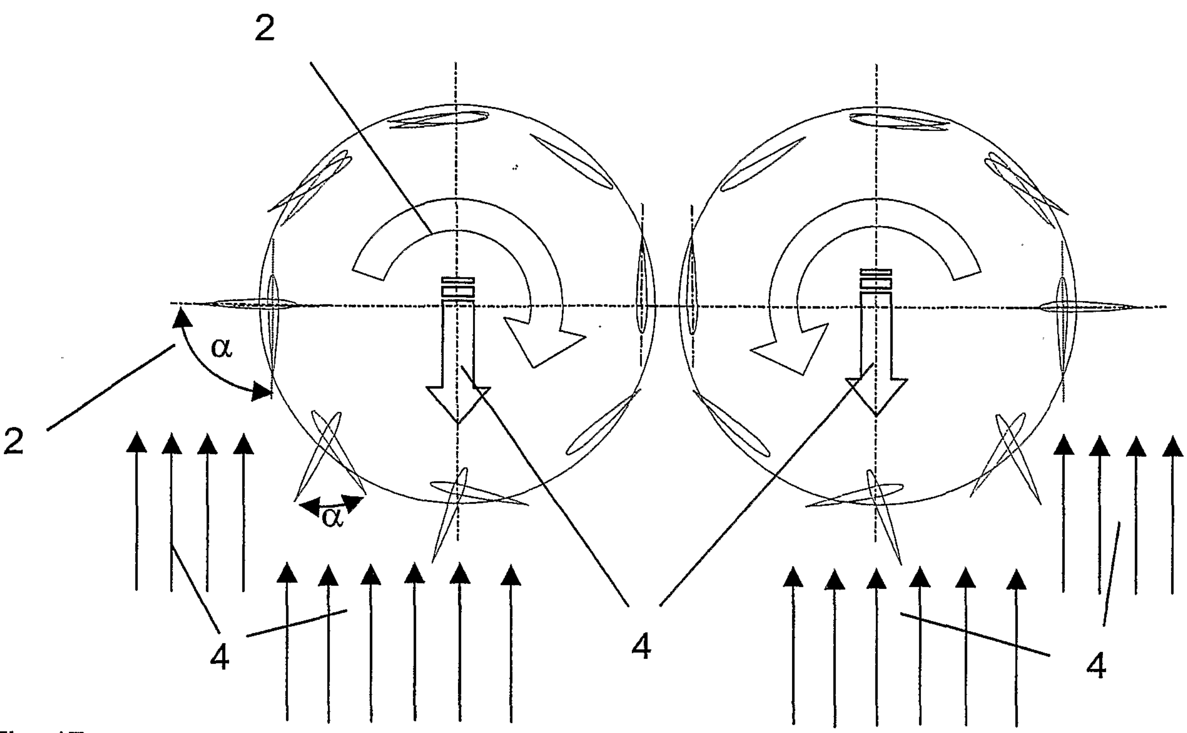


Fig. 17

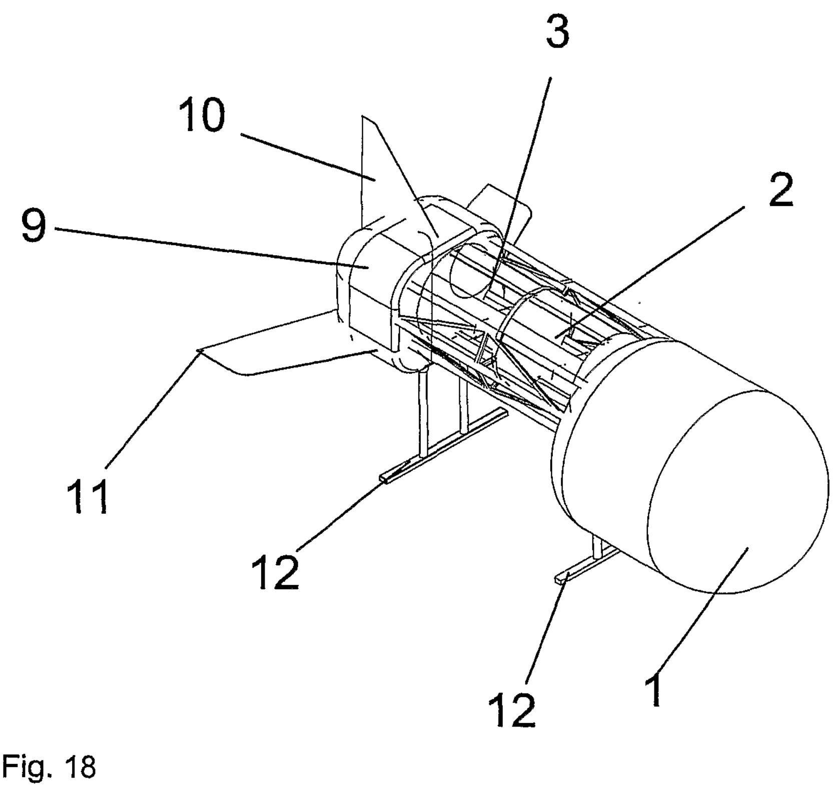


Fig. 18

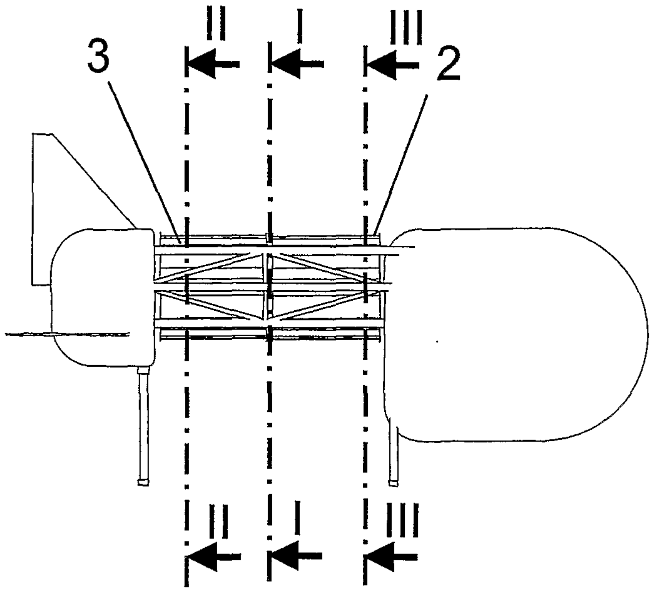


Fig. 18a

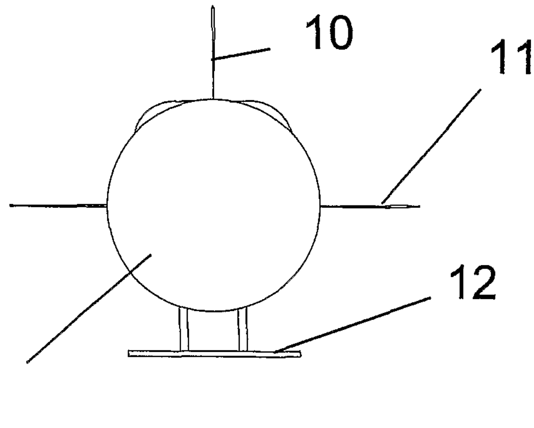


Fig. 18b

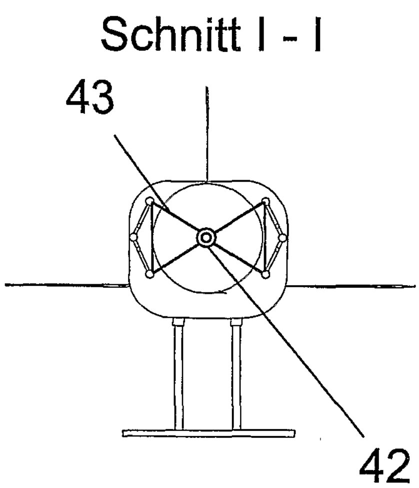


Fig. 18c

Schnitt II - II

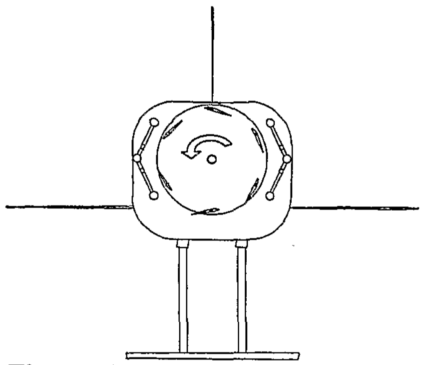


Fig. 18d

Schnitt III - III

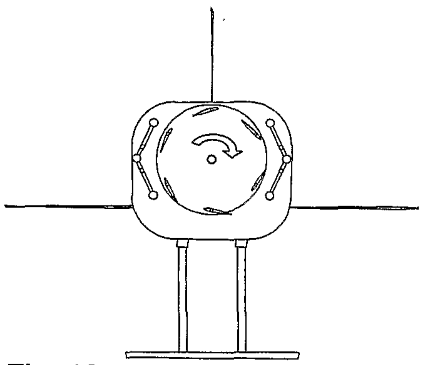


Fig. 18e

Schnitt II - II

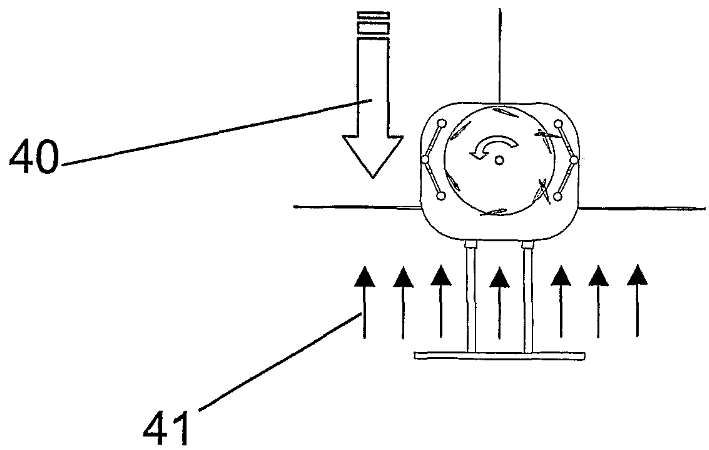


Fig. 18f

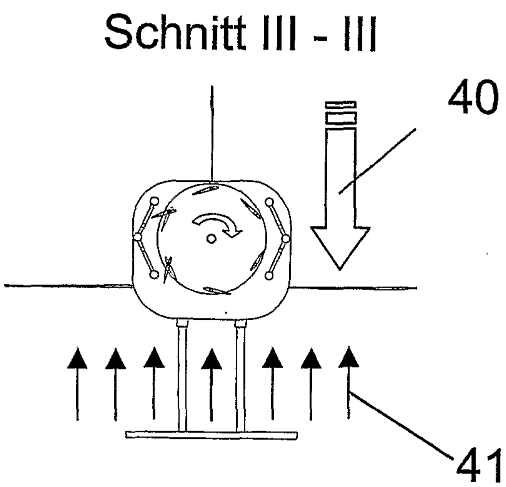


Fig. 18g

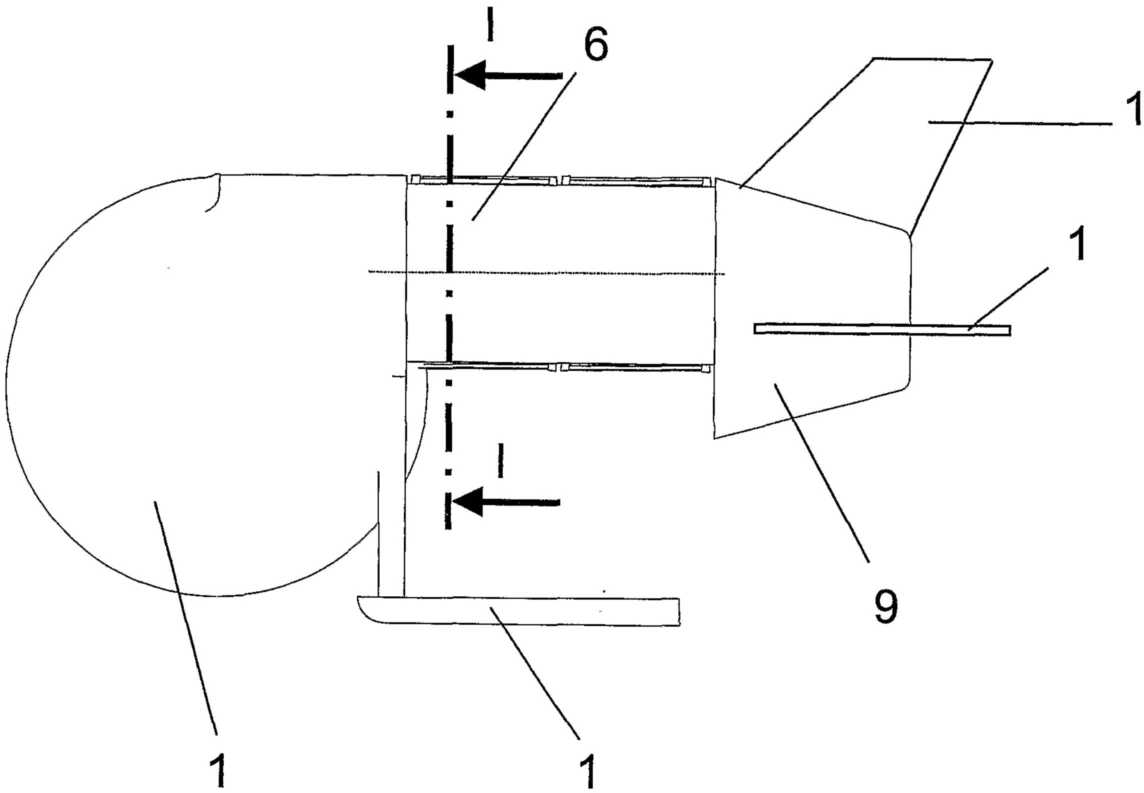


Fig. 19

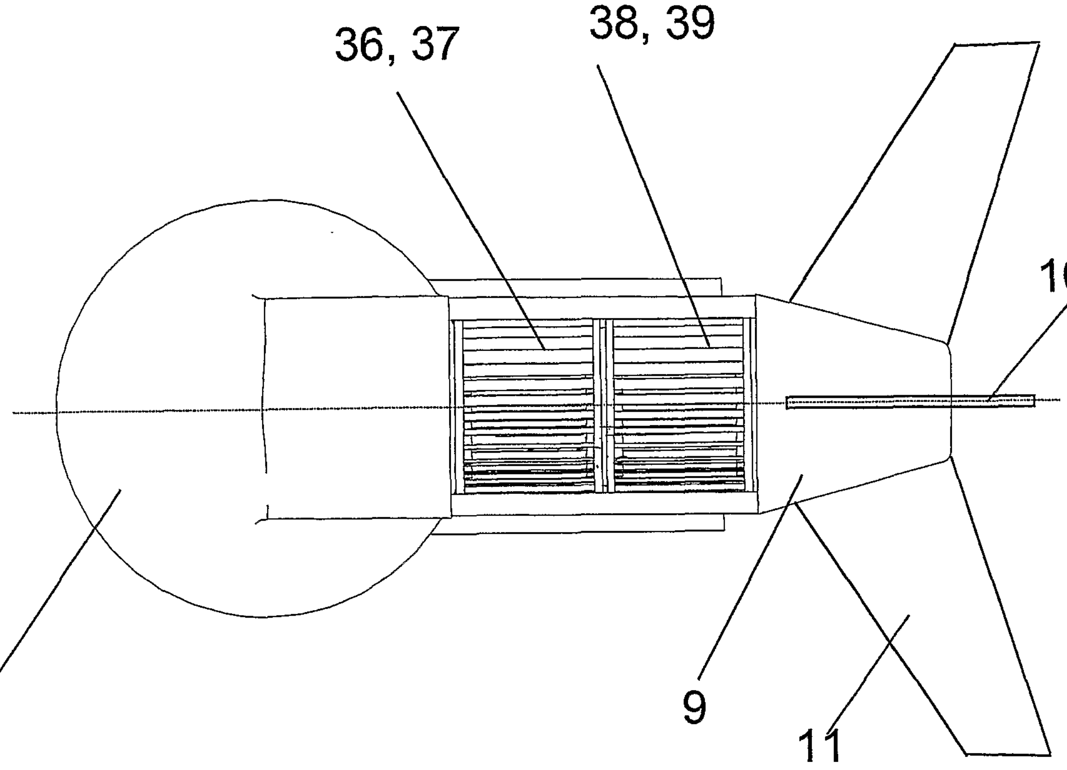


Fig. 19a

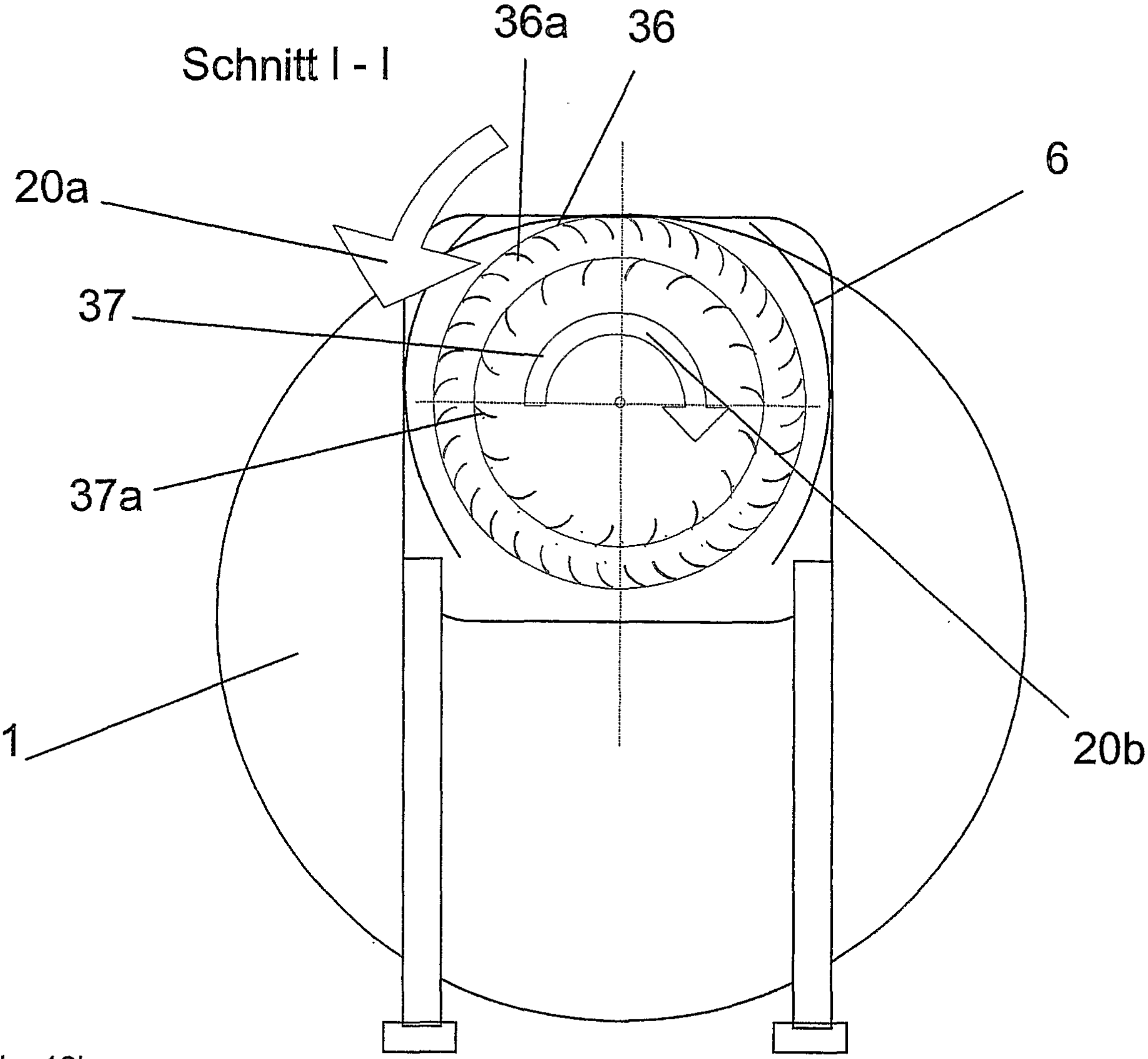


Fig. 19b

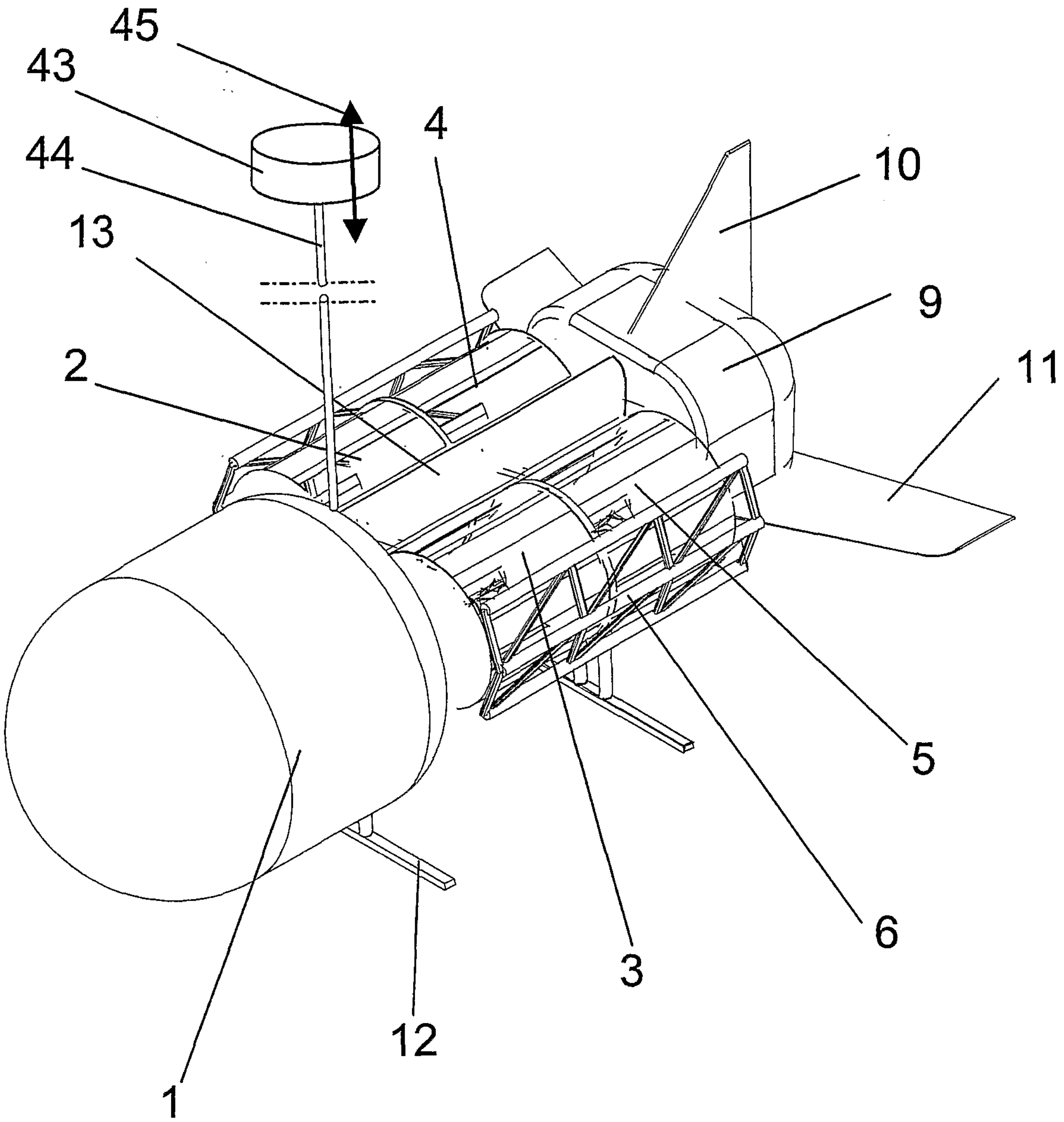


Fig. 20

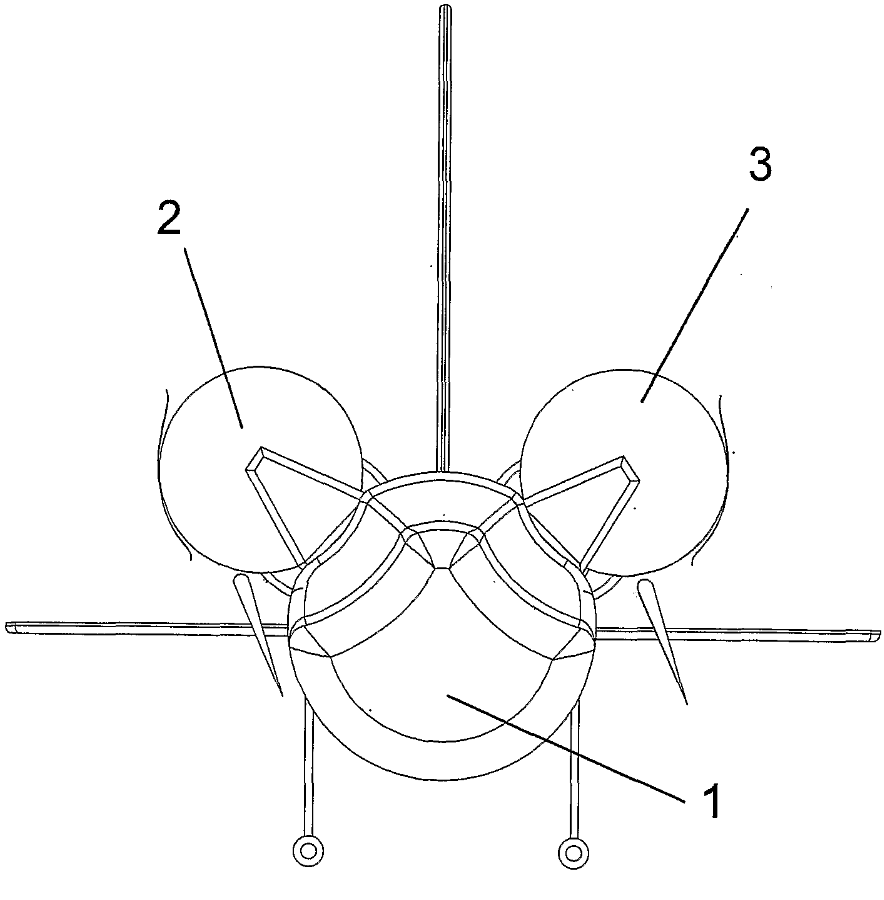


Fig. 21

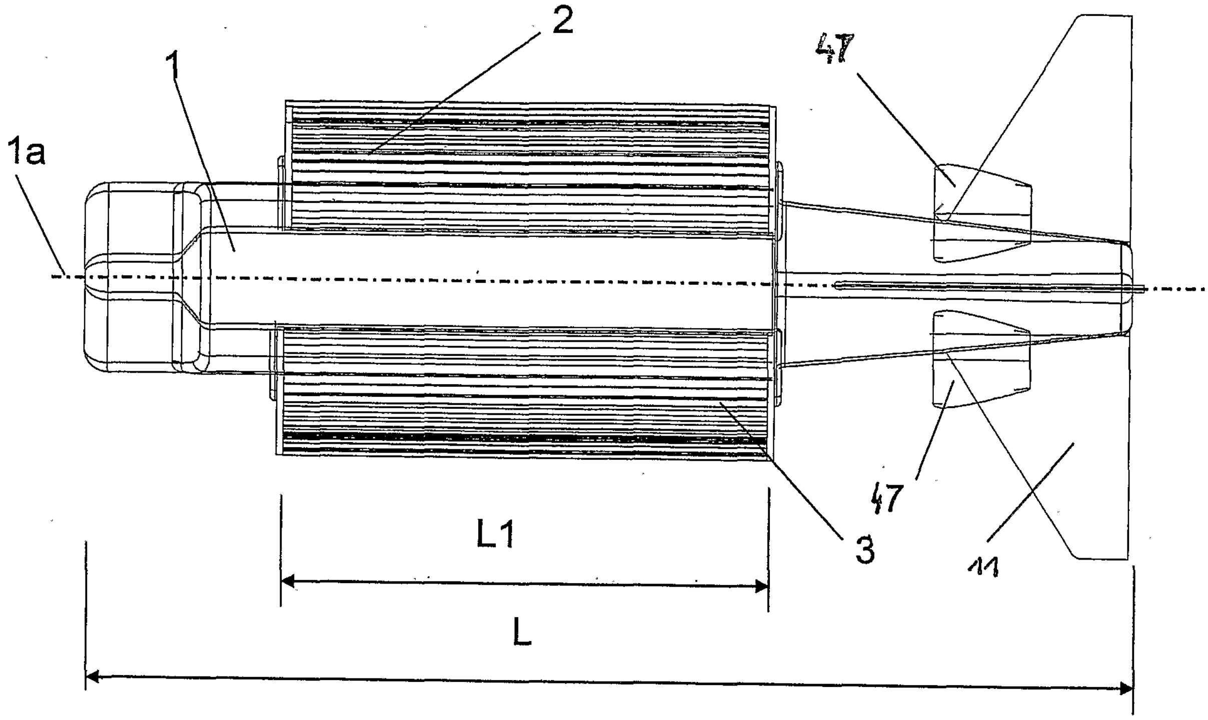


Fig. 22

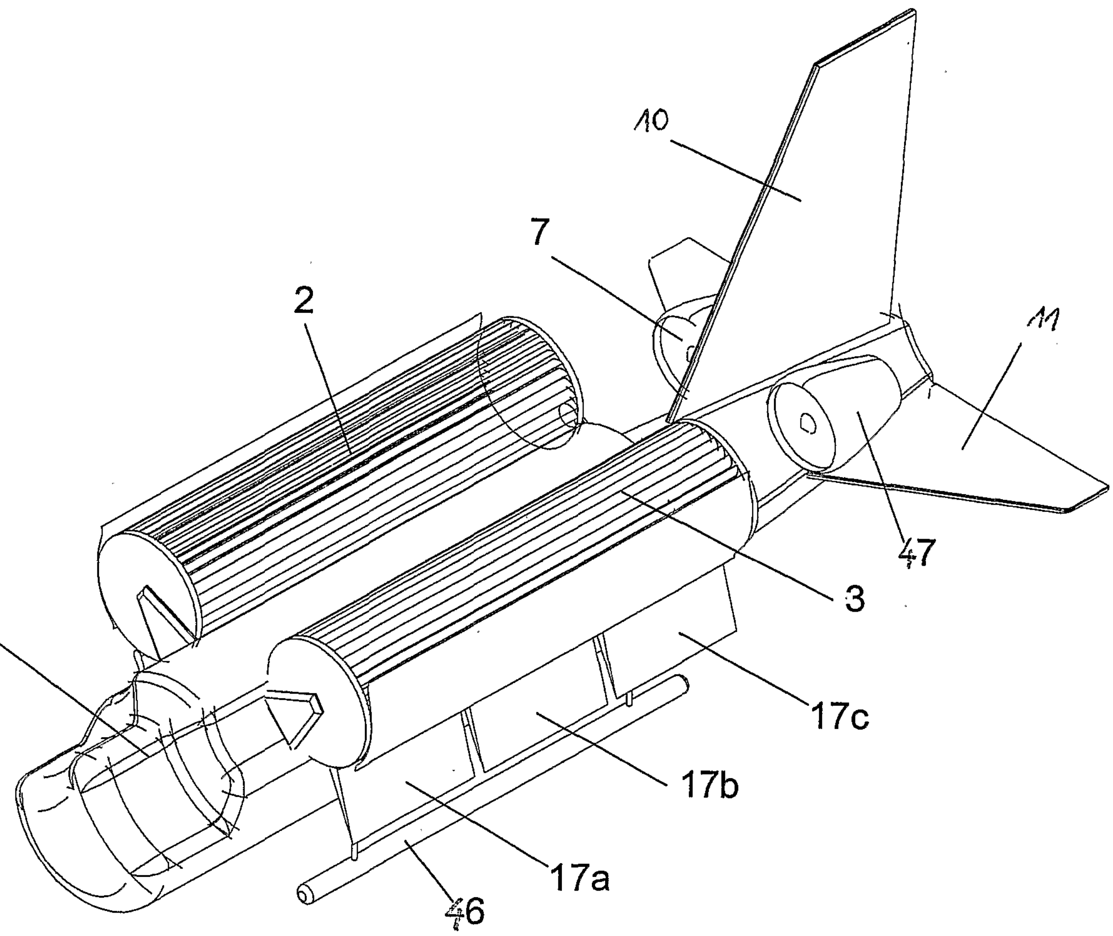


Fig. 23

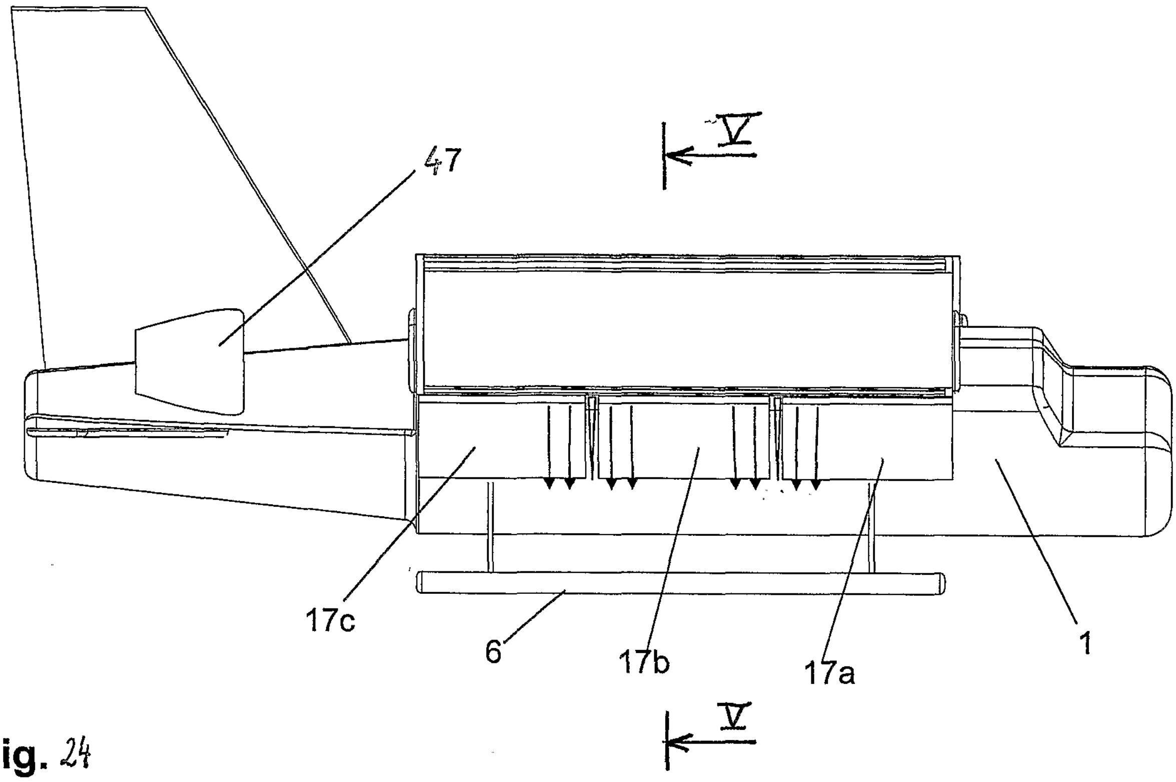

V
47
17c
6
17b
17a
1
V

Fig. 24

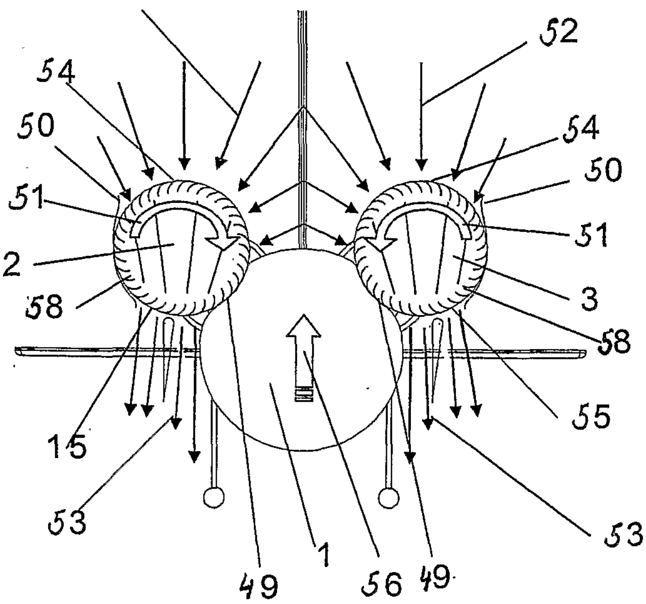

52
54
50
51
2
58
54
50
51
3
58
55
15
53
49
1
56
49
53

Fig. 25

Fig. 26

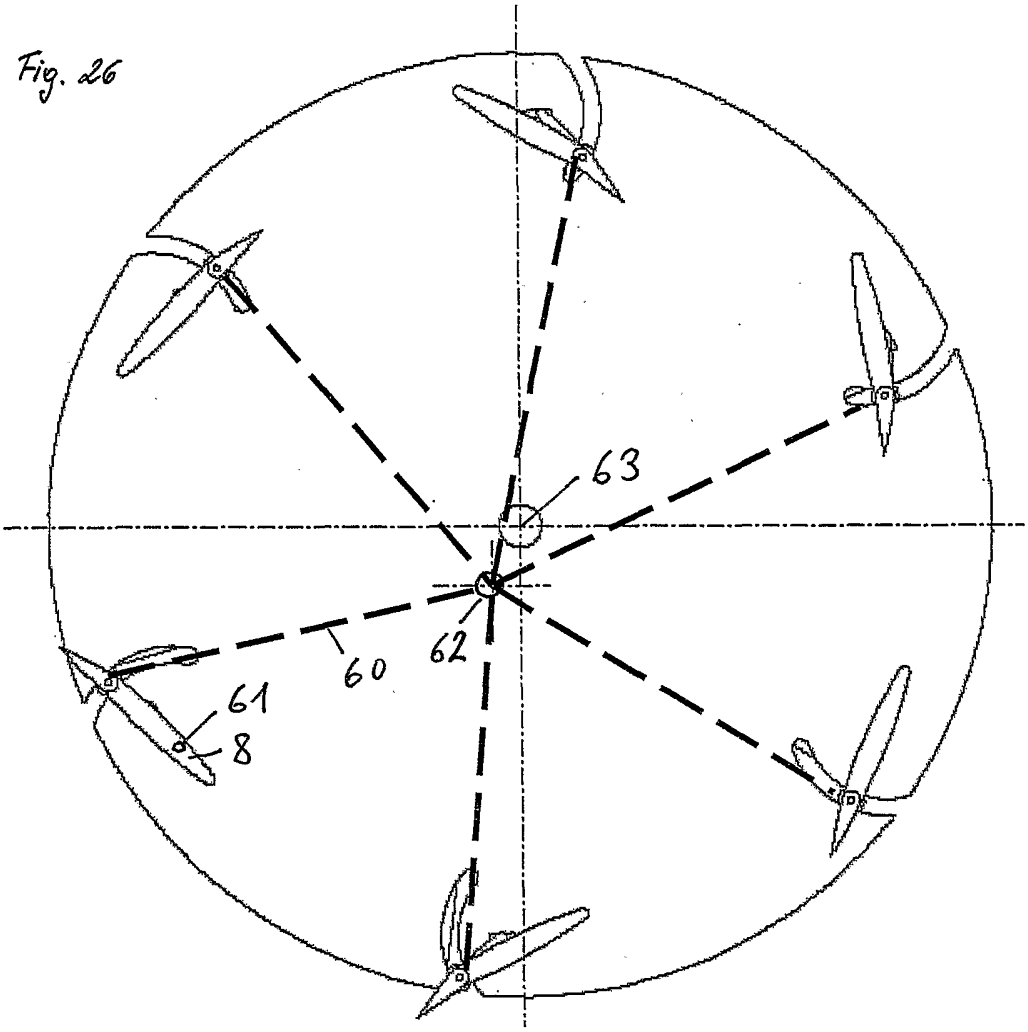
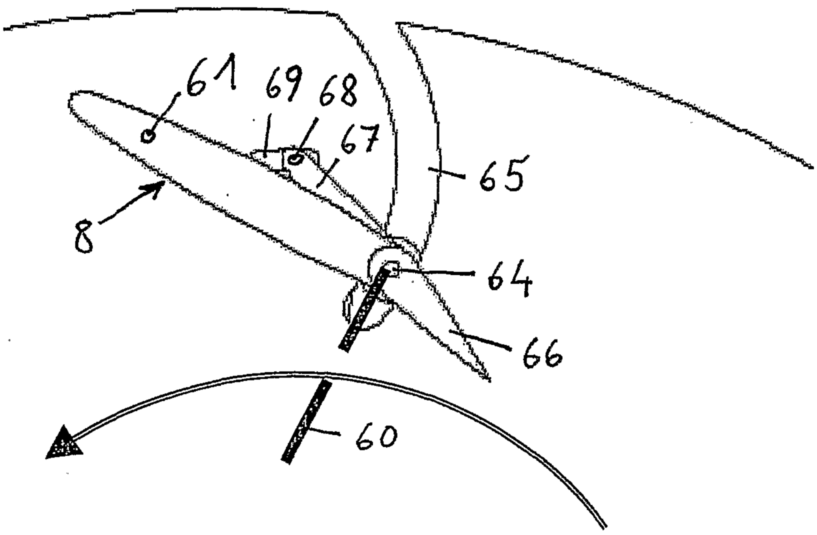


Fig. 27



INTERNATIONAL SEARCH REPORT

International Application No
PCT/AT 03/00371

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 B64C39/00 B64C29/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 B64C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	GB 885 663 A (BRUNO ECK;LAING NIKOLAUS) 28 December 1961 (1961-12-28) page 1, line 14-29 page 2, line 30-59 page 3, line 75-111 page 4, line 47-67 page 5, line 98-123 page 6, line 31-46; figures ---	1-3,6-8, 11-14, 17,19, 21,27-29
X	US 1 761 053 A (RYSTEDT INGEMAR K) 3 June 1930 (1930-06-03) page 2, line 45-98; figures --- -/--	1,2,5,6, 8,11,12, 17,28

[X] Further documents are listed in the continuation of box C.

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Date of the actual completion of the international search	Date of mailing of the international search report
20 April 2004	29/04/2004

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	Salentiny, G

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2 037 377 A (GARDNER ALBERT B) 14 April 1936 (1936-04-14) the whole document	1-4,6,8, 11,12, 17,23, 25,29
A	US 6 007 021 A (TSEPENYUK MIKHAIL) 28 December 1999 (1999-12-28) column 2, line 7 -column 5, line 46; figures	1,4,5,8, 9,11,12, 20,23, 25-29
A	US 5 407 150 A (SADLEIR KIMBERLEY V) 18 April 1995 (1995-04-18) column 14, line 23-42; figures	15,16,18
A	US 3 801 047 A (DELL AQUILA J) 2 April 1974 (1974-04-02) abstract	20

INTERNATIONAL SEARCH REPORT

International Application No
PCT/AT 03/00371

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
GB 885663 A	28-12-1961	NONE	
US 1761053 A	03-06-1930	NONE	
US 2037377 A	14-04-1936	US 1975098 A	02-10-1934
US 6007021 A	28-12-1999	NONE	
US 5407150 A	18-04-1995	AU 663685 B2	19-10-1995
		AU 8223591 A	18-02-1992
		WO 9201603 A1	06-02-1992
		BR 9106696 A	08-06-1993
		EP 0539464 A1	05-05-1993
		JP 6502364 T	17-03-1994
US 3801047 A	02-04-1974	NONE	

INTERNATIONALER RECHERCHENBERICHT

Internationales Aktenzeichen
PCT/AT 03/00371

A. KLASSIFIZIERUNG DES ANMELDUNGSGEGENSTANDES
IPK 7 B64C39/00 B64C29/00

Nach der Internationalen Patentklassifikation (IPK) oder nach der nationalen Klassifikation und der IPK

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Recherchierter Mindestprüfstoff (Klassifikationssystem und Klassifikationssymbole)
IPK 7 B64C

Recherchierte aber nicht zum Mindestprüfstoff gehörende Veröffentlichungen, soweit diese unter die recherchierten Gebiete fallen

Während der internationalen Recherche konsultierte elektronische Datenbank (Name der Datenbank und evtl. verwendete Suchbegriffe)

EPO-Internal, WPI Data

C. ALS WESENTLICH ANGESEHENE UNTERLAGEN

Kategorie°	Bezeichnung der Veröffentlichung, soweit erforderlich unter Angabe der in Betracht kommenden Teile	Betr. Anspruch Nr.
X	GB 885 663 A (BRUNO ECK;LAING NIKOLAUS) 28. Dezember 1961 (1961-12-28) Seite 1, Zeile 14-29 Seite 2, Zeile 30-59 Seite 3, Zeile 75-111 Seite 4, Zeile 47-67 Seite 5, Zeile 98-123 Seite 6, Zeile 31-46; Abbildungen ---	1-3,6-8, 11-14, 17,19, 21,27-29
X	US 1 761 053 A (RYSTEDT INGEMAR K) 3. Juni 1930 (1930-06-03) Seite 2, Zeile 45-98; Abbildungen ---	1,2,5,6, 8,11,12, 17,28

-/--

[X] Weitere Veröffentlichungen sind der Fortsetzung von Feld C zu entnehmen

[X] Siehe Anhang Patentfamilie

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Datum des Abschlusses der internationalen Recherche	Absendedatum des internationalen Recherchenberichts
20. April 2004	29/04/2004
Name und Postanschrift der Internationalen Recherchenbehörde Europäisches Patentamt, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Bevollmächtigter Bediensteter Salentiny, G

Formblatt PCT/ISA/210 (Blatt 2) (Januar 2004)

C.(Fortsetzung) ALS WESENTLICH ANGESEHENE UNTERLAGEN

Kategorie°	Bezeichnung der Veröffentlichung, soweit erforderlich unter Angabe der in Betracht kommenden Teile	Betr. Anspruch Nr.
A	US 2 037 377 A (GARDNER ALBERT B) 14. April 1936 (1936-04-14) das ganze Dokument	1-4,6,8, 11,12, 17,23, 25,29
A	US 6 007 021 A (TSEPENYUK MIKHAIL) 28. Dezember 1999 (1999-12-28) Spalte 2, Zeile 7 -Spalte 5, Zeile 46; Abbildungen	1,4,5,8, 9,11,12, 20,23, 25-29
A	US 5 407 150 A (SADLEIR KIMBERLEY V) 18. April 1995 (1995-04-18) Spalte 14, Zeile 23-42; Abbildungen	15,16,18
A	US 3 801 047 A (DELL AQUILA J) 2. April 1974 (1974-04-02) Zusammenfassung	20

INTERNATIONALER RECHERCHENBERICHT

Internationales Aktenzeichen
PCT/AT 03/00371

Im Recherchenbericht angeführtes Patentdokument	Datum der Veröffentlichung	Mitglied(er) der Patentfamilie	Datum der Veröffentlichung
GB 885663 A	28-12-1961	KEINE	
US 1761053 A	03-06-1930	KEINE	
US 2037377 A	14-04-1936	US 1975098 A	02-10-1934
US 6007021 A	28-12-1999	KEINE	
US 5407150 A	18-04-1995	AU 663685 B2	19-10-1995
		AU 8223591 A	18-02-1992
		WO 9201603 A1	06-02-1992
		BR 9106696 A	08-06-1993
		EP 0539464 A1	05-05-1993
		JP 6502364 T	17-03-1994
US 3801047 A	02-04-1974	KEINE	

(19) österreichisches patentamt

(10) AT 501 864 A1 2006-12-15

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(51) Int. Cl.[8]: **B64C 29/00** (2006.01), **B64C 39/00** (2006.01)

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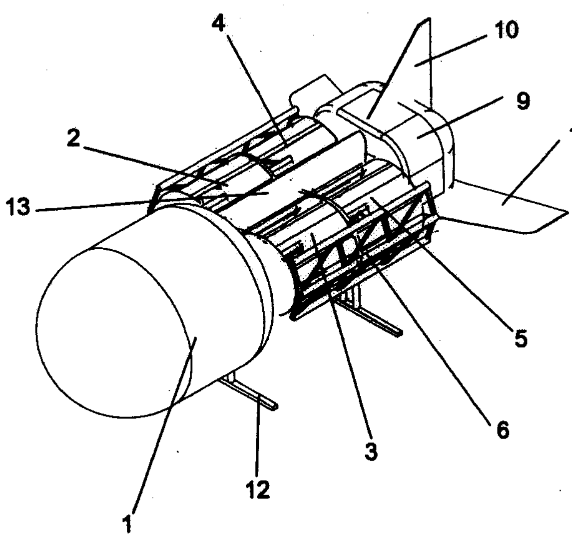
(54) **FLUGGERÄT**

(57) Die Erfindung betrifft ein Fluggerät mit einem System spezieller Auftriebskörper (3, 4, 5, 6 bzw. 36, 37, 38, 39), die um eine Drehachse rotieren, die im Fluggerät vorzugsweise in Längsrichtung angeordnet ist, und das dem Fluggerät Eigenschaften verleiht, die es ermöglichen, aus dem Stillstand senkrecht zu starten, vertikal in die Höhe zu steigen, wahlweise einen Schwebezustand einzunehmen, wahlweise in der Luft eine Vorwärtsbewegung oder Rückwärtsbewegung mit geringer Geschwindigkeit auszuführen, eine Drehbewegung in oder gegen den Uhrzeigersinn um die Vertikalachse auszuführen, in der Luft eine Querbewegung nach Backbord oder Steuerbord auszuführen, in der Luft aus einem Schwebezustand in eine rasche Vorwärtsbewegung überzugehen und vertikal aus der Luft ohne einer zusätzlich überlagerten Horizontalbewegung zu landen. Weiters zeichnet sich die Erfindung dadurch aus, dass keine rotierenden Antriebseinheiten über die Außenkontur des Fluggerätes hinausragen, sodass dem Fluggerät damit Eigenschaften verliehen werden, die ein heran Fliegen an ein festes Hindernis (z. B. Felswand, Häuserwand) erlaubt, ohne dabei Gefahr zu laufen, dass bewegte Elemente bei einer Kollision mit einem festen Hindernis beschädigt werden und zu einem Absturz des Fluggerätes (wie z. B. im Falle eines Hubschraubers) führen würde. In einer bevorzugten Ausführungsvariante sind die um die Drehachse rotierenden Auftriebskörper autorotationsfähig, sodass selbst bei einem Ausfall des Antriebsaggregates oberhalb einer kritischen Höhe, eine sichere Landung möglich ist. Weiters ist dem Piloten ein sicheres und kollisionsfreies Verlassen des Fluggerätes mittels Schleudersitz möglich und ein Aufklärungsgerät kann oberhalb des Rumpfes vertikal in die Höhe verbracht und wieder eingebracht werden, ohne dass eine Kollision mit einem rotierenden Auftriebskörper stattfinden kann.



AT 501 864 A1 2006-12-15

(1

ZUSAMMENFASSUNG

Die Erfindung betrifft ein Fluggerät mit einem System spezieller Auftriebskörper (3, 4, 5, 6 bzw. 36, 37, 38, 39), die um eine Drehachse rotieren, die im Fluggerät vorzugsweise in Längsrichtung angeordnet ist, und das dem Fluggerät Eigenschaften verleiht, die es ermöglichen, aus dem Stillstand senkrecht zu starten, vertikal in die Höhe zu steigen, wahlweise einen Schwebezustand einzunehmen, wahlweise in der Luft eine Vorwärtsbewegung oder Rückwärtsbewegung mit geringer Geschwindigkeit auszuführen, eine Drehbewegung in oder gegen den Uhrzeigersinn um die Vertikalachse auszuführen, in der Luft eine Querbewegung nach Backbord oder Steuerbord auszuführen, in der Luft aus einem Schwebezustand in eine rasche Vorwärtsbewegung überzugehen und vertikal aus der Luft ohne einer zusätzlich überlagerten Horizontalbewegung zu landen. Weiters zeichnet sich die Erfindung dadurch aus, dass keine rotierenden Antriebseinheiten über die Außenkontur des Fluggerätes hinausragen, sodass dem Fluggerät damit Eigenschaften verliehen werden, die ein heran Fliegen an ein festes Hindernis (z. B. Felswand, Häuserwand) erlaubt, ohne dabei Gefahr zu laufen, dass bewegte Elemente bei einer Kollision mit einem festen Hindernis beschädigt werden und zu einem Absturz des Fluggerätes (wie z. B. im Falle eines Hubschraubers) führen würde. In einer bevorzugten Ausführungsvariante sind die um die Drehachse rotierenden Auftriebskörper autorotationsfähig, sodass selbst bei einem Ausfall des Antriebsaggregates oberhalb einer kritischen Höhe, eine sichere Landung möglich ist. Weiters ist dem Piloten ein sicheres und kollisionsfreies Verlassen des Fluggerätes mittels Schleudersitz möglich und ein Aufklärungsgerät kann oberhalb des Rumpfes vertikal in die Höhe verbracht und wieder eingebracht werden, ohne dass eine Kollision mit einem rotierenden Auftriebskörper stattfinden kann.

Fig. 1

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Die Erfindung betrifft ein Fluggerät mit einem System spezieller Auftriebskörper, die als Rotoren ausgebildet sind, mit einer Drehachse die im wesentlichen parallel zur Längsachse des Fluggerätes angeordnet ist, wobei jeder Rotor mit einer bestimmten Anzahl tragflügelähnlicher Rotorblätter versehen ist, die im wesentlichen an zwei Scheibenähnlichen Endkörpern derart angeordnet sind, dass während einer vollen Umdrehung des Auftriebskörpers (Rotors) die Mittelachse des Rotorblattes eine Kreisbewegung mit dem Abstand von der Drehachse als Radius ausführt, und das Rotorblatt während einer vollen Umdrehung individuell in seiner Lage verändert werden kann. Damit kann in jeder augenblicklichen Position des Rotorblattes eine definierte Krafteinwirkung (z. B. Auftriebskraft, Querkraft) auf das Fluggerät erzeugt werden.

Es sind vielfache Anstrengungen unternommen worden, die Vorteile eines Flugzeugs mit denen eines Hubschraubers zu vereinen. Von besonderem Interesse ist dabei die Eigenschaft von Hubschraubern, senkrecht starten und landen zu können, oder auch bei Bedarf in der Luft stillstehen zu können, um beispielsweise Personen zu bergen, bzw. um spezielle Transport- und Montageflugmanöver oder ähnliche Aufgaben zu erfüllen. Nachteilig bei bestehenden Hubschraubern sind, der hohe technische Aufwand, insbesondere im Bereich der Rotorsteuerung, sowie das enorme Absturzrisiko bereits bei geringfügigster Berührung der rotierenden Rotorflügel mit einem Hindernis wie z. B Baumwipfel oder Felswände. Gerade Einsatzbedingungen, wie Alpinbergungen, sind äußerst kritisch, da einerseits eine Position möglichst nahe an z. B. einer Felswand erforderlich wäre, andererseits die geringste Kollision bereits fatale Auswirkungen zur Folge hat; somit kann nur unter Einhaltung entsprechend großer Sicherheitsabstände gearbeitet werden. Ein weiterer Nachteil ist der hohe Treibstoffverbrauch von Hubschraubern, der auch im Reiseflug gegeben ist.

Um diese Nachteile zu vermeiden, sind so genannte VTOL- oder STOL-Flugzeuge entwickelt worden, die vom Aufbau her grundsätzlich Flugzeugen ähneln, jedoch durch verschiedene technische Maßnahmen mit der Fähigkeit ausgestattet sind, senkrecht starten und landen zu können, oder zumindest mit extrem kurzen Start- und Landebahnen auskommen.

Eine solche Lösung ist beispielsweise in der EP 0 918 686 A offenbart. Diese Druckschrift beschreibt ein Flugzeug, das Tragflächen aufweist, die im Wesentlichen durch Querstromrotoren gebildet sind. Auf diese Weise ist es möglich, durch entsprechende Strahlumlenkung einen vertikal nach unten gerichteten Luftstrahl zu erzeugen, um den Senkrechtstart des Fluggerätes zu ermöglichen. Für den Reiseflug kann der Schub entsprechend umgelenkt werden.

Nachteilig bei dieser bekannten Lösung ist zum einen, dass die auf die Auftriebserzeugung optimierten Tragflächen einen hohen Luftwiderstand aufweisen, so dass der Treibstoffverbrauch insbesondere bei höheren Fluggeschwindigkeiten übermäßig groß ist und dass das Fluggerät insgesamt eine relativ große Spannweite aufweist. Es benötigt daher viel Platz und ist auch unter beengten Verhältnissen nicht oder nur schlecht einsetzbar.

Ein weiteres Fluggerät, das Auftrieb unter Verwendung von abgewandelten Querstromventilatoren erzeugt, ist in der DE 196 34 522 A offenbart. Abgesehen von der Frage der nicht unmittelbar ersichtlichen Funktionsfähigkeit eines solchen Fluggerätes sind auch hier die oben beschriebenen Nachteile gegeben.

Ein weiteres Fluggerät mit einem Querstromrotor als Antriebselement ist aus der US 6,016,992 A bekannt. Auch hier ergibt sich durch den Querstromrotor in Flugrichtung eine sehr große Querschnittsfläche, und der Platzbedarf ist ähnlich hoch wie bei den oben beschriebenen Lösungen.

Ein weiteres bekanntes Fluggerät mit der Möglichkeit des Senkrechtstarts ist in der US 3,361,386 A offenbart. Bei diesem Flugzeug sind extrem variable Tragflächen vorgesehen, die mit Öffnungen zum Gasaustritt versehen sind. Durch den systembedingt schlechten Wirkungsgrad eines solchen Systems ist der Treibstoffverbrauch extrem hoch.

Eine weitere Variante eines derartigen Fluggerätes ist auch in der Patentanmeldung AT 10461 beschrieben.

Dem Stand der Technik nahe liegend ist auch jenes Antriebskonzept für Wasserfahrzeuge, welches als Voith - Schneider Antrieb bekannt ist. Dieses seit ca. 75 Jahren bekannte Antriebssystem unterscheidet sich im wesentlichen dadurch, dass die Schwenkbewegung der einzelnen Schaufeln, während einer vollen Umdrehung des Drehkranzes, in einem festen kinematischen Verhältnis zueinander abläuft. Damit ist eine Vorschubkraft immer nur in eine einzige Richtung möglich. Im Unterschied dazu ist bei dem hier vorgestellten erfinderischen rotierenden Auftriebskörper, unabhängig von einer ersten Kraftkomponente, z. B. gleich bleibende vertikale Auftriebskomponente, eine zweite Kraftkomponente in Querrichtung erzeugbar.

Die gegenständliche Erfindung bezieht sich auf weitere Ausführungsvarianten von VTOL-Fluggeräten, die mit rotierenden Auftriebskörpern ausgerüstet sind, deren Drehachse im Wesentlichen parallel zur Längsachse des Fluggerätes angeordnet ist.

Aufgabe der vorliegenden Erfindung ist es, ein Fluggerät zu schaffen, das einen senkrechten Start und eine senkrechte Landung ermöglicht, das in der Luft einen

Schwebezustand einnehmen kann, mit einer Beweglichkeit, die eine langsame Vorwärts-, Rückwärts-, parallele Seitwärtsbewegung nach Backbord oder Steuerbord sowie eine Drehbewegung um die Vertikalachse in bzw. gegen den Uhrzeigersinn ausführen kann, und das gleichzeitig für eine hohe Reisefluggeschwindigkeit geeignet ist. Durch die gewählte Ausbildung der äußeren geometrischen Form des Fluggerätes ist der Übergang von einem Schwebezustand in eine Vorwärtsbewegung mit hoher Reisefluggeschwindigkeit zu gewährleisten. Insbesondere soll dabei eine hohe Treibstofföknomie erreicht werden, bei vergleichsweise geringem, technischem Aufwand. Ein weiterer Anspruch betrifft die Erfüllung der höchsten Sicherheitstechnischen Standards, die dem Fluggerät selbst bei einem Totalausfall der Antriebsmotore eine sichere Landung ermöglichen. Weiters sollen die rotierenden Auftriebskörper mit einer Verkleidung derart geschützt werden, dass das Fluggerät auch sehr nahe an Hindernisse (z. B. Felswand, Hochhauswand) heran manövriert werden kann und dass selbst bei Berührung des Fluggerätes mit einem Hindernis, bedingt durch die gegen Kollision geschützten rotierenden Elemente des Auftriebskörpers, ein Absturz sicher verhindert werden kann. Ein für den Piloten sicheres und kollisionsfreies Verlassen des Fluggerätes mittels Schleudersitz ist ebenfalls möglich, und stellt einen weiteren Anspruch dar.

Erfindungsgemäß werden diese Aufgaben dadurch gelöst, dass das Fluggerät mit Auftriebskörpern versehen ist, die als Rotoren ausgebildet sind, mit einer Drehachse die im wesentlichen parallel zur Längsachse des Fluggerätes angeordnet ist, und dass jeder Rotor mit einer bestimmten Anzahl tragflügelähnlicher Rotorflügel versehen ist, die im wesentlichen an zwei Scheibenähnlichen Endkörpern derart angeordnet sind, dass während einer vollen Umdrehung des Auftriebskörpers (Rotors) die Mittelachse des Rotorblattes eine Kreisbewegung mit dem Abstand von der Drehachse als Radius ausführt, und das Rotorblatt während einer vollen Umdrehung individuell in seiner Lage verändert werden kann. Damit kann in jeder augenblicklichen Position des Rotorblattes eine definierte Krafteinwirkung (z. B. Auftriebskraft, Querkraft) auf das Fluggerät erzeugt werden.

Durch geeignete Wahl der Anordnung der Auftriebskörper im Fluggerät, ist zudem der Raum oberhalb der Pilotenkanzel freigehalten, sodass dem Piloten ein sicheres und kollisionsfreies Verlassen des Fluggerätes mittels Schleudersitz möglich ist (dies ist z. B. bei einem Hubschrauber nicht möglich).

Für den militärischen Einsatzbereich bietet diese Anordnung der Auftriebskörper eine weitere Möglichkeit und zwar können für Aufklärungszwecke Radar- bzw. andere optische Geräte auch oberhalb des Fluggerätes angeordnet werden. Mit diesem Fluggerät ist es nicht notwendig eine schützende Geländeformation zu verlassen, ohne zuvor mit einem flexibel mit dem Fluggerät verbundenen Aufklärungsgerät, welches z. B. vertikal oberhalb des im Schwebezustand verharrenden Fluggerätes in die Höhe verbracht und anschließend wieder eingeholt werden kann, das Geschehen hinter der Geländeformation erfasst und beurteilt zu haben.

Die erfindungsgemäße Lösung erlaubt ein Manövrieren des Fluggeräts auch bei niedrigen Geschwindigkeiten oder im Schwebflug, ohne die Drehzahl des Antriebsaggregats verändern zu müssen, da Richtung und Stärke der Auftriebskräfte durch die Steuerung der Rororblätter in weiten Grenzen variierbar sind. Dadurch wird eine extrem große Wendigkeit erreicht.

Durch die Anordnung der Auftriebskörper parallel zum Rumpf können mehrere Vorteile gleichzeitig erreicht werden. Zum einen können die Auftriebskörper einen relativ großen Durchmesser aufweisen, ohne die Querschnittsfläche in Fortbewegungsrichtung allzu sehr zu erhöhen, wodurch auch im schnellen Reiseflug ein geringer Treibstoffbedarf gegeben ist. Zum anderen ist das erfindungsgemäße Fluggerät äußerst kompakt aufgebaut und benötigt somit nicht nur wenig Platz in einem Hangar oder dergleichen, sondern ist auch extrem wendig. Dies ermöglicht beispielsweise die Landung auf Waldlichtungen oder im inner städtischen Bereich zwischen Bauwerken, wo die Landung eines Hubschraubers aufgrund des vorgegebenen Rotordurchmessers nicht mehr möglich wäre. Über dies sind die als Rotor ausgebildeten Auftriebskörper besonders robust im Aufbau und umfassen im Allgemeinen außer den Rotorblättern selbst keine weiteren beweglichen Teile, so dass der technische Aufwand vertretbar ist. Durch die Anbringung der Auftriebskörper im unmittelbaren Nahbereich des Rumpfes ist die mechanische Beanspruchung der Rotoraufhängungen sehr gering, so dass eine entsprechende Leichtbauweise möglich ist, die wiederum zur Treibstoffersparnis beiträgt.

Eine besonders raumökonomische Anordnung der einzelnen Bauteile ist gegeben, wenn die Auftriebskörper im oberen Bereich des Rumpfes angeordnet sind. Zusätzlich wird dadurch eine besonders aerodynamisch günstige Ausführung erreicht, da der Ansaugbereich völlig frei und unbehindert durch sonstige Bauteile des Fluggerätes angeströmt werden kann.

Eine weitere besonders begünstigte Ausführungsvariante der Erfindung sieht vor, dass die Auftriebskörper durch Gasturbinen gegenläufig angetrieben sind. Ähnlich wie bei Hubschraubern ist auch hier bei Einsatz von Gasturbinen ein besonders günstiges Verhältnis von Leistung zu Eigengewicht gegeben. Ein zusätzlicher Vorteil gegenüber Hubschraubern besteht bei der vorliegenden Erfindung darin, dass die Drehzahlen der rotierenden Auftriebskörper wesentlich höher liegen als die von üblichen Hubschrauberrotoren, so dass sich der bauliche Aufwand für Getriebe wesentlich verringert. Je nach Baugröße, Einsatzzweck und Sicherheitsvorschriften können die beiden Rotoren von einer gemeinsamen Gasturbine angetrieben werden, oder es kann jedem Auftriebskörper eine eigene Gasturbine zugeordnet werden.

Der Wirkungsgrad der Auftriebskörper kann insbesondere dadurch weiter verbessert werden, dass die im Rotor beweglich angeordneten Rotorblätter aus mindestens einer feststehenden Achse und zwei unabhängig voneinander beweglichen Rotorblattsegmenten bestehen, damit die Rotorblattgeometrie in jedem Augenblick in jeder aktuellen Position optimal an die jeweilige Situation angepasst werden kann; damit können sowohl die Auftriebskräfte und Seitenkräfte optimiert und die Widerstandskräfte minimiert werden.

Besonders hohe Reisegeschwindigkeiten können dadurch erreicht werden, dass zusätzliche Triebwerke zur Erzeugung eines Schubs für den Vortrieb des Fluggerätes vorgesehen sind. An sich ist es möglich und grundsätzlich für geringere Reisegeschwindigkeiten auch ausreichend, dass der Vortrieb durch die verstellbaren Rotorflügel der Auftriebskörper erzeugt wird, in dem das Fluggerät in eine nach vorne abgesenkte Lage gebracht wird und aus der resultierenden Auftriebskraft eine Vorschubkraft abgeleitet wird. Die Reisegeschwindigkeit ist jedoch in diesem Fall begrenzt, so dass für höhere Reisegeschwindigkeiten in vorteilhafter Weise zusätzliche Triebwerke eingesetzt werden. Diese können beispielsweise als Mantelstromtriebwerke ausgebildet werden. Der Start- und Landevorgang kann dadurch unterstützt werden, dass die zusätzlichen Triebwerke schwenkbar angeordnet sind. Einerseits kann dadurch die Auftriebskraft erhöht werden, wenn der Triebwerksstrahl senkrecht nach unten gerichtet ist, und andererseits kann durch entsprechende Steuerung des Schwenkwinkels die Manövrierbarkeit zusätzlich erhöht werden.

Der Treibstoffverbrauch beim Senkrechtstart bzw. bei der Landung und beim Schwebeflug wird maßgeblich von der umgesetzten Luftmenge beeinflusst. Es ist daher insbesondere günstig, wenn sich die Auftriebskörper über mindestens 40%, vorzugsweise über mindestens 70% der Länge des Rumpfes erstrecken. Auf diese Weise ist es möglich, bei vorgegebener Querschnittsfläche eine größtmögliche Auftriebsleistung der Auftriebskörper zu erzielen.

Die Manövrierfähigkeit, insbesondere im Schwebeflug und beim Start bzw. bei der Landung, kann dadurch verbessert werden, dass im Bereich der Luftauslassöffnungen verstellbare Leitschaufeln vorgesehen sind. Bei niedrigen Fluggeschwindigkeiten ist die Möglichkeit der Steuerung durch das Leitwerk stark eingeschränkt, so dass sich eine ausreichende Manövrierbarkeit durch die individuelle Verstellbarkeit der Rotorblätter ergibt. Um eine Rotation des Fluggerätes auch um eine vertikale Achse zu ermöglichen, ist es in diesem Zusammenhang besonders bevorzugt, wenn die verstellbaren Rotorblätter in zwei paarweise gegenläufigen Auftriebskörpern angeordnet sind und aus jeweils zwei Segmenten bestehen, die unabhängig voneinander betätig bar sind. Weitere verstellbare Leitschaufeln, die um eine Querachse des Fluggerätes schwenkbar sind, ermöglichen eine Vorwärts- und Rückwärtsbewegung im Schwebezustand, die besonders fein steuerbar ist.

Weiters ist es besonders bevorzugt, wenn die Auftriebskörper mit einer äußeren Verkleidung als mechanischen Schutz der Rotorblätter gegen eine Kollision mit einem festen Hindernis ausgebildet sind. Dies bedeutet, dass die Verkleidung nicht nur zur Aufnahme der Lagerung der Rotorwelle, sondern auch in mechanisch entsprechend robuster Weise ausgebildet ist, um die Auftriebskörper gegenüber einer Beschädigung zu schützen, wenn das Fluggerät mit geringer Relativgeschwindigkeit eine Kollision mit einem Hindernis erleidet.

In der Folge wird die vorliegend Erfindung anhand der in den Figuren dargestellten Ausführungsbeispiele näher erläutert.

Es zeigen Fig. 1 eine schematische Ansicht eines erfindungsgemäßen Fluggerätes in axonometrischer Darstellung, Fig. 2 eine Seitenansicht des Fluggerätes von Fig. 1, Fig. 3 einen Schnitt des Fluggerätes von Fig. 1 entlang der Linie A – A in Fig. 2, Fig. 4 einen Schnitt des Fluggerätes von Fig. 1 entlang der Linie A – A in Fig. 2 mit der Darstellung einer geöffneten bzw. geschlossenen Verkleidung der Auftriebskörper, wie sie für eine hohe Reisegeschwindigkeit vorgesehen sind, Fig. 5 eine Ansicht des Fluggerätes von Fig. 1 von vorne, Fig. 6 eine Ansicht des Fluggerätes von Fig. 1 von oben, Fig. 7 - Fig. 7b zeigen schematisch einen Auftriebskörper des Fluggerätes von Fig. 1, Fig. 8 - Fig. 8b zeigen die Anordnung, Drehrichtung und Wirkungsweise des Auftriebskörpers des Fluggerätes von Fig. 1, Fig. 9 bis Fig. 9b zeigen ein Rotorblatt mit zwei beweglichen Segmenten im Querschnitt in der Stellung Auftriebskräfte neutral, maximaler Auftrieb und negativer Auftrieb des Fluggerätes von Fig. 1, Fig. 10 – Fig. 10d zeigen Rotorblätter Anstellungen in ausgewählten Positionen entlang der Drehrichtung des Auftriebskörpers des Fluggerätes von Fig. 1, Fig. 11 zeigt eine Variante eines Auftriebskörpers mit einteiligen Rotorblättern und mechanischer Anstellung der Rotorblätter eines Auftriebskörpers des Fluggerätes von Fig. 1, Fig. 12 zeigt die einzelnen Auftriebskräfte der Auftriebskörper zur Erzielung eines stabilen Gleichgewichtes in der Luft des Fluggerätes von Fig. 1, Fig. 12a und Fig. 12b zeigen die Lage der Einzel- und Gesamtmassenschwerpunkte des Fluggerätes von Fig. 1, Fig. 13 zeigt die nach vorne geneigte Lage des Fluggerätes von Fig. 1 zur Erzielung einer Vorwärtsantriebskomponente für eine langsame Vorwärtsbewegung, Fig. 14 – Fig. 14d zeigen die Auftriebskörperanordnung und die Anstellung der Rotorblätter zur Erzeugung von Seitenkräften für die Querbewegung des Fluggerätes von Fig. 1, Fig. 15 zeigt die Erzeugung einer paarweise gegensinnig wirkenden Kraftkomponente quer zur Längsachse des Fluggerätes zur Erzeugung einer Drehbewegung des Fluggerätes um die Vertikalachse, Fig. 16 – Fig. 16c zeigen eine besondere Variante eines Auftriebskörpers mit „doppelter" Länge und schränk baren Rotorblättern zur Erzeugung unterschiedlicher Auftriebs- bzw. Querkräfte des Fluggerätes von Fig. 1, Fig. 17 zeigt die Anstellung der Rotorblätter während eines Sinkfluges im freien Fall zwecks Autorotation des Auftriebskörpers z. B. nach einem Motorausfall des Fluggerätes von Fig. 1, Fig. 18 – Fig. 18g zeigen eine Ausführungsvariante eines Fluggerätes mit nur zwei Auftriebskörpern, die gegenläufig angetrieben, hintereinander in einer Mittelachse des Fluggerätes angeordnet sind, Fig. 19 – Fig. 19b zeigen eine Ausführungsvariante eines Fluggerätes mit einem System gegenläufiger Querstromrotore mit einer gemeinsamen Drehachse, Fig. 20 zeigt eine schematische Ansicht eines erfindungsgemäßen Fluggerätes mit der Anordnung eines mit dem Fluggerät flexibel verbundenen Aufklärungsgerätes.

Das Fluggerät gem. Fig. 1 bis Fig. 6 besteht aus einem Rumpf (1) mit einer Längsachse (1a) und vier parallel zu dieser Längsachse in bevorzugter Weise oberhalb der Schwerpunktlage S (32) angeordnete Auftriebskörper (2, 3, 4 und 5), die von einem Seitenschutz (6) gegen Kollision mit einem festen Hindernis geschützt sind. Im hinteren Bereich (9) befinden sich in an sich bekannter Weise ein Höhenleitwerk (11) und ein Seitenleitwerk (10), vorzugsweise auch das Antriebsaggregat (z. B. eine od. zwei Gasturbine(n) und das Getriebe) sowie zusätzliche Antriebsaggregate (hier nicht näher dargestellt), ausgeführt als z. B. Mantelstromtriebwerke, die dem Fluggerät eine hohe Reisefluggeschwindigkeit verleihen bzw. bei entsprechender schwenkbarer Ausführung den Start- und Landevorgang unterstützen können. Kufen bzw. ähnliche Standbeine (12) stützen das Fluggerät am Boden ab. Mittels Längsstreben (13, 14), die eine strömungsgünstige Querschnittsform oder eine Gewichtsoptimierte Fachwerkskonstruktion aufweisen können, ist der hintere Bereich des Fluggerätes mit dem vorderen Bereich verbunden, weiters ist mit den Längstreben und dem Seitenschutz eine stabile Konstruktion für eine Lagerung (hier nicht näher dargestellt) der Auftriebskörper im mittleren Bereich vorgesehen. In Fig. 2 sind die Längenverhältnisse ersichtlich, wonach die Länge der rotierenden Auftriebskörper etwa 50 % der Gesamtlänge, vorzugsweise 30 bis 70 %, des Fluggerätes entspricht. In Fig. 3 sind die gegenläufig um die Drehachsen (7a, 7b) rotierenden Auftriebskörper (2, 3, 4, 5) mit den Drehrichtungen (20a, 20b) und den zur Erzeugung der Auftriebskraft erforderlichen Rotorblättern (8) ersichtlich. Für eine hohe Reisegeschwindigkeit bei gleichzeitiger Treibstofföokonomie, sind die zusätzlichen Antriebsaggregate, hier nicht näher dargestellt, vorgesehen und zur Reduzierung des Luftwiderstandes, werden die Auftriebskörper, die bei einer hohen Reisegeschwindigkeit nicht den erforderlichen Auftrieb erzeugen können, mittels geeigneter Verkleidungsschürzen strömungsgünstig im Fluggerät abgedeckt. Gemäß

Fig. 4 können diese Verkleidungsschürzen als kompakte Flächen (40a, 40b) ausgebildet sein (wie z. B. in Fig. 4 im geöffneten Zustand, für eine optimale Wirkung der Auftriebskörper, dargestellt), bzw. als ein System von Lamellen (40a', 40b', 41a', 41b'), die wahlweise zu einer geschlossenen Verkleidung oder für einen ungehinderten Luftdurchlass angestellt werden können. Wie in Fig. 7 dargestellt, besteht ein Auftriebskörper (2, 3, 4, 5) im Wesentlichen aus einer Drehachse (7), aus zwei Endscheiben (2a - 2b, 3a – 3b, 4a – 4b, 5a – 5b) mit dem Durchmesser D (23b) und einer bestimmten Anzahl (vorzugsweise 4 bis 10) von Rotorblättern (8), die beweglich um eine Schwenkachse (8a) in den beiden Endscheiben (z. B. 2a – 2b) angeordnet sind, und bei einer vollen Umdrehung eine Kreisbahn (23a) mit dem Radius R (23) beschreiben. Die Tiefe des Rotorblattes t (8e) ist Abhängig von der Größenordnung der Gesamtkonstruktion und beträgt ca. 30 bis 50% des Kreisbahnradius R (23), die Länge L (8d) des Rotorblattes (8) beträgt vorzugsweise ca. 25 bis 35 % der Gesamtlänge des Fluggerätes. Im Betriebszustand rotiert der Auftriebskörper mit Nenndrehzahl (vorzugsweise ca. 750 bis 3000 1/min) um die Drehachse (7), und während einer vollen Umdrehung werden die Rotorblätter (8) in jeder augenblicklichen Position individuell in Bezug auf die Tangente (23b) der Kreisbahn (23a) mit dem Radius R (23) angestellt, sodass im Bereich der oberen und unteren Extremlage maximale Auftriebskräfte erzeugt werden können und in den beiden vertikalen Extrempositionen ausschließlich Strömungswiderstandskräfte auf das Rotorblatt einwirken. Die bevorzugte Anordnung der Drehrichtung (20) der Auftriebskörper im Fluggerät ist gegenläufig. In Fig. 8 sind die Strömungsverhältnisse näher dargestellt, wobei aufgrund der Rotorblättergeometrie die Tragflügeltheorie maßgeblich ist, der zufolge jeweils unterhalb des angestellten Rotorblattes bei einer definierten Relativgeschwindigkeit eine Druckerhöhung und oberhalb ein Unterdruck erzeugt wird. Die entsprechenden Kraftkomponenten, die auf ein Rotorblatt einwirken, resultieren aus diesen beiden Druckkomponenten. Bei entsprechender Anstellung der Rotorblätter relativ zur Tangente (23b) der Kreisbahn (23a) während einer vollen Umdrehung der Auftriebskörper mit Nenndrehzahl wird Umgebungsluft bevorzugt von oben angesaugt (18a), in den rotierenden Auftriebskörper hineingepresst (18b), nach unten angesaugt (19a) und hinausgepresst (19b). Eine optimale Ausführungsvariante ist in den Fig. 9, Fig. 9a und Fig. 9b dargestellt. Bei dieser Ausführungsvariante besteht das Rotorblatt (8) aus mindestens drei Elementen und zwar einer stabilen Schwenkachse (8a), einer beweglichen Rotorblattnase (8b) und einer beweglichen Rotorblattspitze (8c). Für den Normalbetrieb sind die Rotorblattnase (8b) um den Winkel α (21a), vorzugsweise um +/- 3° - 10° relativ zur Tangente der Kreisbahn (23a) schwenkbar und die Rotorblattspitze (8c) um den Winkel β (21b), vorzugsweise um +/- 3° bis 10° relativ zur Tangente der Kreisbahn (23a) schwenkbar. Für den Sonderfall „Autorotation" sind Rotorblattspitze und Rotorblattnase um > 90°, vorzugsweise ca. 105° aus schwenkbar. Gemäß Fig. 9a ist eine vertikale Kraftkomponente Fa (22) in Richtung Drehachse (7) des Auftriebskörpers erzeugbar, wenn bei Nenndrehzahl in der oberen Extremposition die Rotorblattnase (8b) mit dem Winkel $\alpha < 0°$ und die Rotorblattspitze mit dem Winkel $\beta > 0°$, jeweils bezogen auf die Tangentenrichtung (23b) der Umlaufkreisbahn (23a), angestellt werden und vice versa gemäß Fig. 9b ist eine vertikale Kraftkomponente Fa (22) entgegen Richtung Drehachse (7) des Auftriebskörpers erzeugbar, wenn bei Nenndrehzahl in der oberen Extremposition die Rotorblattnase (8b) mit dem Winkel $\alpha > 0°$ und die Rotorblattspitze mit dem Winkel $\beta < 0°$, jeweils bezogen auf die Tangentenrichtung (23b) der Umlaufkreisbahn (23a), angestellt werden. In Fig. 10 sind die beiden gegenläufig angetriebenen Auftriebskörper mit den zur Erzeugung einer maximalen Auftriebskraft bei Nenndrehzahl optimalen Anstellungen der Rotorblätter in den unterschiedlichen Positionen im Detail dargestellt. Fig. 10a (Detail W von Fig. 10) zeigt die Winkelverhältnisse der Rotorblattnase und Rotorblattspitze beim Eintritt in die obere Umlaufbahn nach dem Verlassen der neutralen Vertikalposition, Fig. 10b (Detail X von Fig. 10) zeigt die Winkelverhältnisse der Rotorblattnase und Rotorblattspitze in der oberen Extremposition der Umlaufbahn, Fig. 10c (Detail Y von Fig. 10) zeigt die Winkelverhältnisse der Rotorblattnase und Rotorblattspitze in der oberen Umlaufbahn vor dem Eintritt in die die neutrale Vertikalposition, Fig. 10d (Detail Z von Fig. 10) zeigt die Winkelverhältnisse der Rotorblattnase und Rotorblattspitze in der unteren Extremposition der Umlaufbahn.

Eine vereinfachte Variante eines Auftriebskörpers ist in Fig. 11 dargestellt. Diese Variante unterscheidet sich von der zuvor beschriebenen dadurch, dass die Rotorblätter (8) einteilig um eine Schwenkachse schwenkbar ausgeführt sind und mechanisch mit Hilfe eines Kopplungsgliedes (28), welches als Gestänge oder einer sonstigen Konstruktion, zur Übertragung von Zug- und Druckkräften, ausgeführt sein kann, angesteuert werden können. In einer bevorzugten Ausführungsvariante wird das Kopplungsglied in einer speziellen Kulisse (29, 30), die in den beiden Endscheiben (2a-2b, ... 5a-5b) untergebracht ist, derart geführt, dass, zur Erzeugung einer optimalen Auftriebskraft bei Nenndrehzahl, während einer vollen Umdrehung des Auftriebskörpers (2, 3, 4, 5) um die Drehachse (7) mit der Drehrichtung (20) und dem jeweils aktuellen Drehwinkel δ (31) das Rotorblatt (8) in der oberen Extremlage mit dem Winkel α' (21c), in der unteren Extremlage mit dem Winkel α'' (21d) $> \alpha'$ (21c) und in den beiden seitlichen Extremlagen jeweils vertikal, d. h. parallel zur Tangentenrichtung der Umlaufkreisbahn (23a), angestellt werden kann. Seitenkräfte zur Erzeugung einer Seitwärtsbewegung bzw. einer Drehbewegung um die Vertikalachse des Fluggerätes werden durch eine entsprechende Verstellung der Kulisse (29, 30) in Querrichtung (27x) erreicht, wobei unter Beibehaltung der Drehzahl des Auftriebskörpers die Auftriebskräfte unverändert bleiben. Eine Beeinflussung der Auftriebskräfte ist durch Verstellung der Kulisse (29, 30) durch Veränderung der Mittelpunktslage (27) in Vertikalrichtung (27z) vorgesehen. Die Mittelachse (27y) liegt parallel zur Drehachse (7). Ein Fluggerät, ausgerüstet mit einem Auftriebskörper gemäß dieser Ausführungsvariante wäre sogar vollständig mechanisch steuerbar.

Eine stabile Gleichgewichtslage (Fig. 12 bis Fig. 12b) in der Luft ist dadurch gegeben, dass jeder einzelne Auftriebskörper (2, 3, 4, 5) individuelle Auftriebskräfte A_1 bis A_4 (35a, 35b, 35c und 35d) erzeugen kann und damit ein Gleichgewichtszustand zum Gesamtmassenschwerpunkt S (32) der Gesamtmasse m (33) bzw. zu den Hauptteilmassenschwerpunkten (32a) der Teilmasse aus Pilotenkanzel m_1 (33a), mit dem Teilschwerpunktsabstand s_1 (34a), und (32b) der Teilmasse aus dem rückwärtigen Bereich des Fluggerätes m_2 (33b), mit dem Teilschwerpunktsabstand s_2 (34b), und dem seitlichen Schwerpunktsabstand s_3 (34c) des Gesamtmassenschwerpunkt S (32) der Gesamtmasse m (33) zu jeder Situation hergestellt werden kann. Damit kann jederzeit auch auf sich verändernde Gleichgewichtslagen reagiert werden.

Nach Erreichen einer definierten Höhenposition, die mittels der rotierenden Auftriebskörper (2, 3, 4, 5) eingenommen werden kann, ist ein Übergang von einem Schwebezustand in eine langsame Vorwärtsbewegung bzw. Rückwärtsbewegung dadurch möglich, dass das Fluggerät eine Neigungslage (Fig. 13) einnimmt und aus der resultierenden Auftriebskraft (35a, 35b) der Auftriebskörper eine Kraftkomponente (35a', 35b') abgeleitet werden kann, die eine Vorwärts- bzw. Rückwärtsbeschleunigung ermöglicht, während die vertikale Kraftkomponente (35a", 35b") das Fluggerät weiterhin vertikal im Gleichgewicht hält.

Eine Bewegung des Fluggerätes quer zur Längsachse ist im Schwebezustand durch eine spezielle Anstellung der Rotorblätter zur Tangentenrichtung (23b) der Bewegungsbahn (23a) der Rotorblätter möglich. In Fig. 14 ist eine Querbewegung mit der Geschwindigkeit v_x (36) dargestellt, die dadurch erreicht wird, dass gemäß Fig. 14a die Rotorblätter in der Position der Vertikalen Extremlage in eine entsprechende Neigungslage (21) gebracht werden, sodass von einer Richtung Luft angesaugt (18a) und quasi quer durch das Fluggerät ausgepresst (19b) wird; auch hier ist die Tragflügeltheorie anzuwenden. In Fig. 14b ist die Rotorblattstellung in einer neutralen Lage dargestellt, während gemäß Rotorblattanstellung nach Fig. 14c auf das Fluggerät eine Kraftkomponente Fq (22)von der Drehachse weg ausgeübt werden würde und eine Bewegung mit der Geschwindigkeit v_x (36) von rechts nach links zur Folge hätte und gem. Darstellung nach Fig. 14d auf das Fluggerät eine Kraftkomponente Fq (22) in entgegen gesetzter Richtung, in Richtung der Drehachse ausgeübt werden würde und eine Bewegung mit der Geschwindigkeit v_x (36) von links nach rechts zur Folge hätte. Durch paarweise gegensinnige Erzeugung der Kraftkomponenten Fq (22) im vorderen und rückwärtigen Bereich des Auftriebskörpers gemäß Fig. 15, kann eine Drehbewegung (36a) im Schwebezustand um die Vertikalachse (1b) des Fluggerätes im bzw. gegen den Uhrzeigersinn erreicht werden.

Die gleichen wie zuvor beschriebenen Effekte und Manöver lassen sich auch dann erreichen, wenn anstatt vier nur zwei paarweise gegenläufig angeordnete Auftriebskörper (2, 3) eingesetzt werden, die jedoch mit einer doppelten Länge 2L (8d) ausgeführt werden (Fig. 16). Bei dieser Ausführungsvariante sind die Rotorblätter elastisch um die Schwenkachse (8a) deformierbar. Die Rotorblattnase (8b) und die Rotorblattspitze (8c) können parallel an beiden Enden verschoben werden oder unterschiedlich. In Fig. 16a ist eine neutrale Lage des Rotorblattes (Schnitt II-II von Fig. 16) dargestellt, wie sie bei einer gegensinnigen Verschiebung der beiden Enden des Rotorblattes gem. Fig. 16b (Schnitt I-I von Fig. 16) und Fig. 16c (Schnitt III-III von Fig. 16) entsteht. Damit ist es möglich, bei einer Ausführungsvariante mit nur zwei gegensinnig rotierenden Auftriebskörpern, unterschiedliche Schwerpunktslagen im Flug zu korrigieren, Vorwärts- und Rückwärtsbewegungen mit geringer Fluggeschwindigkeit auszuführen und Drehbewegungen um die Vertikalachse ausführen zu können.

Bei genügend großer Verstellmöglichkeit der Schwenkbewegung des Rotorblattes ist im Sinkflug nach einem z. B. Ausfall eines Antriebsaggregates oberhalb einer kritischen Flughöhe eine Autorotation der Auftriebskörper und dadurch ein sicherer Landevorgang möglich. Fig. 17 zeigt die entsprechenden Anstellungswinkel α (21) der Rotorblätter und den Relativluftstrom (41) sowie die Rotationsrichtung (20) der Auftriebskörper, wenn das Fluggerät mit der Sinkgeschwindigkeit (40) im freien Fall in vertikaler Richtung nach unten fällt.

Eine weitere Ausführungsvariante eines Fluggerätes mit zwei gegensinnig rotierenden Auftriebskörpern (2, 3) ist in Fig. 18 dargestellt, wobei Fig. 18a eine Seitenansicht und Fig. 18b eine Frontansicht zeigt. Die beiden gegensinnig rotierenden Auftriebskörper sind entlang der Mittelachse des Fluggerätes entlang einer gemeinsamen Drehachse hintereinander angeordnet. Fig. 18c zeigt einen Schnitt I-I von Fig. 18a, worin die Lagerung der Drehachse der Auftriebskörper und die Seitenschutzverkleidung dargestellt sind. Fig. 18d zeigt den Schnitt II-II von Fig. 18a und Fig. 18e den Schnitt III-III von Fig. 18a woraus die Anordnung und Drehrichtung der beiden hintereinander liegenden Auftriebskörper ersichtlich sind, in der Darstellung für einen üblichen Schwebezustand bzw. Steigflug. Fig. 18f zeigt den Schnitt II-II von Fig. 18a und Fig. 18g zeigt den Schnitt III-III von Fig. 18a in der Stellung der Rotorblätter zur Erreichung der Autorotation im freien Sinkflug nach z. B. Ausfall eines Antriebsaggregates.

Fig. 19 zeigt eine weitere Ausführungsvariante eines Fluggerätes, geeignet für den vertikalen Start- und Landevorgang, ausgeführt jedoch mit Auftriebskörpern (36, 37, 38, 39), die als Querstromrotoren ausgebildet sind. Fig. 19a zeigt die

Draufsicht eines derartigen Fluggerätes und Fig. 19b eine Darstellung gem. Schnitt I-I von Fig. 19. Bei dieser Ausführungsvariante sind so genannte Querstromrotoren im Einsatz, die mit äußeren Strömungsleiteinrichtungen (6) versehen sind, die entsprechend verstellbar angeordnet sind und damit wiederum eine schier unbegrenzte Manövrierbarkeit (Vorwärtsbewegung, Rückwärtsbewegung, Querbewegung, Drehbewegung um die Vertikalachse) erreichen lassen. Diese Auftriebskörper, ausgeführt als Querstromrotoren bestehen aus jeweils zwei runden Endscheiben, die eine Vielzahl von Rotorflügeln (36a, 37a) tragen und um eine Drehachse rotieren. In einer bevorzugten Ausführungsvariante sind zur Erhöhung von strömungstechnischen Wirkungsgraden, in jeweils einen äußeren Querstromrotor (36) ein innerer kleinerer Querstromrotor (37), mit gegenläufiger Drehrichtung, eingefügt.

Bedingt durch die Tatsache, dass oberhalb des Fluggerätes keine rotierenden Aggregate vorhanden sind, ist dem Piloten im Bedarfsfall auch ein gefahrloses und sicheres Verlassen des Fluggerätes auch mittels Schleudersitz möglich. Weiters kann gemäß Fig. 20 oberhalb des Fluggerätes auch ein als Aufklärungsgerät (43) bezeichnetes Aggregat (Radar, optischer Sensor, ...) vorgesehen sein, welches bei Bedarf, im Schwebezustand des Fluggerätes, mittels einer flexiblen Verbindung (44) vertikal in die Höhe verbracht und anschließend wieder eingezogen werden kann. Dies ist u. a. dann sinnvoll, wenn mit dem Fluggerät im militärischen Einsatz ein Unterfliegen feindlicher Radarstrahlen hinter schützender Deckungen im Gelände oder in Gebäudefluchten erreicht werden soll, und zur Erfassung der militärischen Situation z. B. hinter einer schützenden Geländeformation, anstatt eines kurzfristigen gefahrvollen „Auftauchens" nur das Aufklärungsgerät (43) vertikal in die Höhe geschossen, die militärische Situation erfasst und anschließend das Aufklärungsgerät mit der flexiblen Verbindung wieder sicher in den Rumpf des Fluggerätes eingebracht wird.

Die vorliegende Erfindung beschreibt ein Fluggerät, welches die Möglichkeit eines senkrechten Starts und einer senkrechten Landung aufweist, eine fast unbegrenzte Manövrierbarkeit im Schwebezustand erlaubt, eine hohe Reisegeschwindigkeit bei gleichzeitiger Treibstofförkonomie bietet, dem Piloten im Bedarfsfall ein sicheres Verlassen des Fluggerätes ermöglicht und ein flexibel angeordnetes Aufklärungsgerät oberhalb des Fluggerätes unterbringt.

PATENTANSPRÜCHE

1. Fluggerät bestehend aus einem Rumpf (1) und mindestens zwei am Rumpf (1) angebrachten, hohlzylindrisch ausgebildeten Auftriebskörpern (2, 3, 4, 5), und eine definierte Anzahl von beweglichen Rotorblättern (8) aufweisen, die sich über den Umfang des Auftriebskörpers vorzugsweise gleich verteilt erstrecken, **dadurch gekennzeichnet**, dass die Mittelachsen der Rotorblätter (8) im wesentlichen parallel zur Längsachse des Fluggerätes ausgerichtet sind, dass die Auftriebskörper (2, 3, 4, 5) vorzugsweise gegenläufig rotieren, und dass mindestens ein Antriebsaggregat vorgesehen ist, um die Auftriebskörper (2, 3, 4, 5) mit Nenndrehzahl anzutreiben.

2. Fluggerät nach Anspruch 1, **dadurch gekennzeichnet,** dass diese Auftriebskörper oberhalb der Schwerpunktslage des Fluggerätes angeordnet sind.

3. Fluggerät nach Anspruch 1 oder 2, **dadurch gekennzeichnet,** dass die Auftriebskörper (2, 3) durch Gasturbinen gegenläufig angetrieben sind.

4. Fluggerät nach einem der Ansprüche 1 bis 3, **dadurch gekennzeichnet,** dass für eine hohe Reisegeschwindigkeit zusätzliche Triebwerke vorgesehen sind.

5. Fluggerät nach einem der Ansprüche 1 bis 4, **dadurch gekennzeichnet,** dass diese zusätzlichen Triebwerke schwenkbar ausgeführt sein können, um eine zusätzliche Unterstützung beim Start, bei der Landung oder bei sonstigen Manövern zu ermöglichen.

6. Fluggerät nach einem der Ansprüche 1 bis 5, **dadurch gekennzeichnet,** dass das Fluggerät mit zwei Auftriebskörpern (2, 3) ausgeführt ist, die entlang der Mittelachse des Fluggerätes hintereinander liegend, gegenläufig rotierend angeordnet sind.

7. Fluggerät nach einem der Ansprüche 1 bis 5, **dadurch gekennzeichnet,** dass das Fluggerät mit zwei gegenläufig rotierenden Auftriebskörpern (2, 3) ausgeführt ist, deren Mittelachse parallel nebeneinander liegen.

8. Fluggerät nach einem der Ansprüche 1 bis 5, **dadurch gekennzeichnet,** dass das Fluggerät mit vier Auftriebskörper (2, 3, 4, 5) ausgeführt ist, wobei jeweils zwei Auftriebskörper gegenläufig rotieren und parallel angeordnet sind.

9. Fluggerät nach einem der Ansprüche 1 bis 8, **dadurch gekennzeichnet,** dass mittels individuell verstellbarer Rotorblätter (8) bei Nenndrehzahl Auftriebskräfte und Seitenkräfte erzeugt werden können.

10. Fluggerät nach einem der Ansprüche 1 bis 9, **dadurch gekennzeichnet,** dass mittels individuell verstellbarer Rotorblätter (8) bei Nenndrehzahl im Schwebezustand unterschiedliche Schwerpunktlagen ausgeglichen werden können.

11. Fluggerät nach einem der Ansprüche 1 bis 10, **dadurch gekennzeichnet,** dass mittels der individuell verstellbaren Rotorblätter (8) bei Nenndrehzahl ein vertikaler Steigflug, ein Schwebezustand, eine langsame Vorwärts- bzw. Rückwärtsbewegung, eine Drehbewegung gegen bzw. im Uhrzeigersinn und ein vertikaler Sinkflug ausgeführt werden kann.

12. Fluggerät nach einem der Ansprüche 1 bis 11, **dadurch gekennzeichnet,** dass die Auftriebskörper (8) mit Abdeckungen (40, 41) versehen sind, ausgeführt als kompakte Abdeckungen oder als ein System von Lamellen, die einerseits einen ungehinderten Luftdurchlass gewährleisten und für eine hohe Reisegeschwindigkeit, wo der Wirkungsgrad der Auftriebskörper begrenzt ist, die Strömungsverluste reduzieren.

13. Fluggerät nach einem der Ansprüche 1 bis 12, **dadurch gekennzeichnet,** dass die Auftriebskörper seitlich eine Schutzverkleidung (6) aufweisen, die einen ungehinderten Luftdurchlass gewährleisten, im Bedarfsfall jedoch den rotierenden Auftriebskörper gegen Kollision mit einem festen Hindernis schützen.

14. Fluggerät nach einem der Ansprüche 1 bis 13, **dadurch gekennzeichnet,** dass der Auftriebskörper mit Rotorblättern (8) versehen ist, die Tragflügelähnlich ausgebildet sind und deren vorderer Teil unabhängig vom rückwärtigen Teil um eine Schwenkachse (8a) beweglich ist.

15. Fluggerät nach einem der Ansprüche 1 bis 13, **dadurch gekennzeichnet,** dass der Auftriebskörper mit Rotorblättern (8) versehen ist, die Tragflügelähnlich ausgebildet sind und als Ganzes um eine Schwenkachse (8a) beweglich sind.

16. Fluggerät nach einem der Ansprüche 1 bis 13 und 15, **dadurch gekennzeichnet,** dass das Fluggerät mechanisch gesteuert werden kann.

17. Fluggerät nach einem der Ansprüche 1 bis 15, **dadurch gekennzeichnet,** dass der Auftriebskörper im Wesentlichen aus einer Drehachse (7), zwei Endscheiben (z. B. 2a, 2b) und Rotorblättern (8) besteht.

18. Fluggerät nach einem der Ansprüche 1 bis 17, **dadurch gekennzeichnet,** dass oberhalb der Pilotenkanzel keine rotierenden Aggregate vorhanden sind und im Bedarfsfall der Pilot das Fluggerät mittels Schleudersitz sicher verlassen kann.

19. Fluggerät nach einem der Ansprüche 1 bis 18, **dadurch gekennzeichnet,** dass oberhalb des Fluggerätes keinerlei rotierende Aggregate vorhanden sind, sodass ein spezielles Aufklärungsgerät (43) vertikal in die Höhe geschossen und wieder eingebracht werden kann.

20. Fluggerät nach einem der Ansprüche 1 bis 19, **dadurch gekennzeichnet,** dass die Rotorblätter derart angestellt werden können, dass bei einem Totalausfall eines Antriebsaggregates oberhalb einer kritischen Höhe, der Auftriebskörper im Sinkflug des Fluggerätes in Autorotation versetzt werden kann und eine sichere Landung des Fluggerätes möglich ist.

21. Fluggerät nach einem der Ansprüche 1 bis 6 und 18 bis 19, **dadurch gekennzeichnet,** dass der Auftriebskörper als Querstromrotor ausgeführt ist.

22. Fluggerät nach einem der Ansprüche 1 bis 6 und 18, 19 und 21, **dadurch gekennzeichnet,** dass zwei Querstromrotoren gegenläufig rotierend hintereinander angeordnet sind.

23. Fluggerät nach einem der Ansprüche 1 bis 6 und 18, 19 und 21, **dadurch gekennzeichnet,** dass in jeweils einem äußeren Querstromrotor ein zweiter kleinerer Querstromrotor mit gegenläufiger Drehrichtung eingeschrieben ist.

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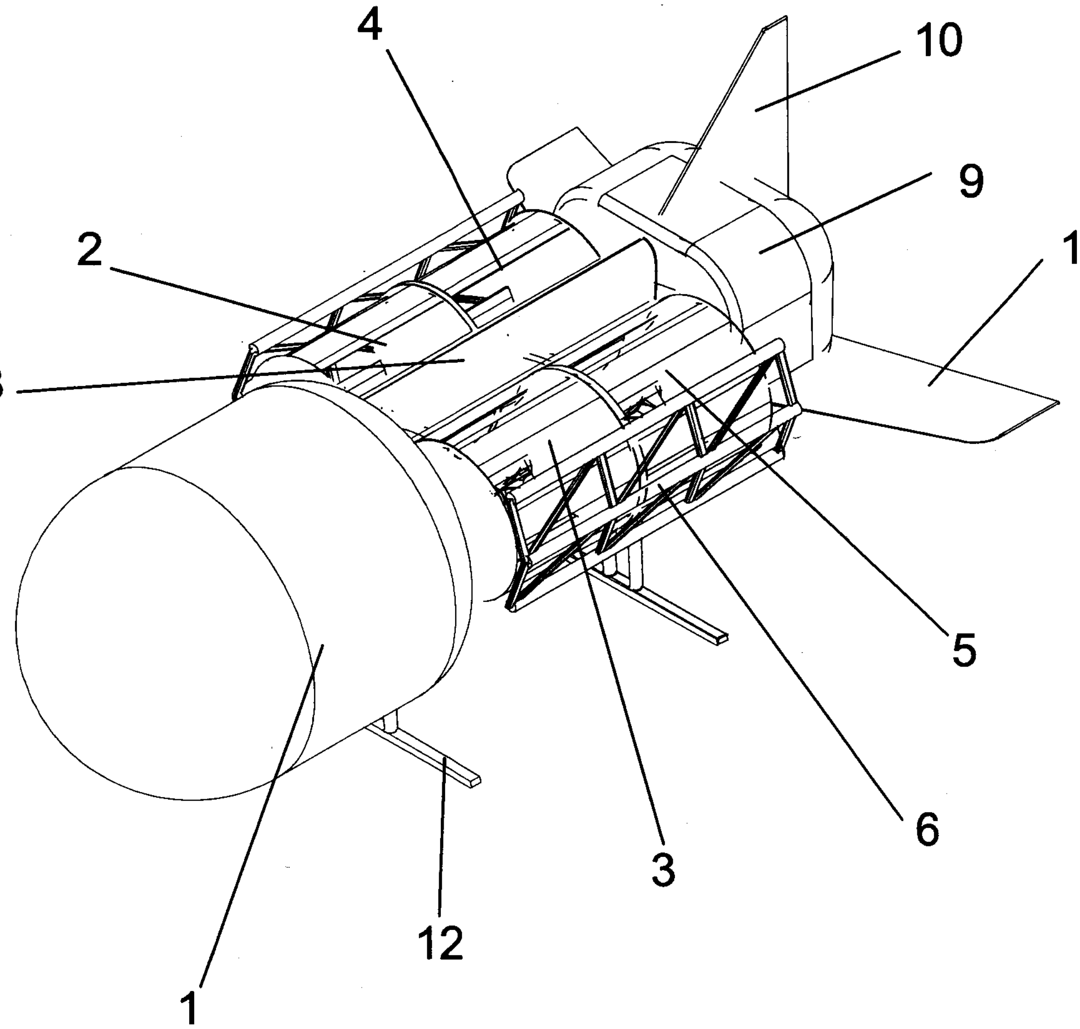

Fig. 1

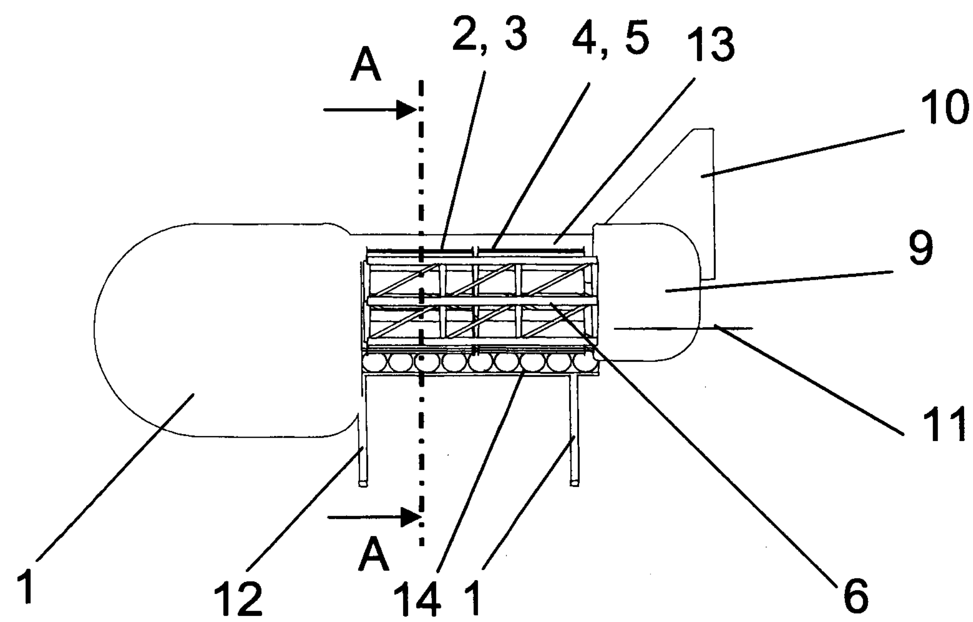

Fig. 2

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Schnitt A-A

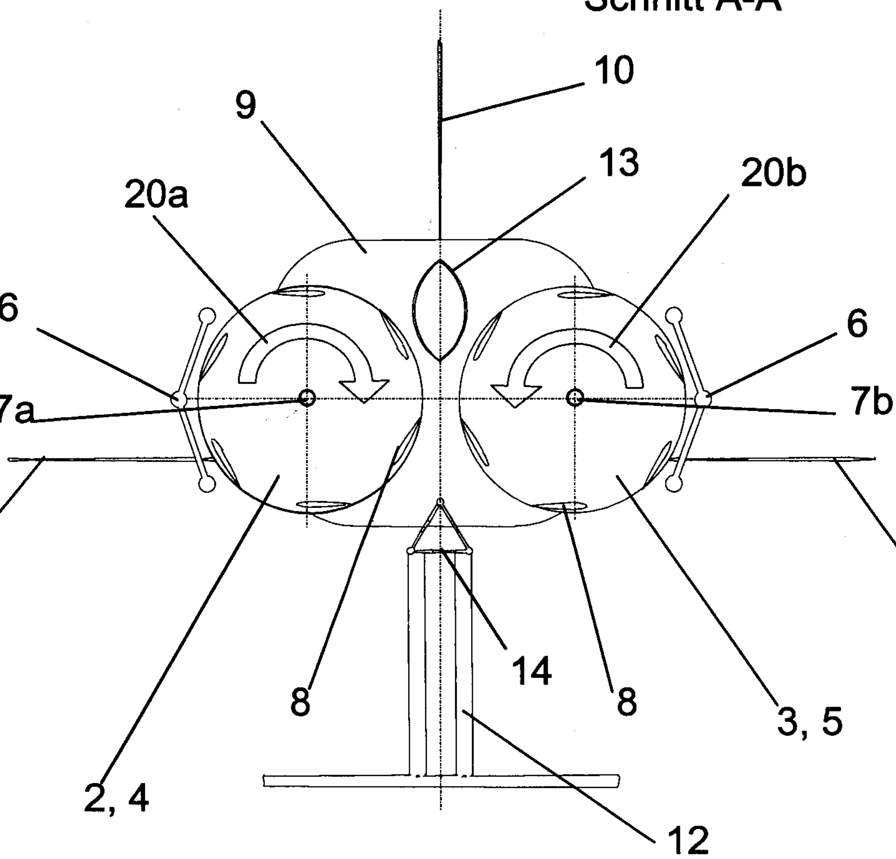

Fig. 3

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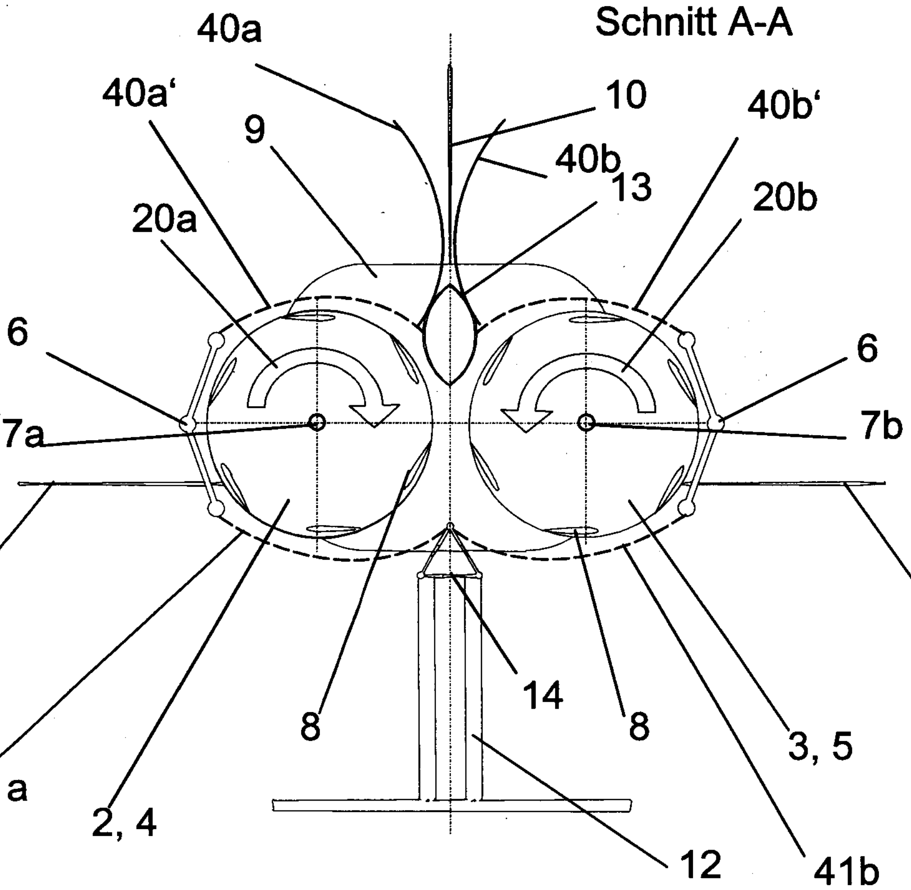

Fig. 4

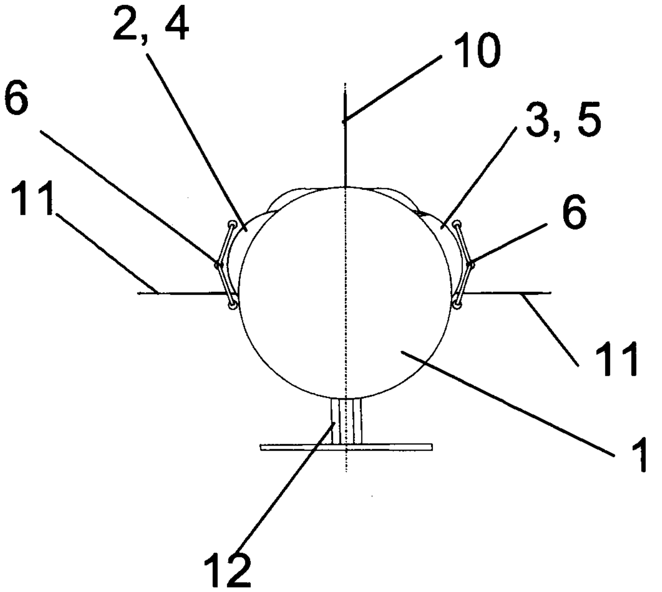

Fig. 5

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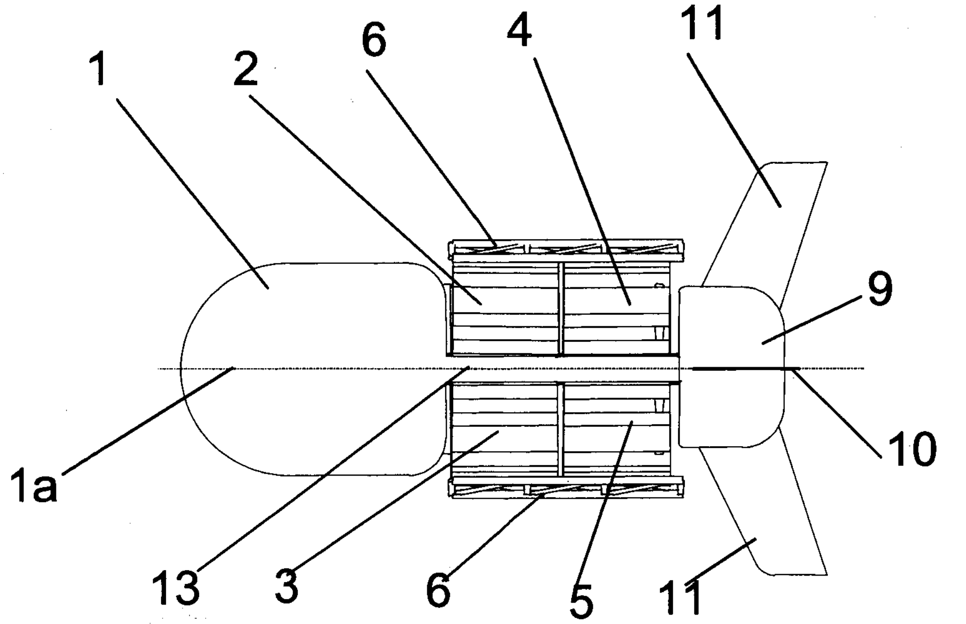

Fig. 6

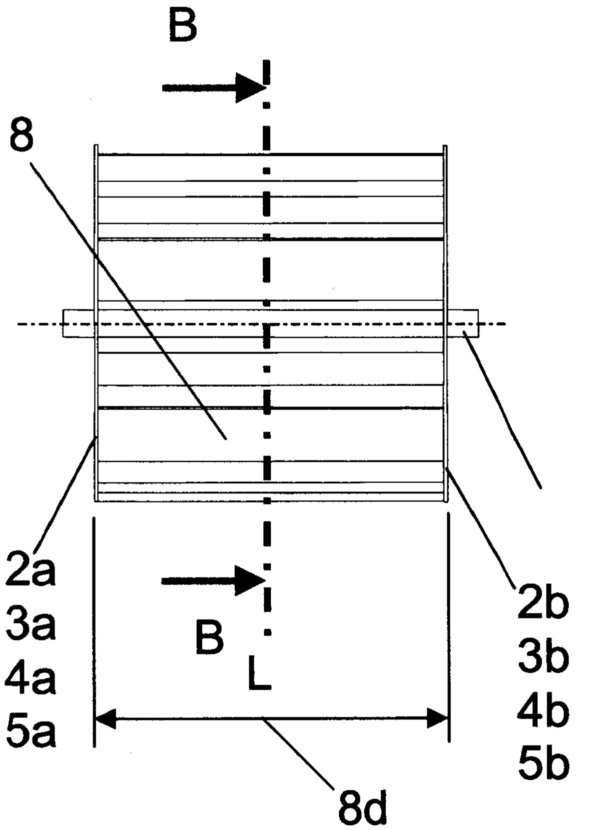

Fig. 7

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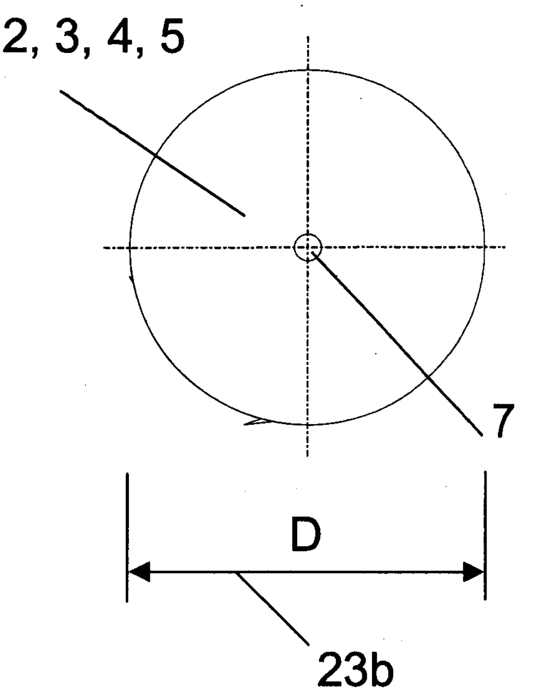

Fig. 7a

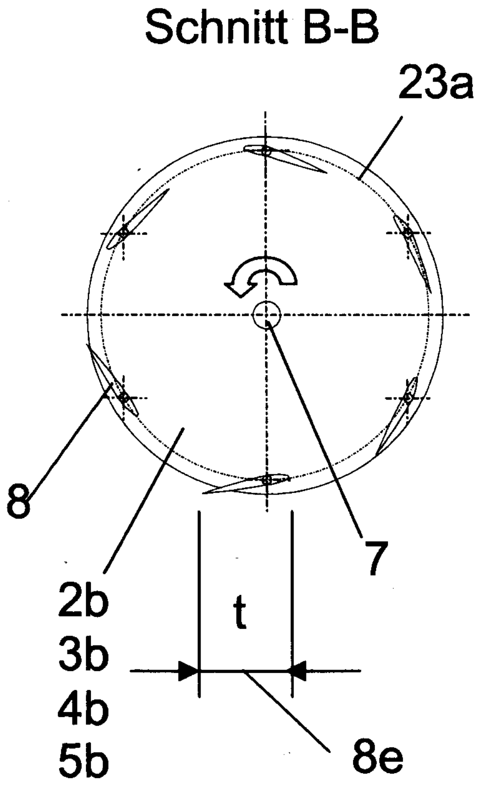

Fig. 7b

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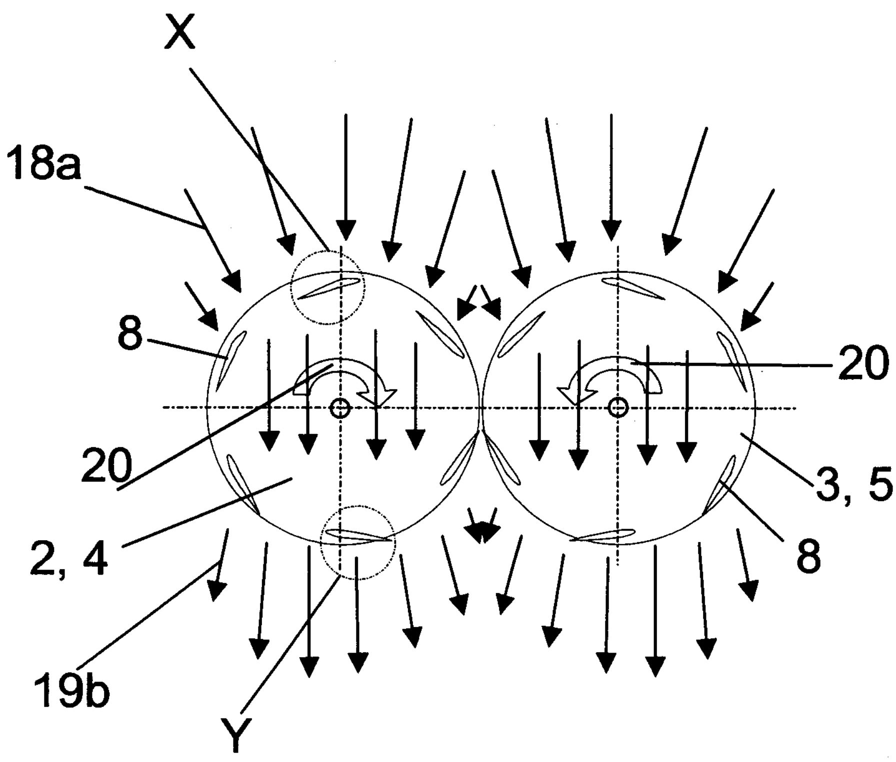

Fig. 8

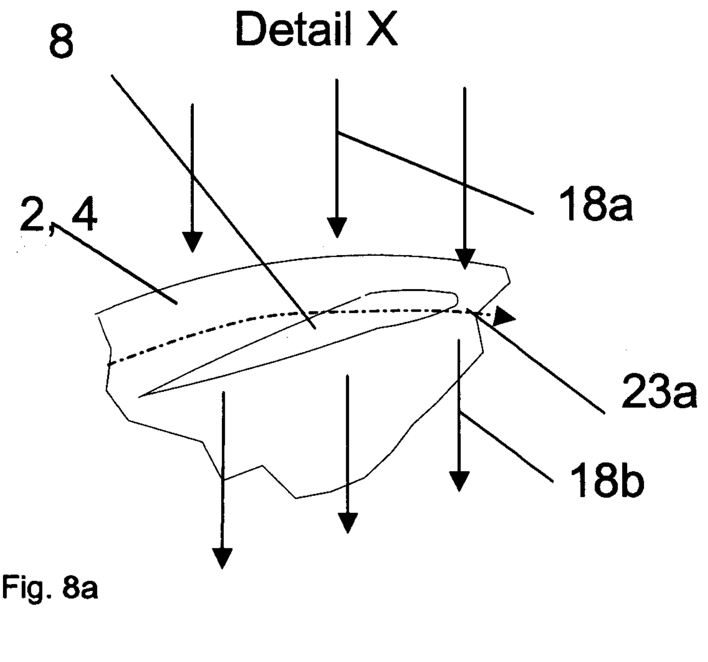

Fig. 8a

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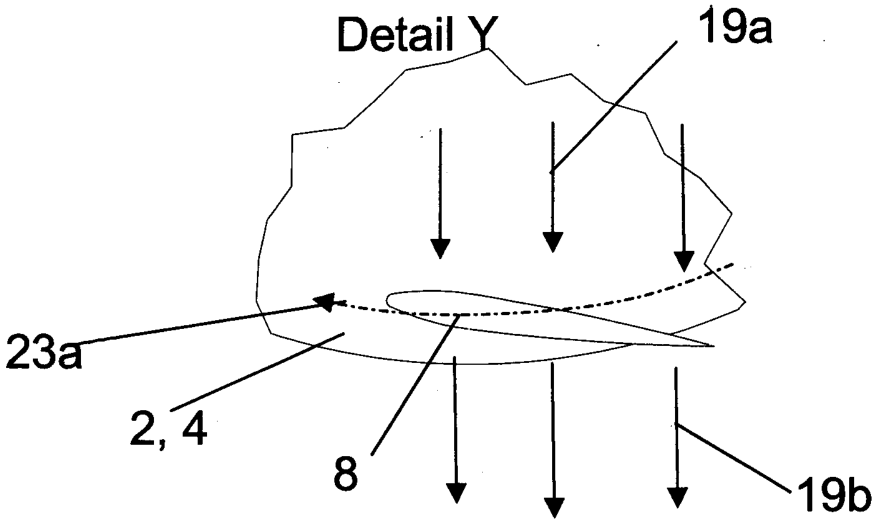

Fig. 8b

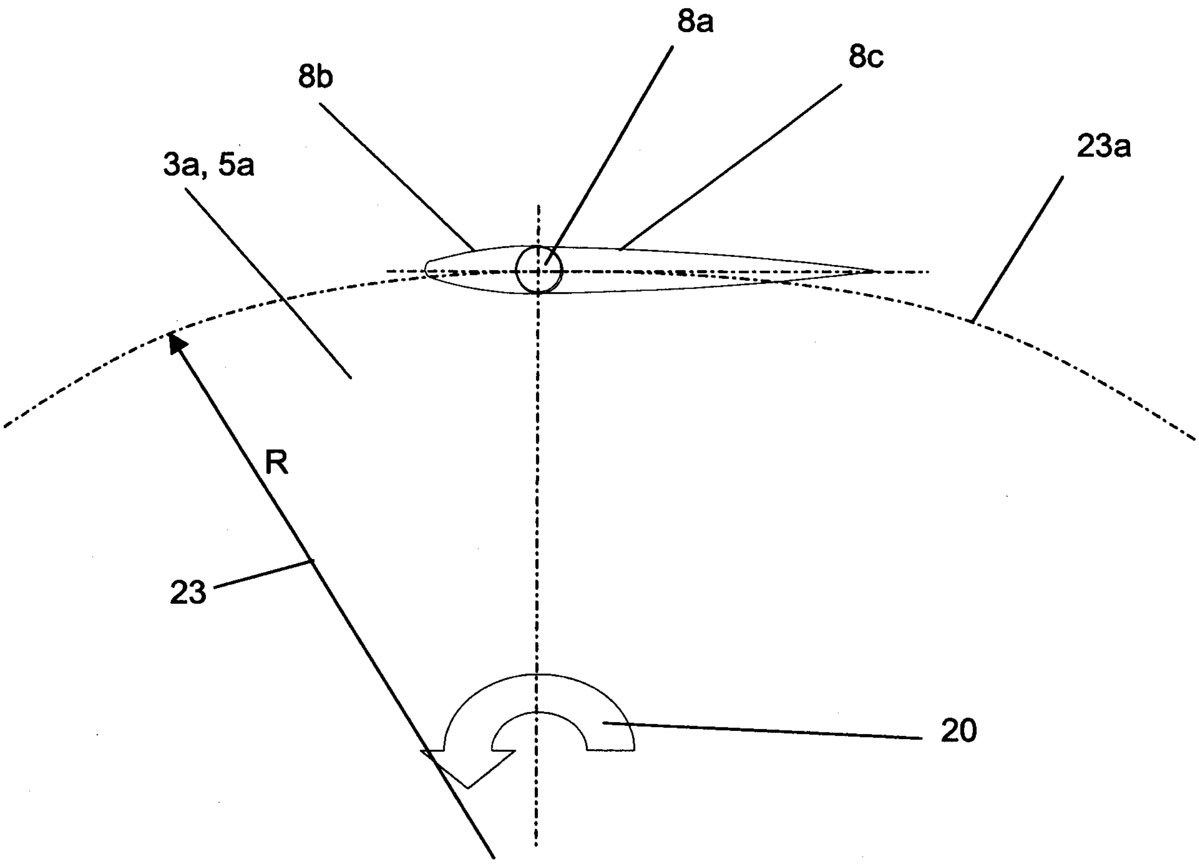

Fig. 9

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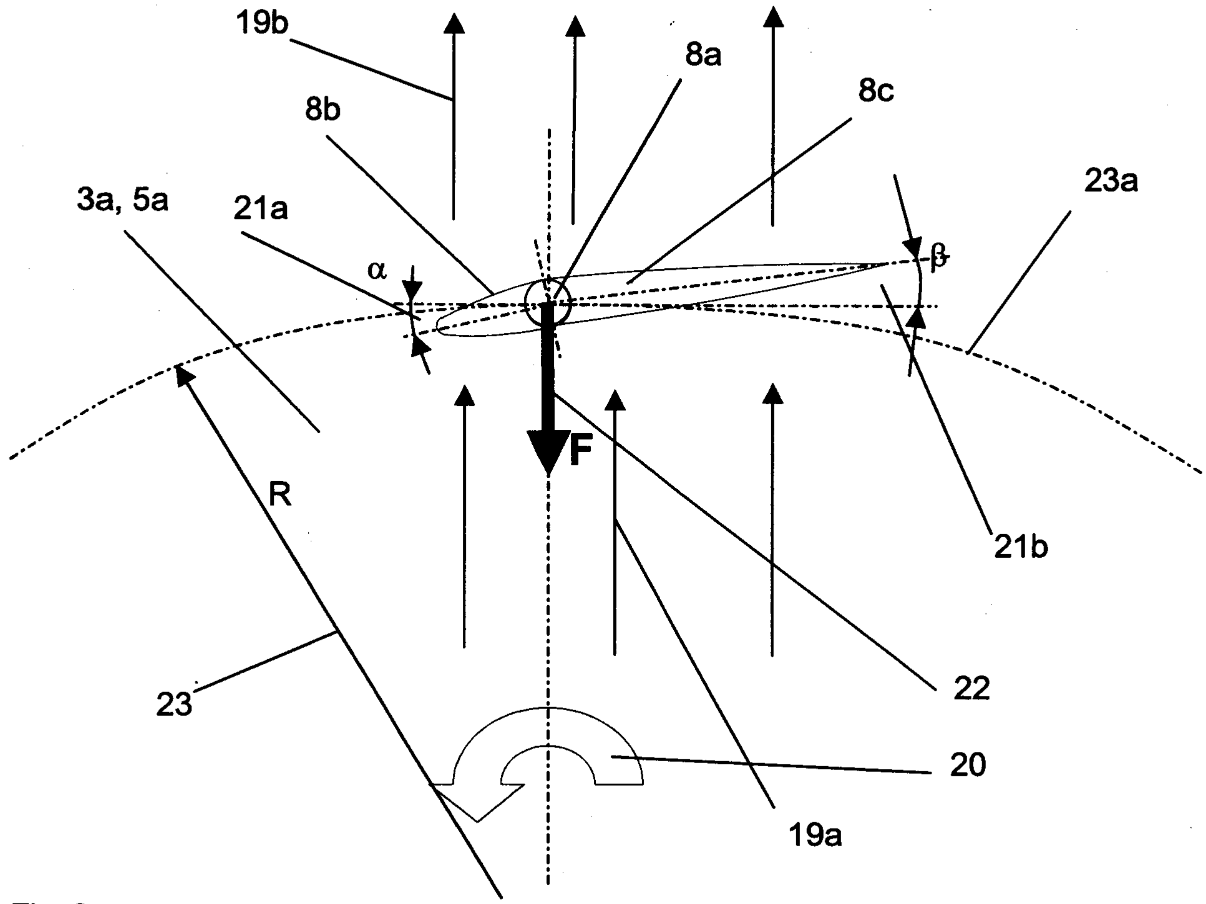

Fig. 9a

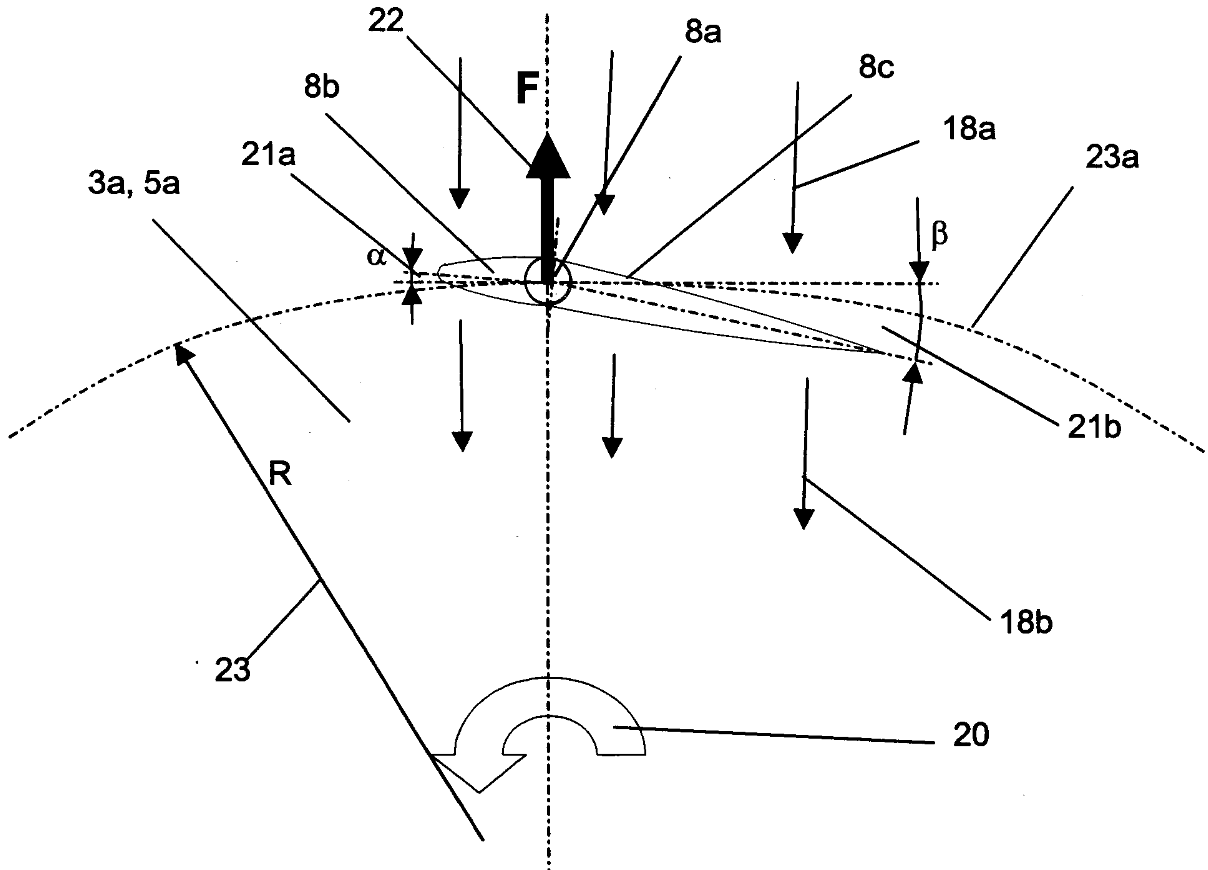

Fig. 9b

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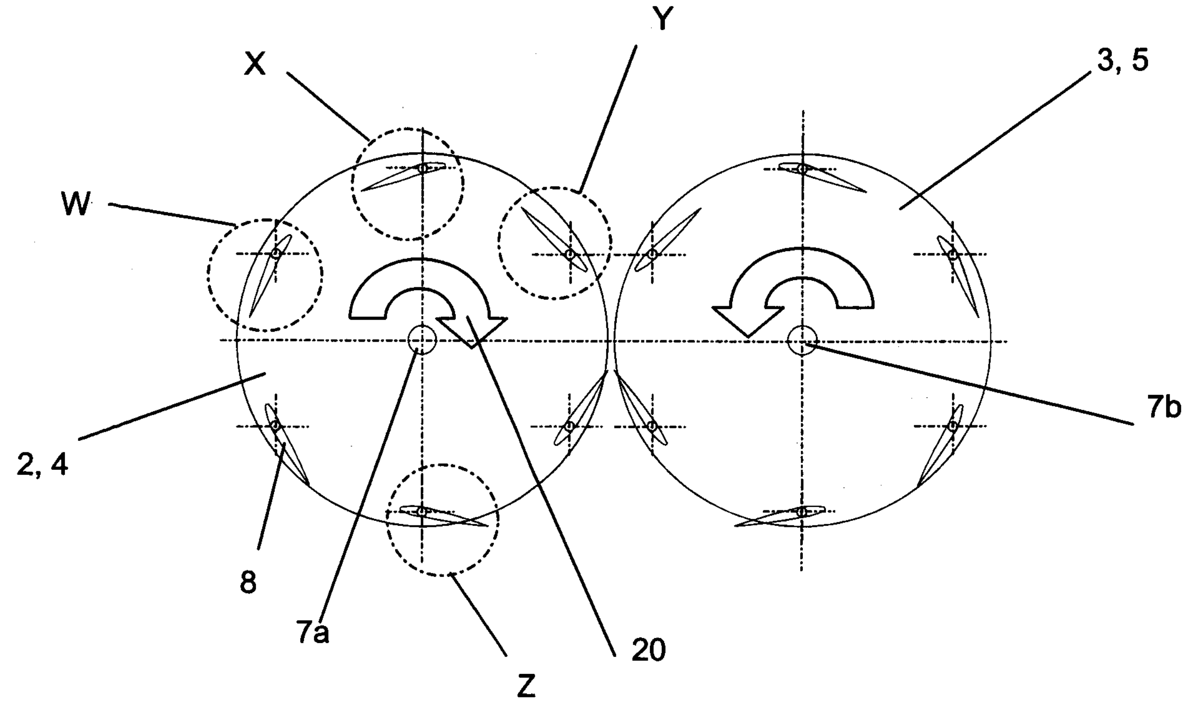

Fig. 10

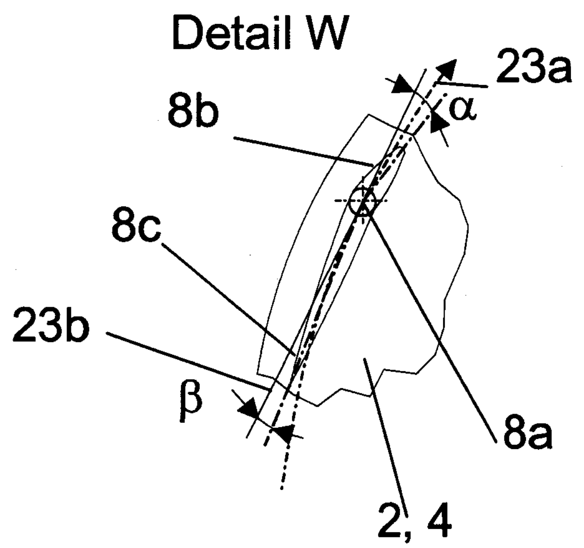

Fig. 10a

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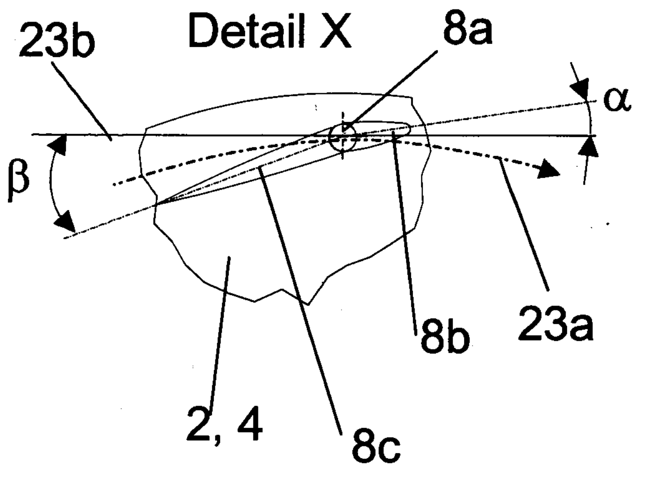

Fig. 10b

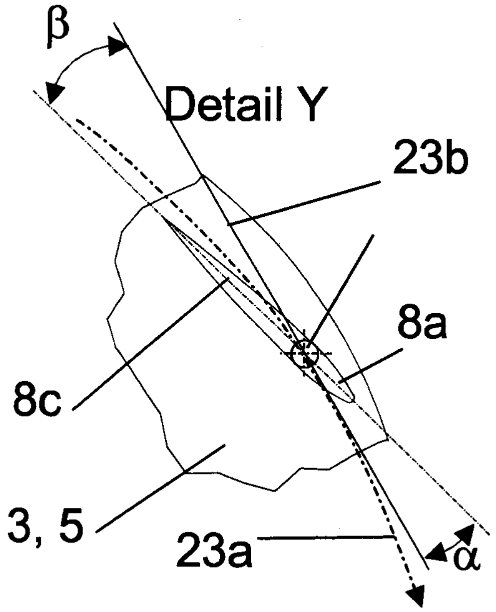

Fig. 10c

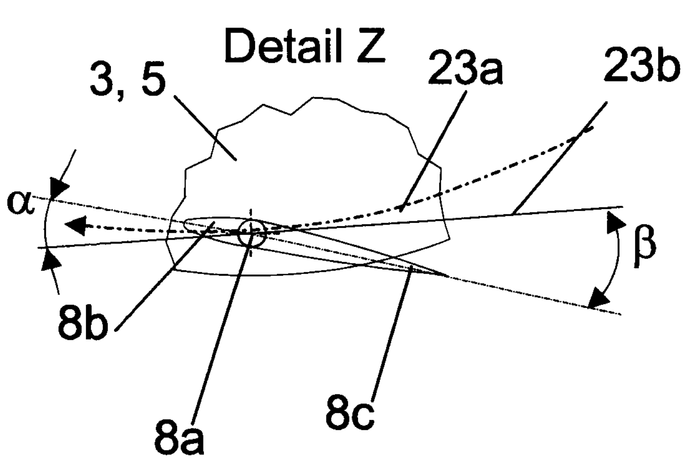

Fig. 10d

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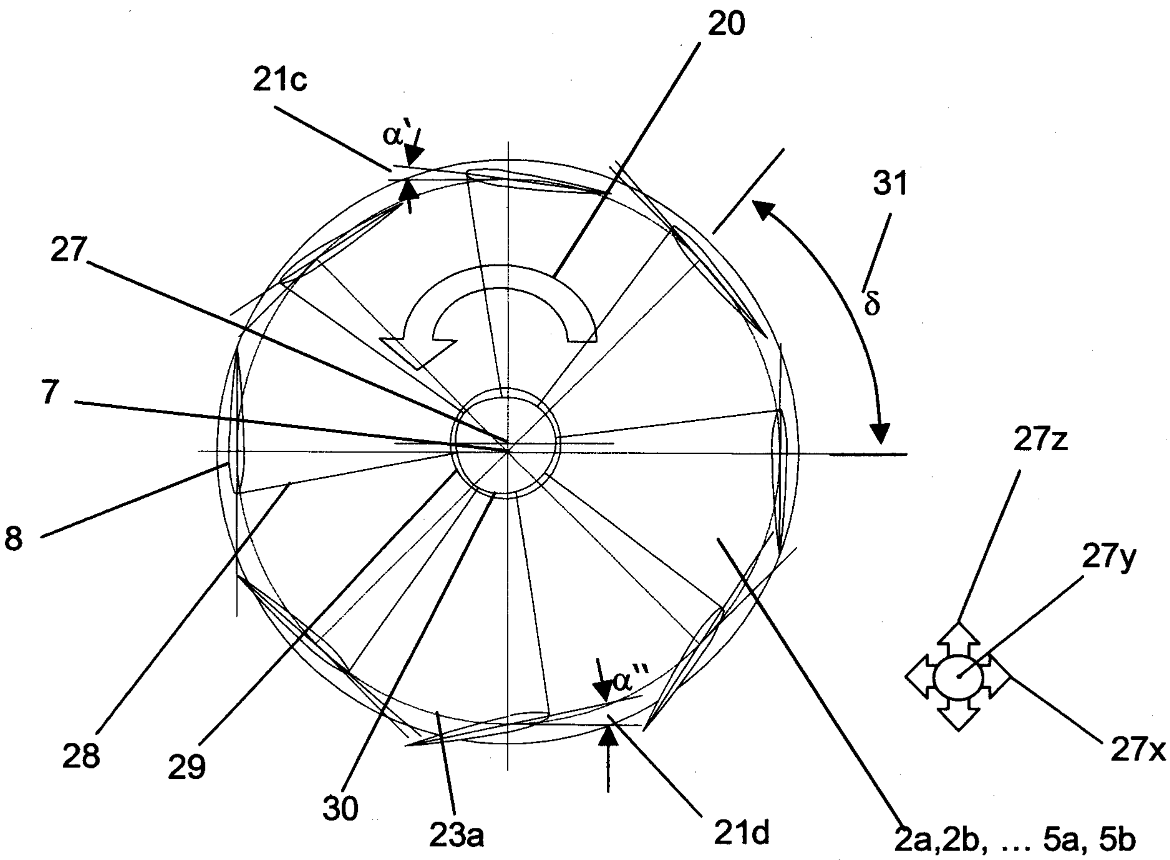

Fig. 11

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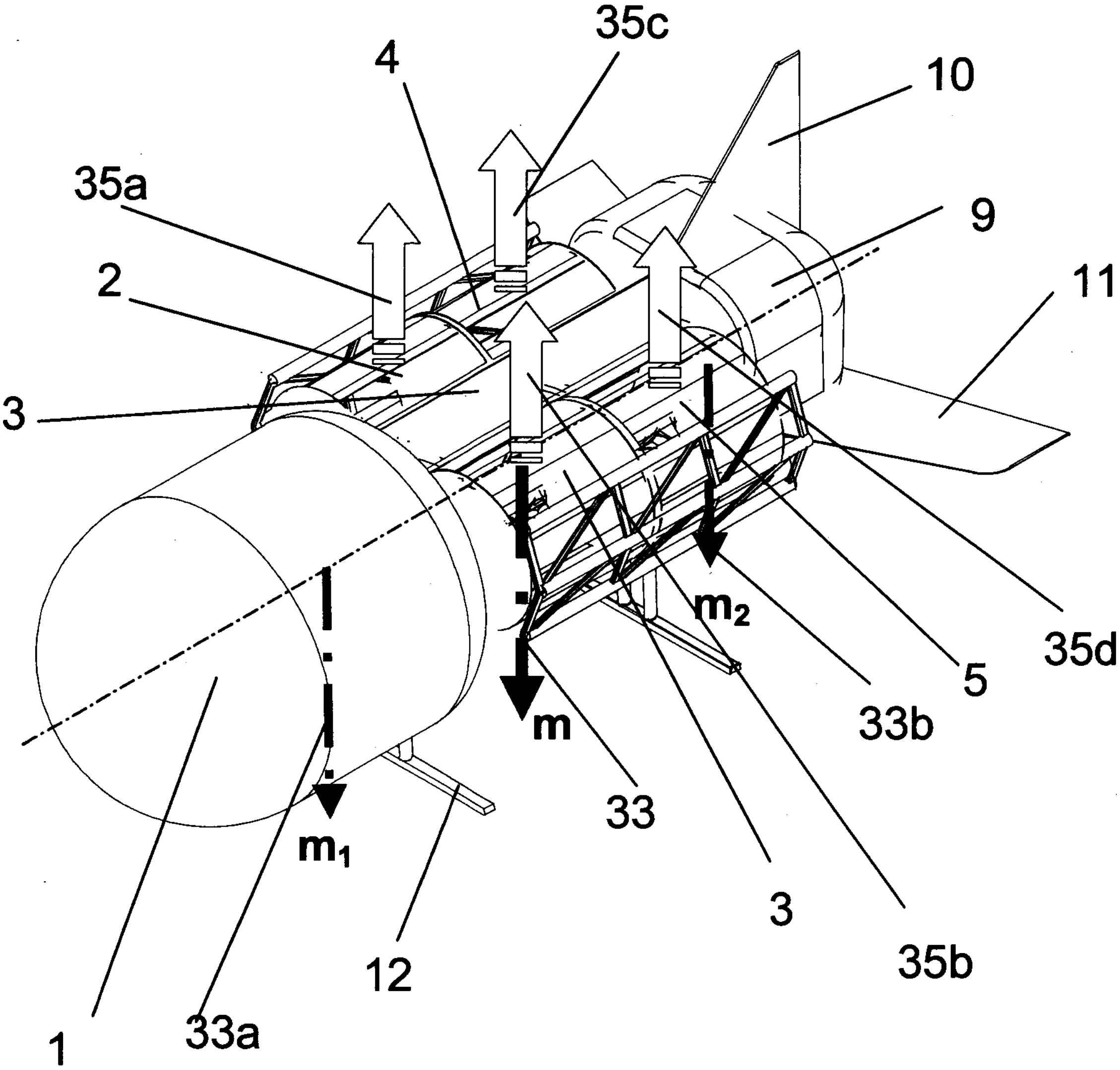

Fig. 12

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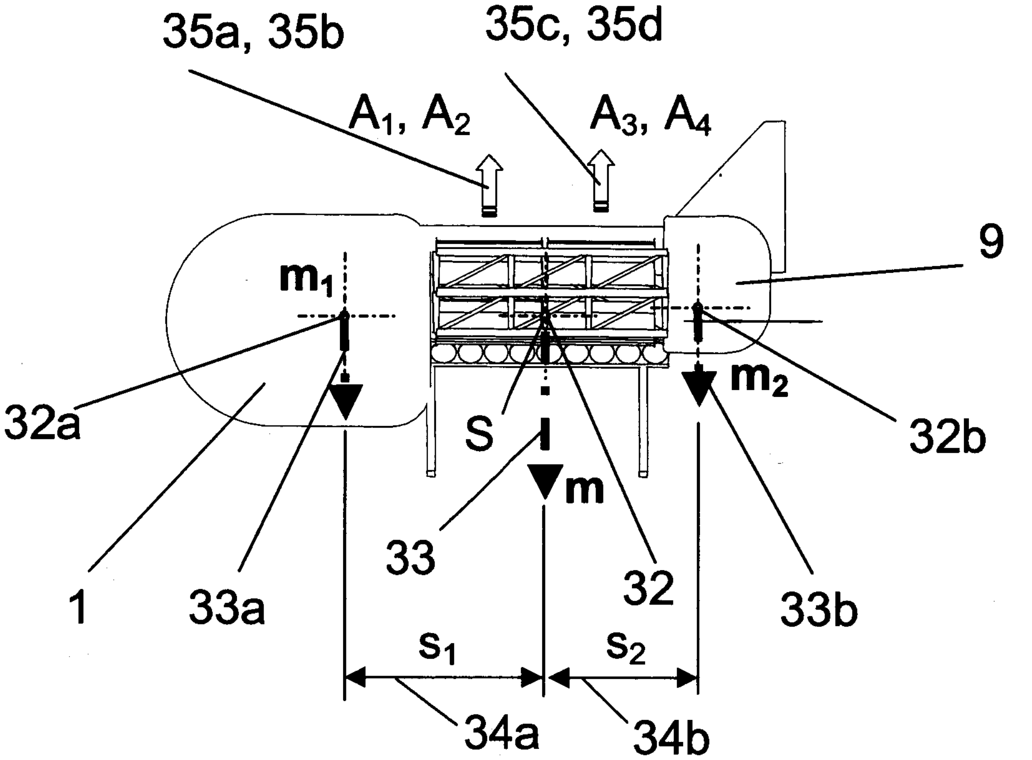

Fig. 12a

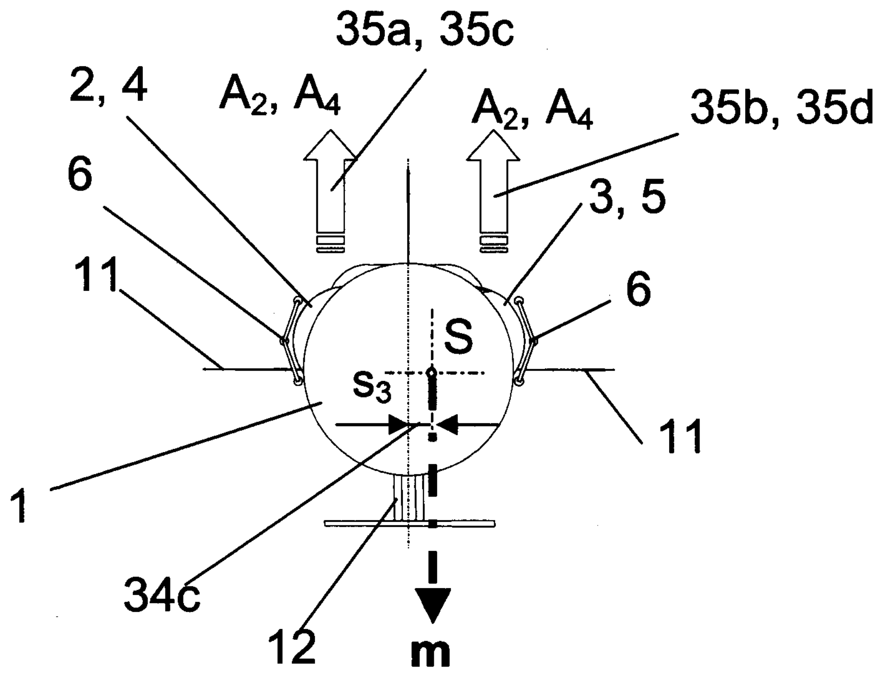

Fig. 12b

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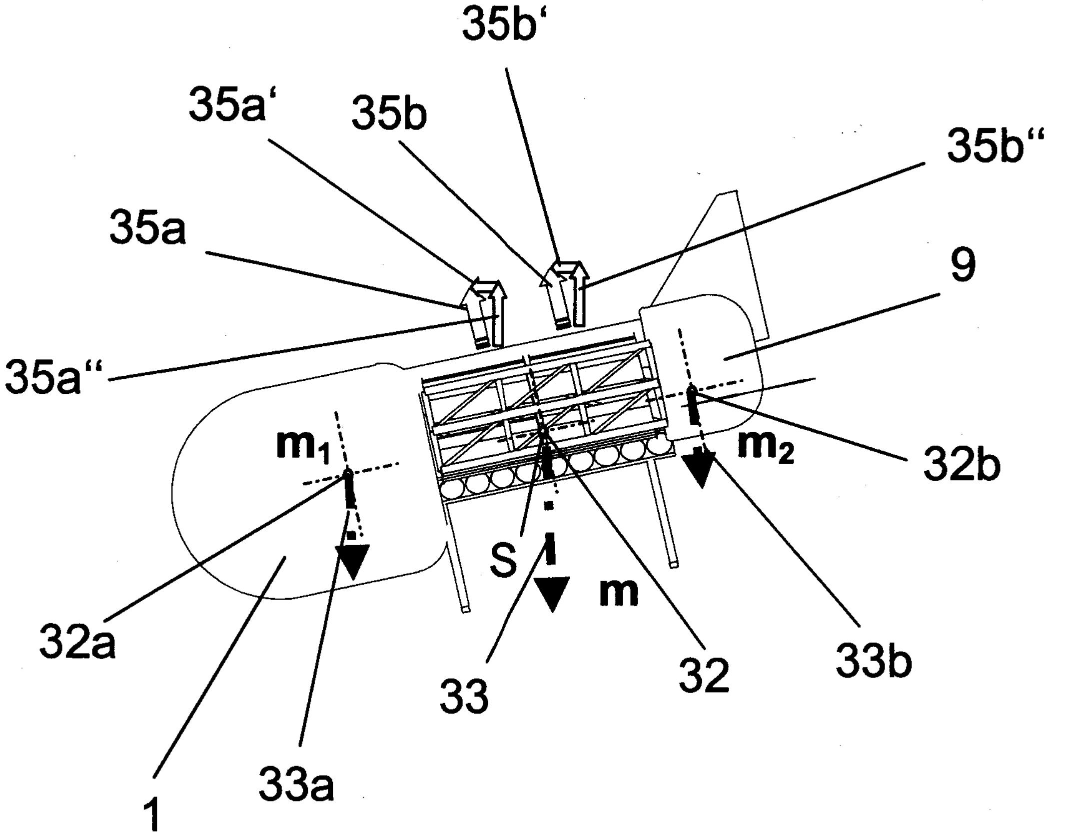

Fig. 13

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Schnitt A-A

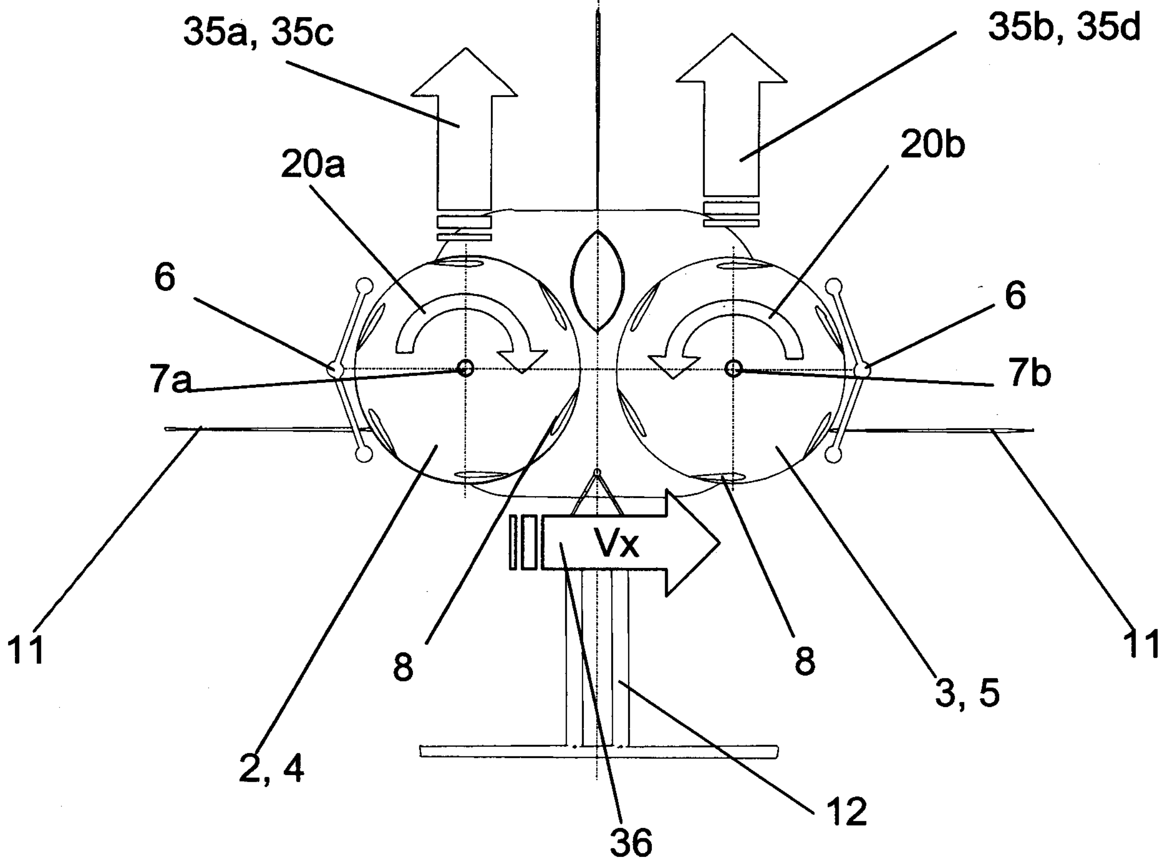

Fig. 14

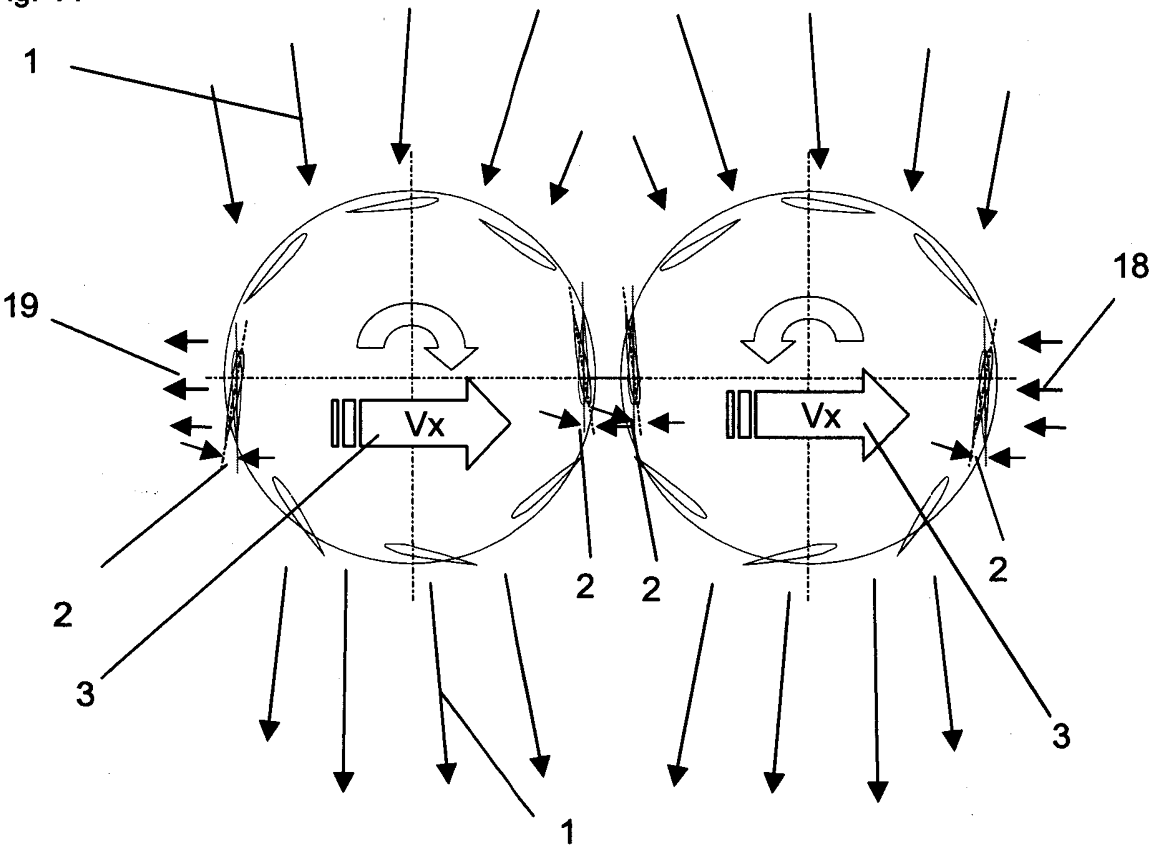

Fig. 14a

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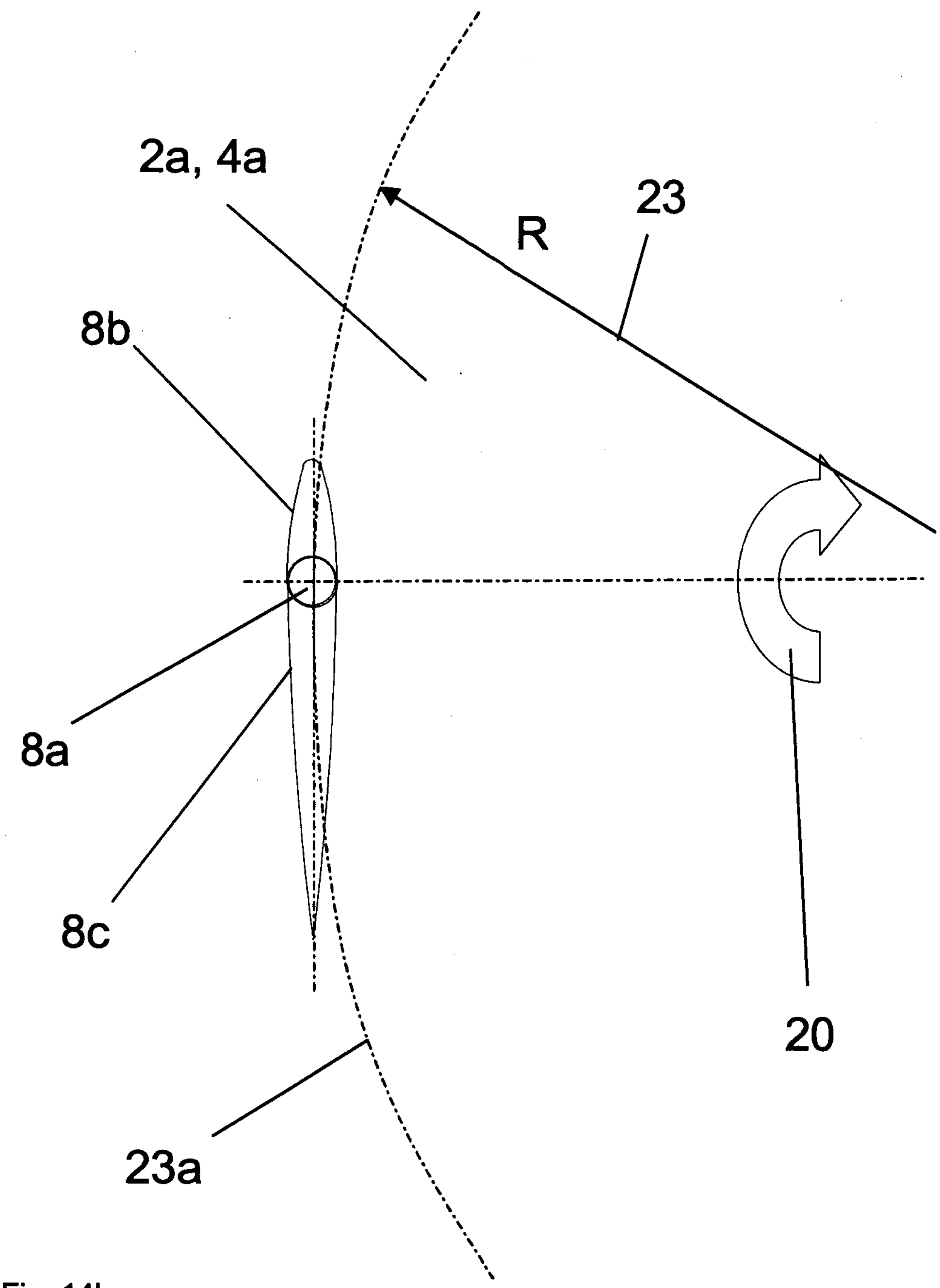

Fig. 14b

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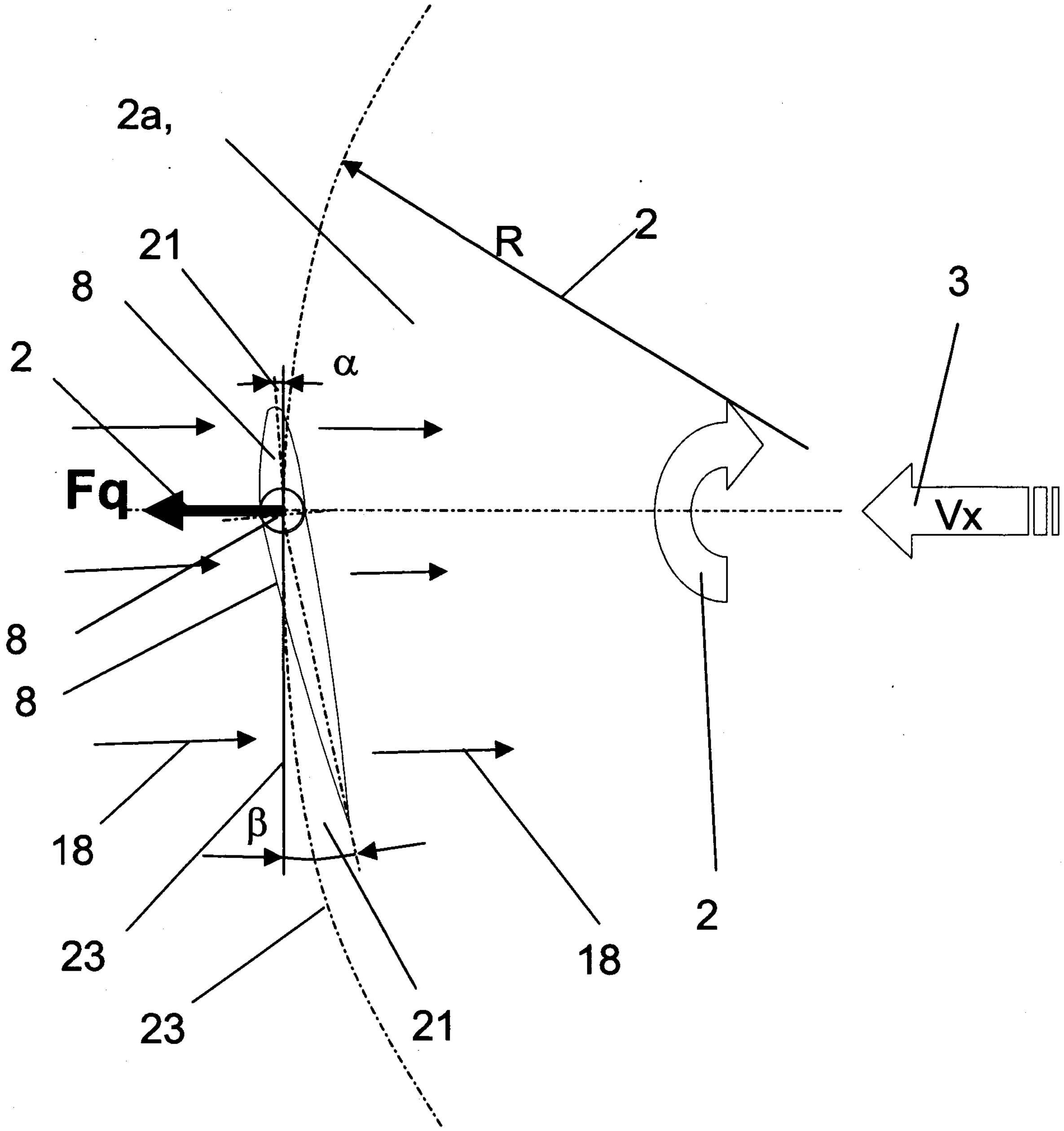

Fig. 14c

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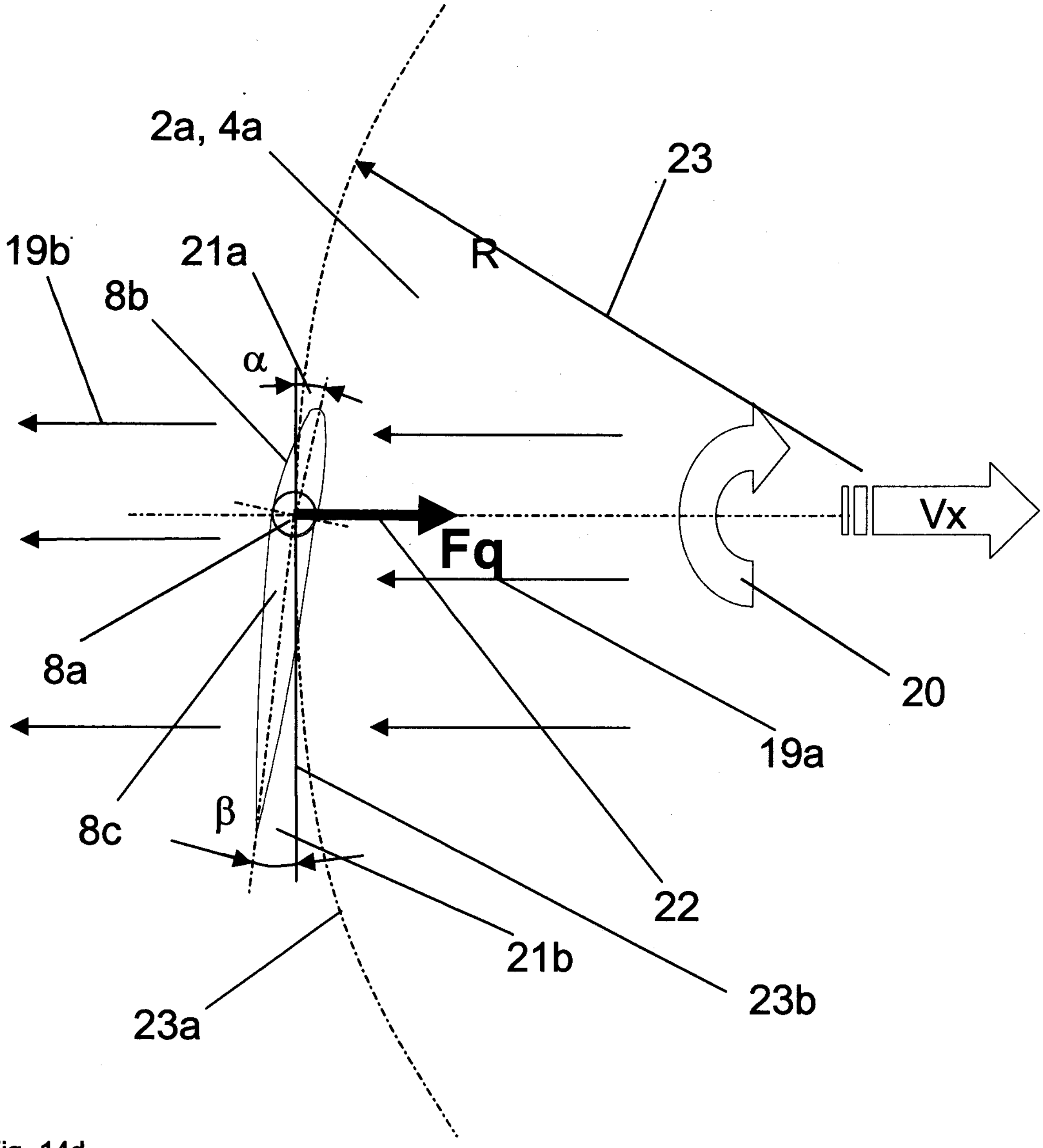

Fig. 14d

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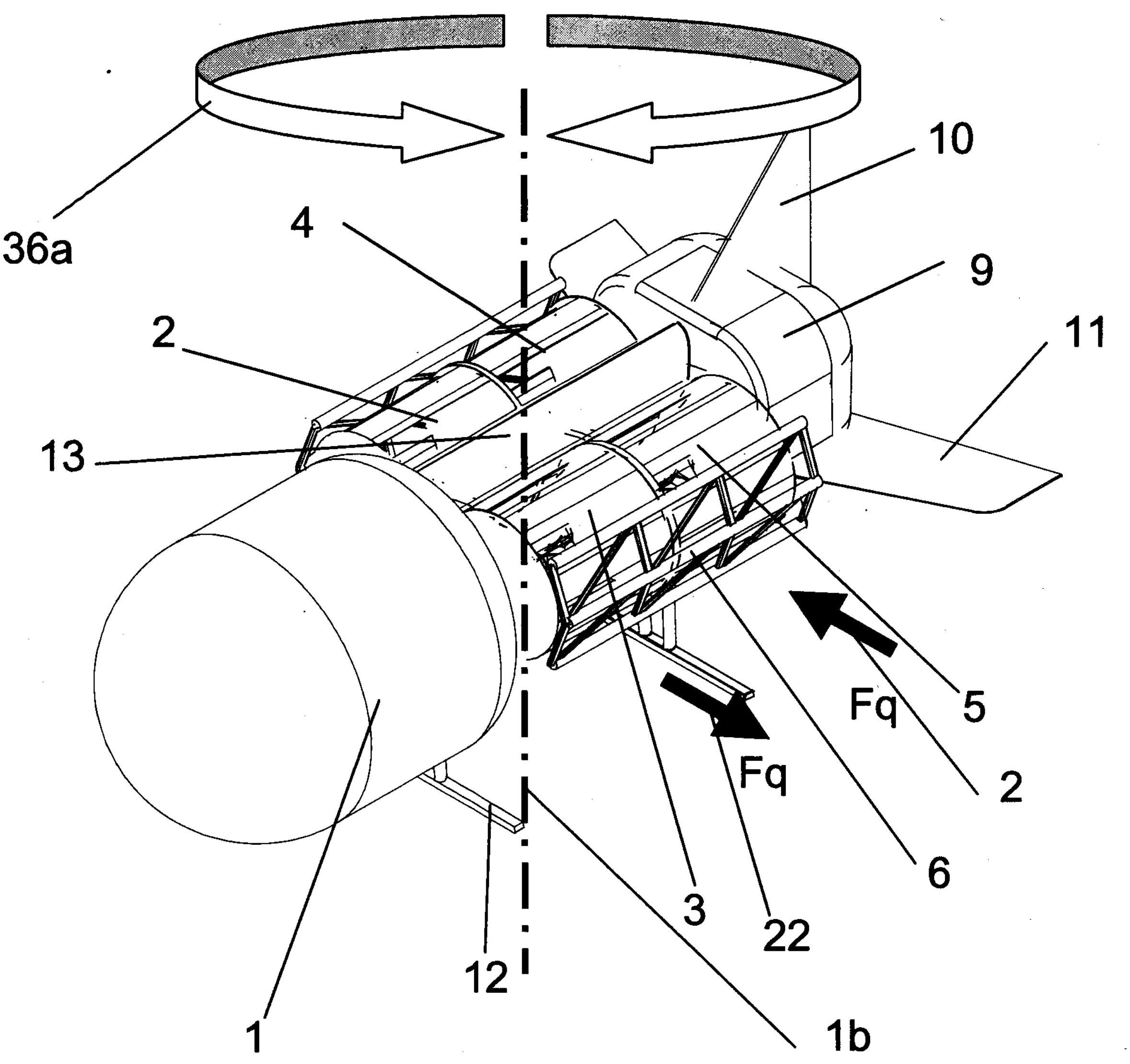

Fig. 15

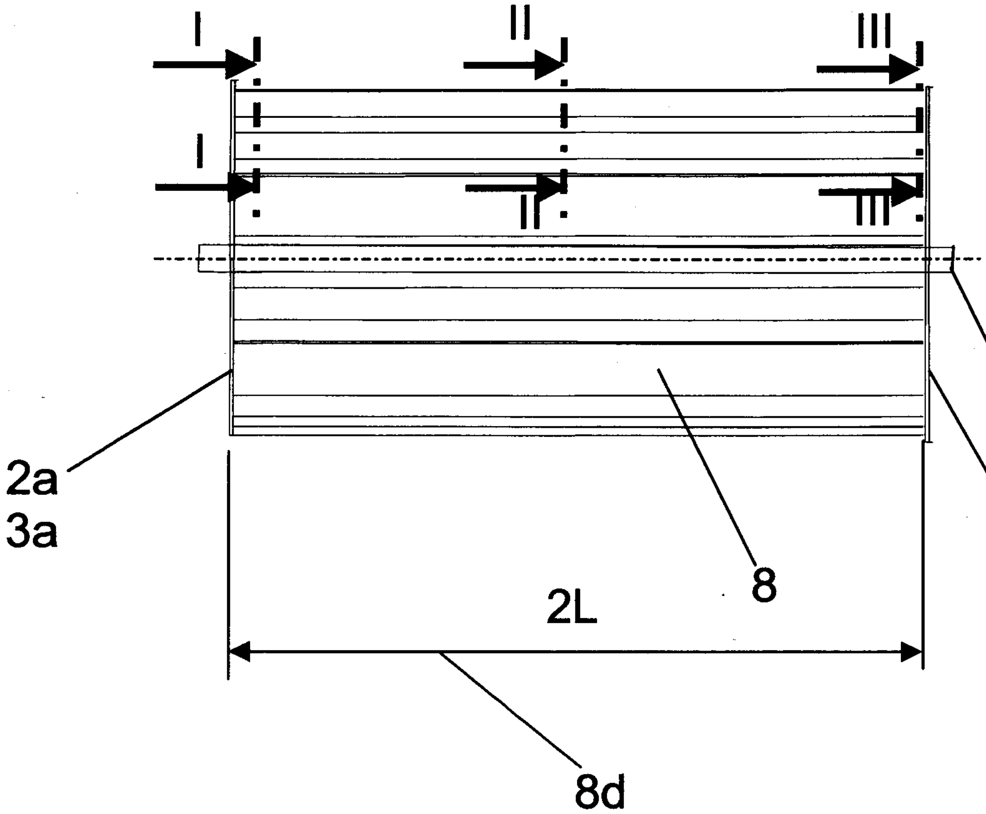

Fig. 16

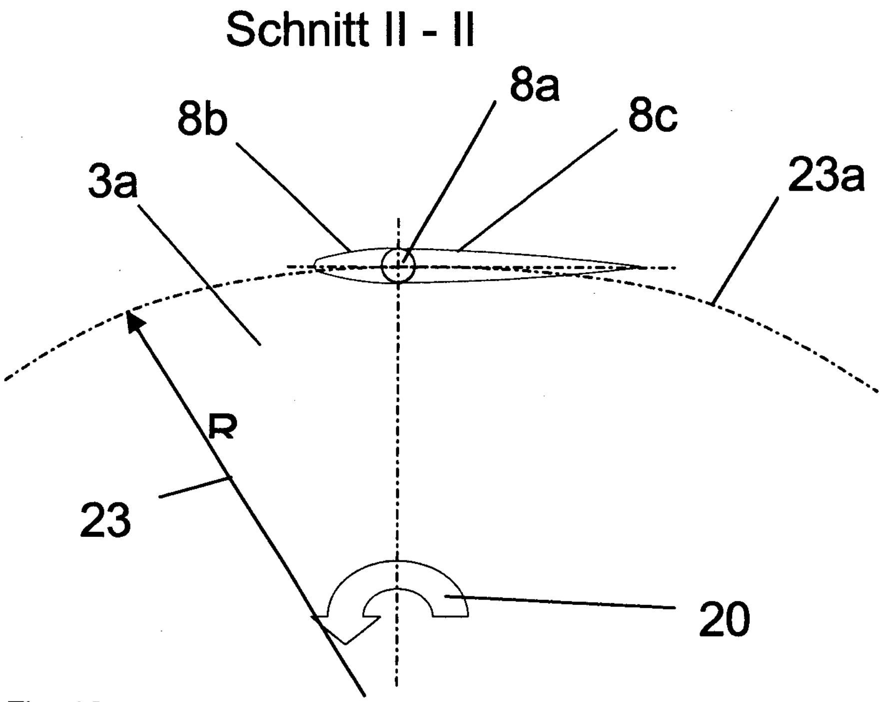

Fig. 16a

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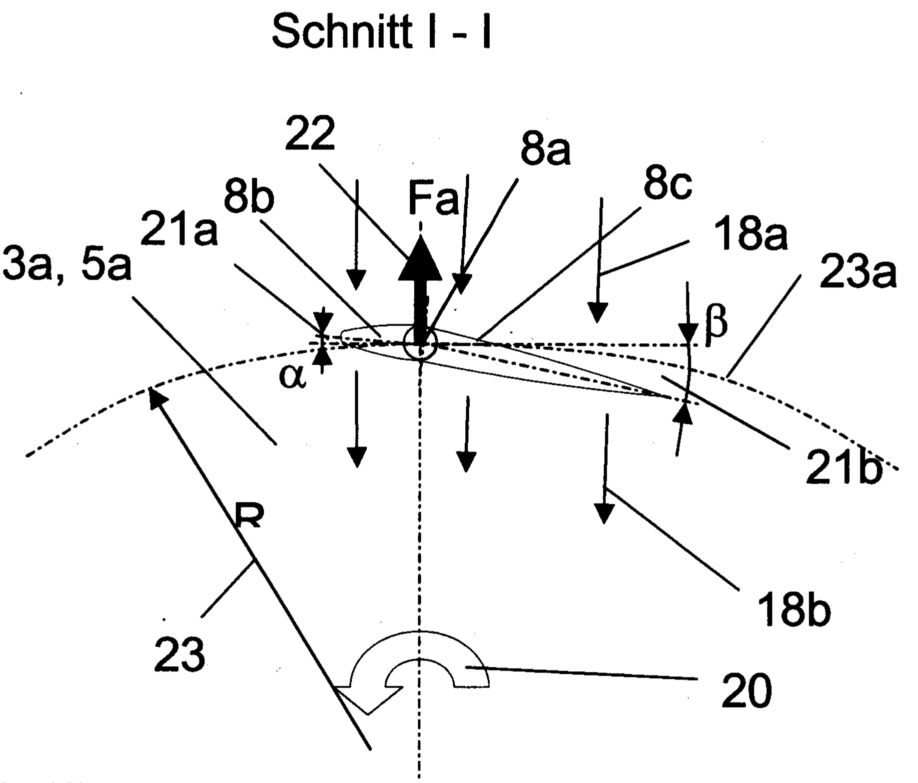

Fig. 16b

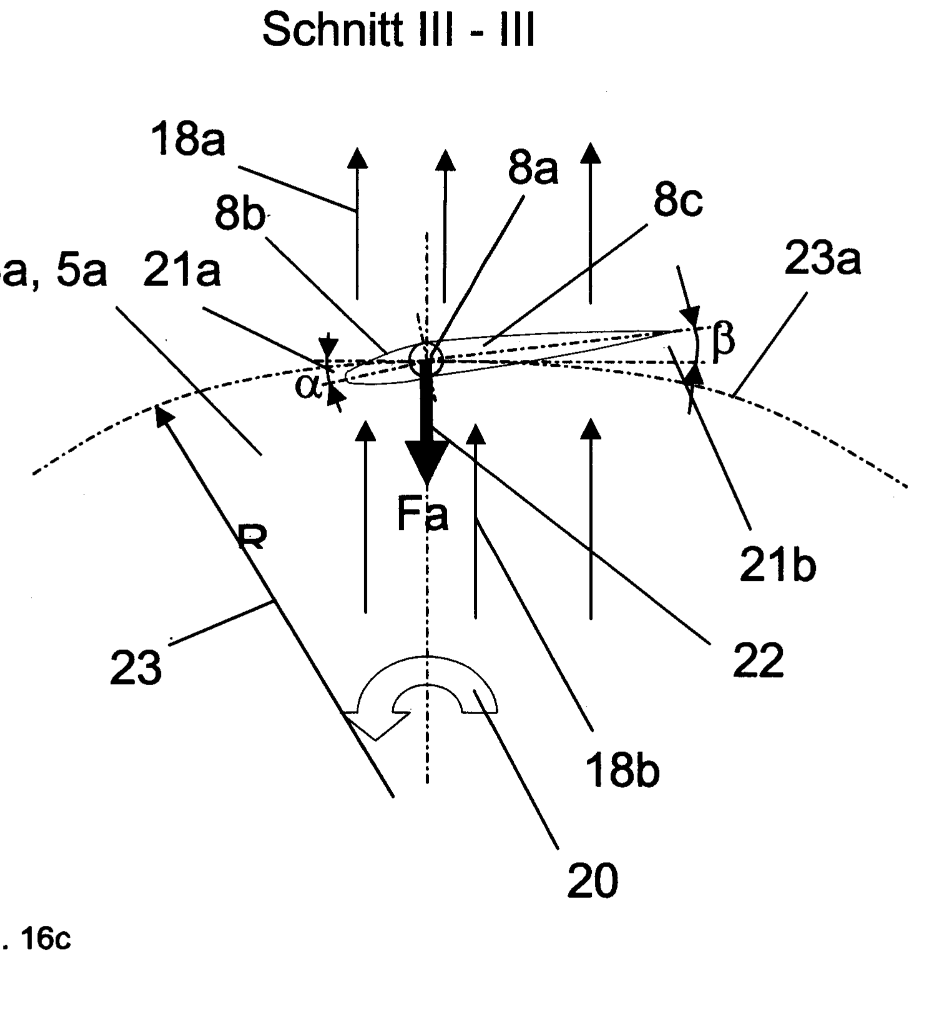

Fig. 16c

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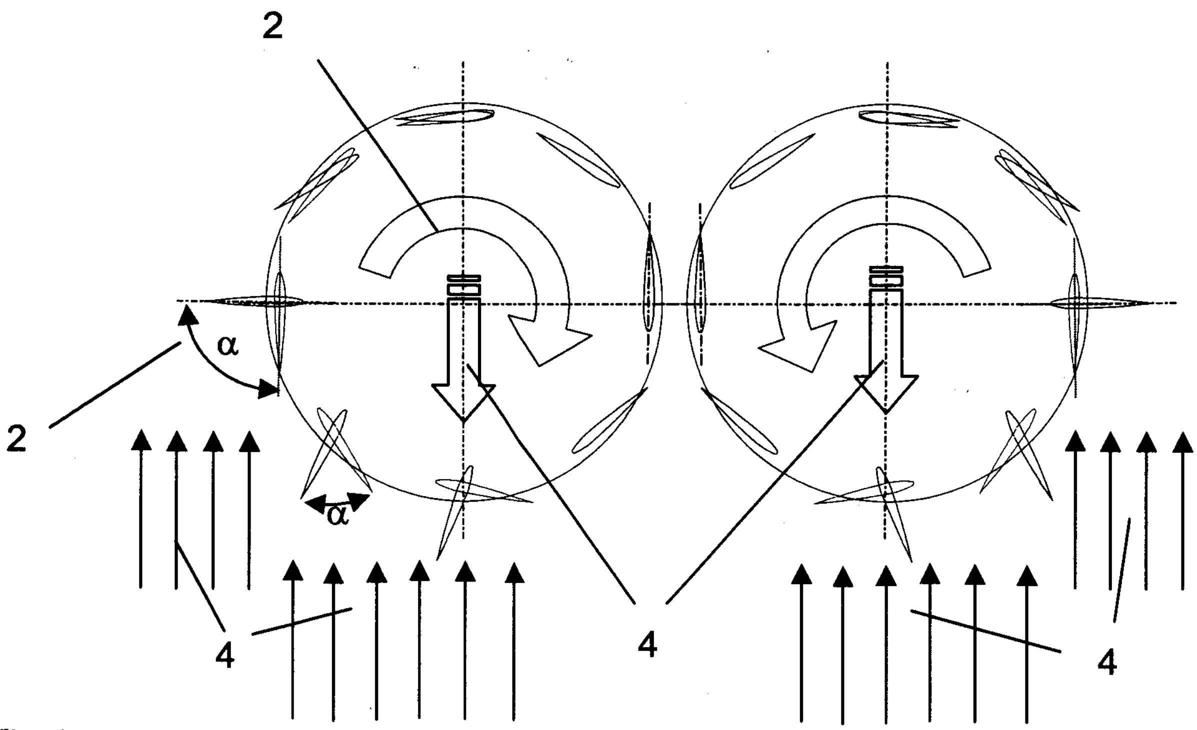

Fig. 17

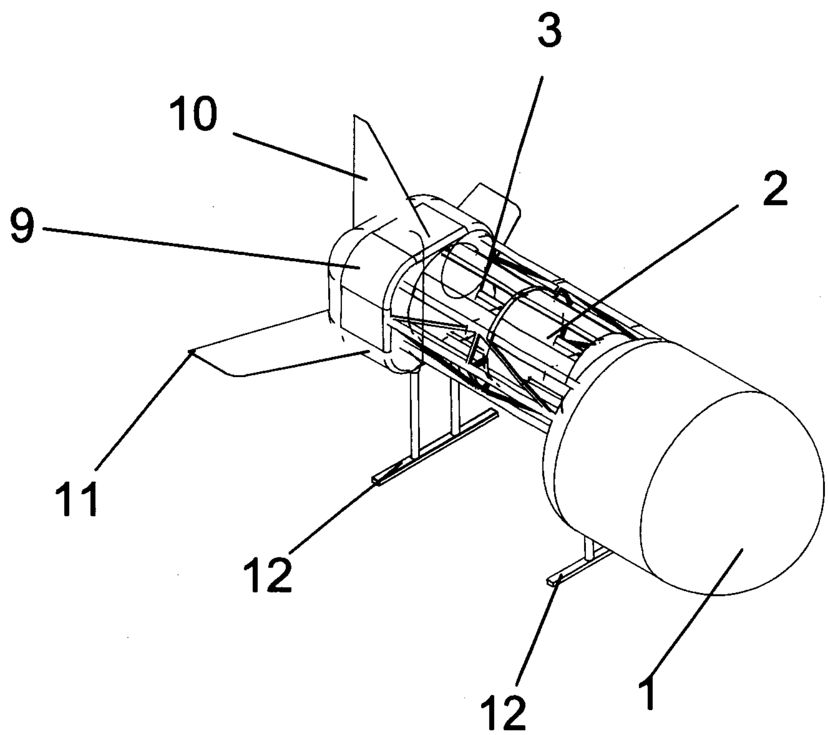

Fig. 18

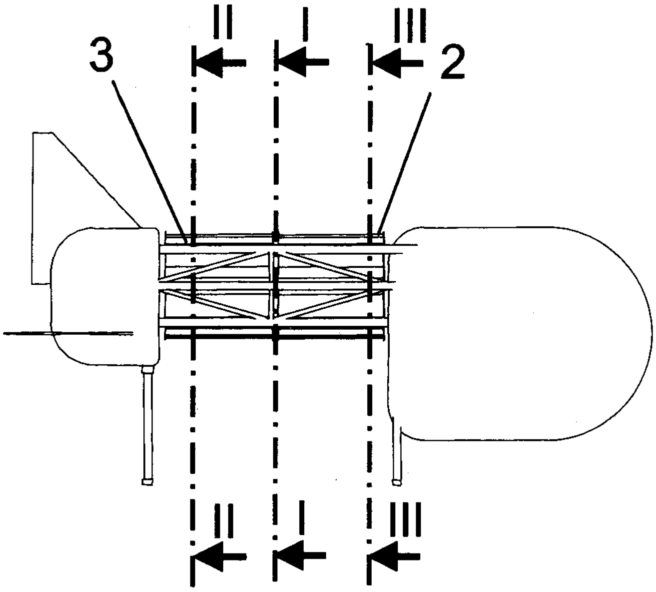

Fig. 18a

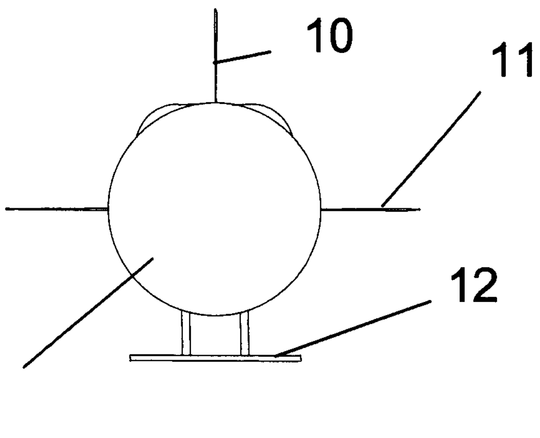

Fig. 18b

Schnitt I - I

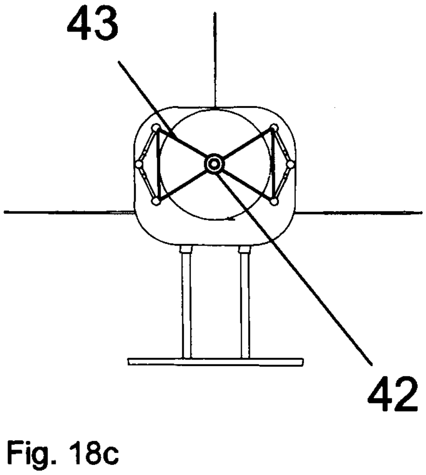

Fig. 18c

Schnitt II - II

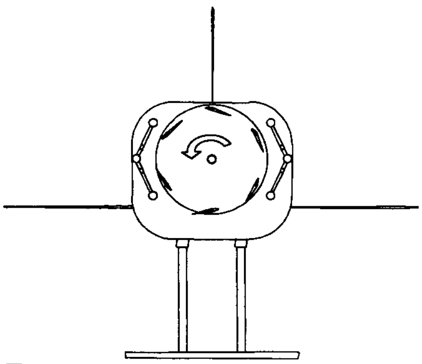

Fig. 18d

Schnitt III - III

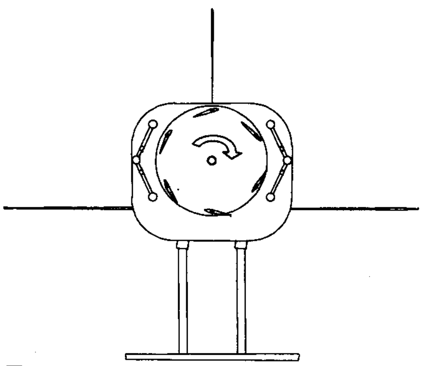

Fig. 18e

Schnitt II - II

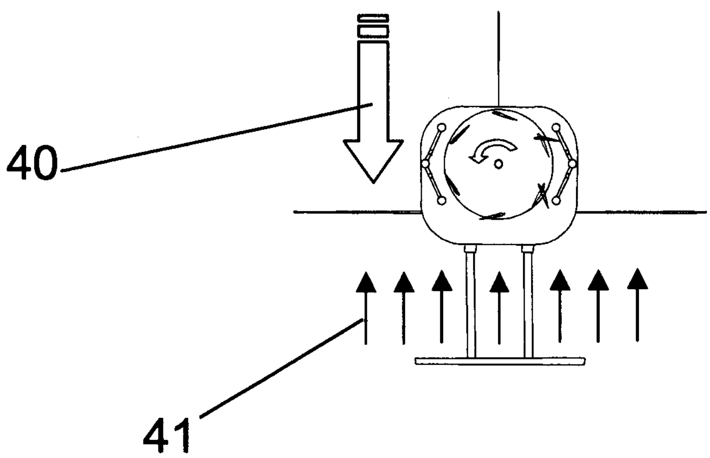

Fig. 18f

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(1)

Schnitt III - III

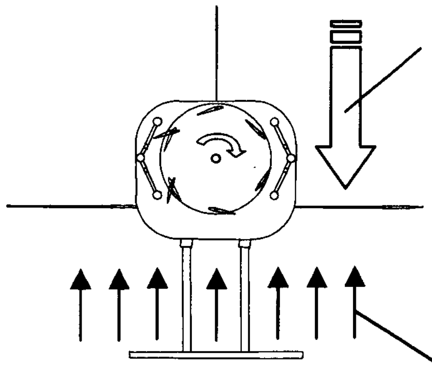

Fig. 18g

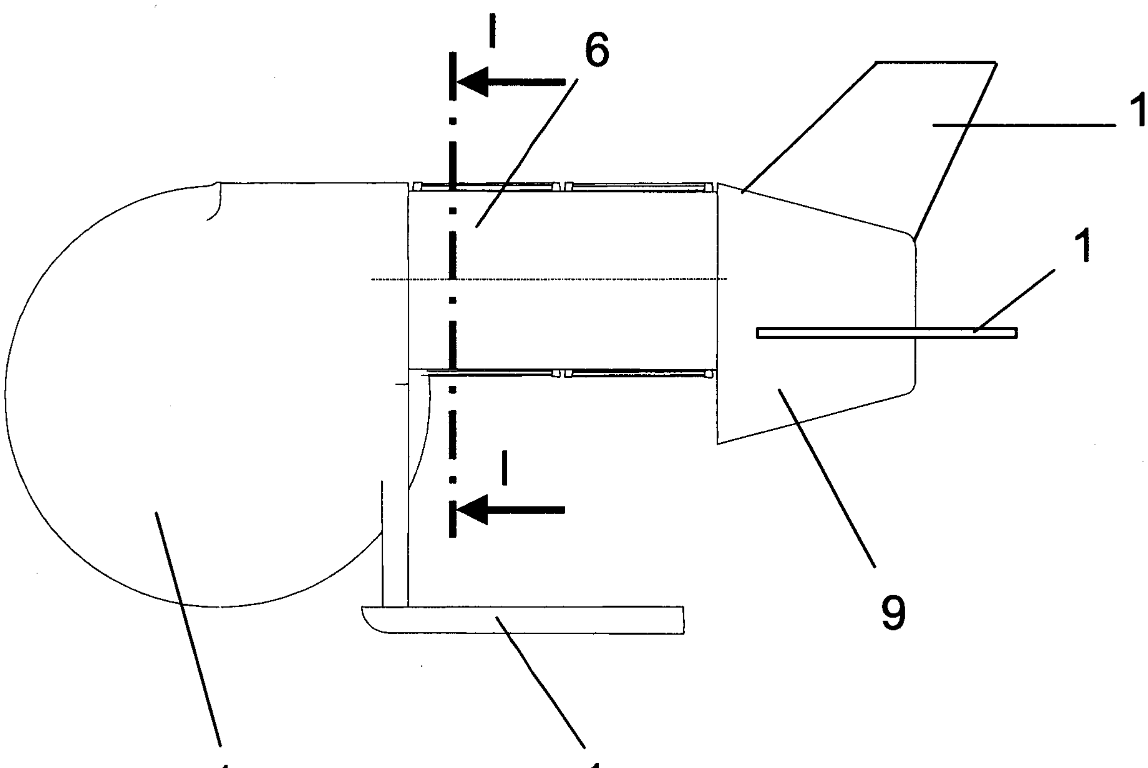

Fig. 19

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(1

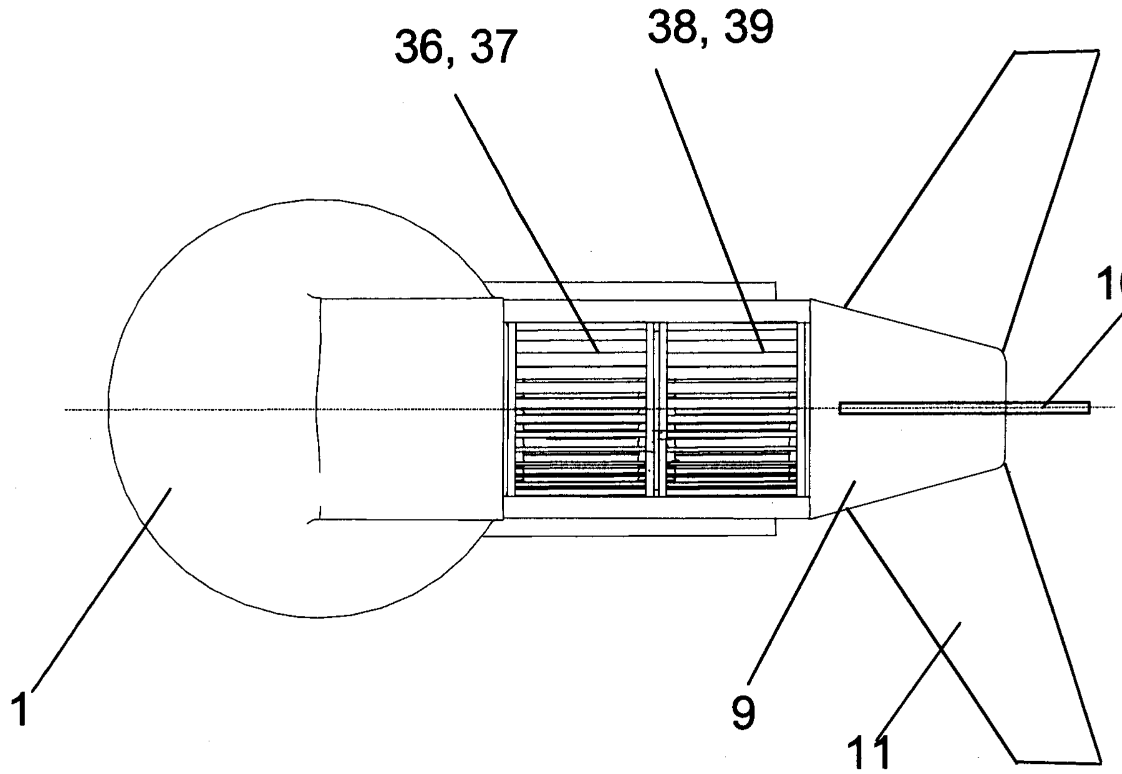

Fig. 19a

0 15 04

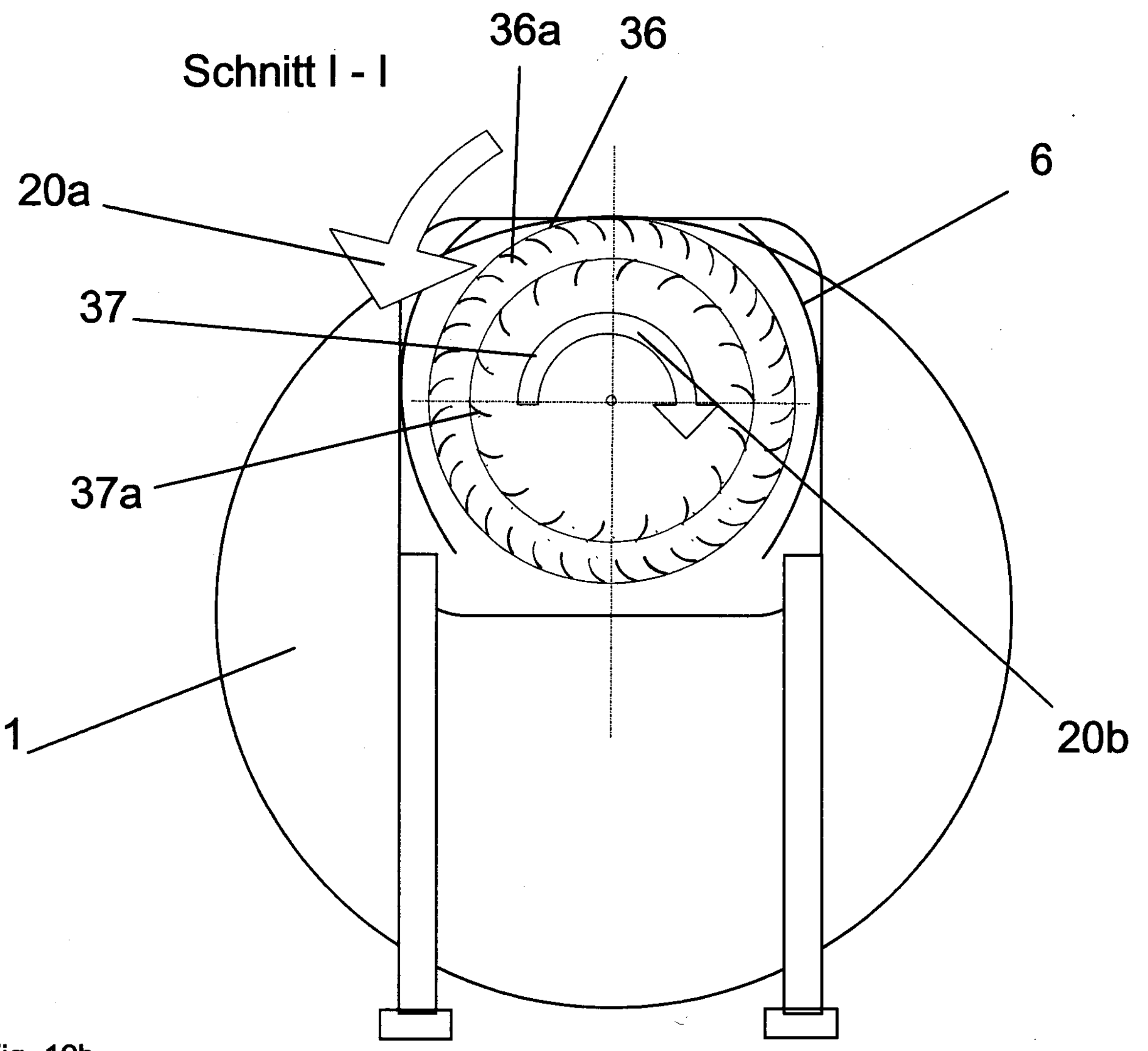

Fig. 19b

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(1

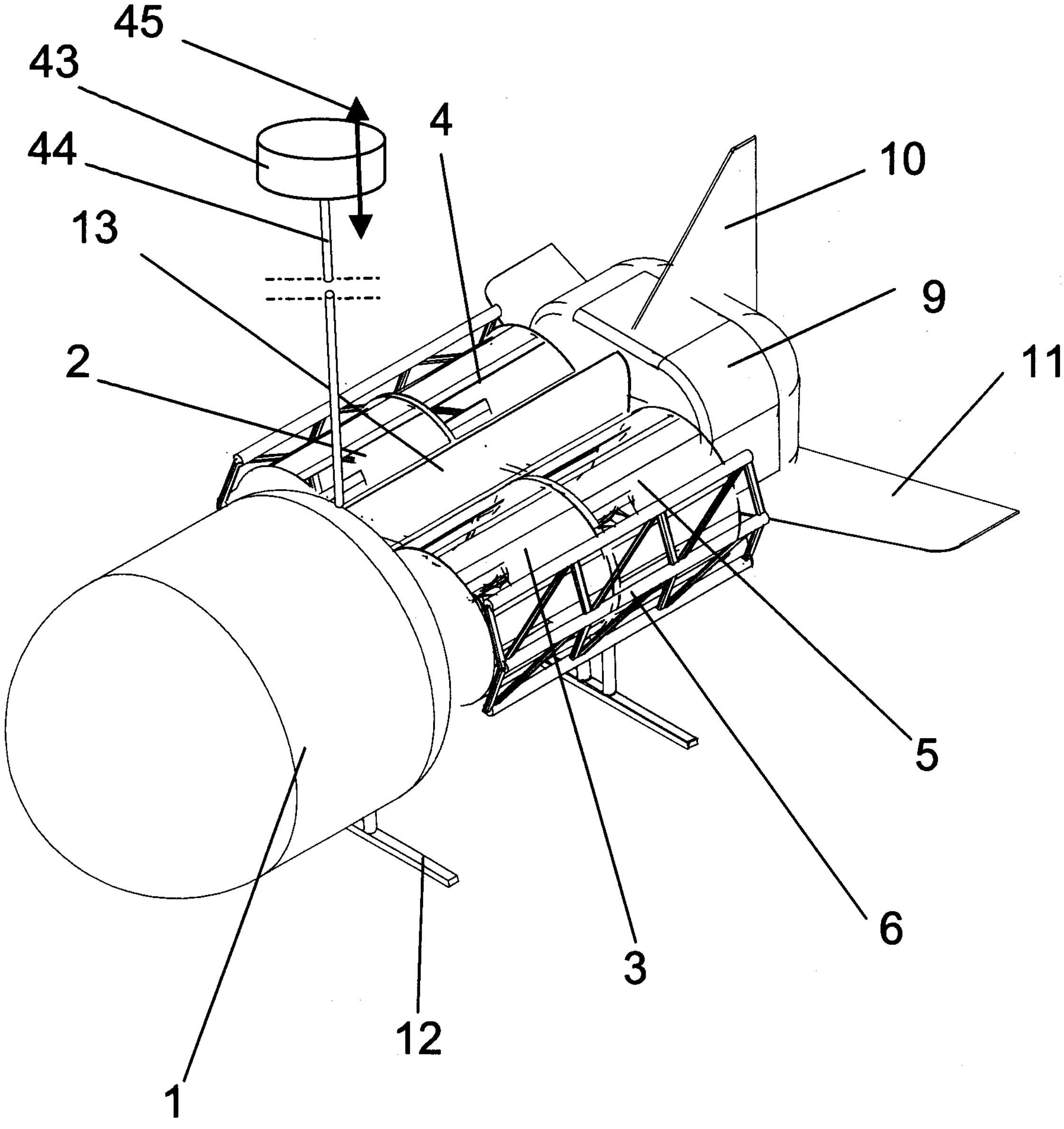

Fig. 20

10664v2p
Aktenz.: 4A A 673/2003
Klasse: B 64 C

(neue) PATENTANSPRÜCHE

1. Fluggerät mit einem Rumpf (1) und mindestens zwei am Rumpf (1) angebrachten Auftriebskörpern (2, 3, 4, 5), die im Wesentlichen hohlzylindrisch ausgebildet sind und die eine Vielzahl von tragflügelähnlich ausgebildeter Rotorblätter (8) aufweisen, die sich über den Umfang der Auftriebskörper (2, 3, 4, 5) erstrecken und beweglich um ihre Längsachse schwenkbar angeordnet sind, wobei der Umfang der Auftriebskörper (2, 3, 4, 5) durch mindestens eine Leitfläche (49, 50) teilweise abgedeckt ist, und wobei die Auftriebskörper (2, 3, 4, 5) durch mindestens ein Antriebsaggregat angetrieben sind und jeweils eine Zylinderachse aufweisen, die im Wesentlichen parallel zu einer Längsachse (1a) des Fluggerätes ist, **dadurch gekennzeichnet,** dass die Auftriebskörper (2, 3, 4, 5) mit Rotorblättern (8) versehen sind, deren hintere Teile unabhängig von der vorderen Teilen um eine Schwenkachse (8a) beweglich sind.

2. Fluggerät nach Anspruch 1, **dadurch gekennzeichnet**, dass diese Auftriebskörper oberhalb der Schwerpunktslage des Fluggerätes angeordnet sind.

3. Fluggerät nach Anspruch 1 oder 2, **dadurch gekennzeichnet**, dass die Auftriebskörper (2, 3) durch Gasturbinen gegenläufig angetrieben sind.

4. Fluggerät nach einem der Ansprüche 1 bis 3, **dadurch gekennzeichnet,** dass für eine hohe Reisegeschwindigkeit zusätzliche Triebwerke vorgesehen sind.

5. Fluggerät nach einem der Ansprüche 1 bis 4, **dadurch gekennzeichnet,** dass diese zusätzlichen Triebwerke schwenkbar ausgeführt sein können, um eine zusätzliche Unterstützung beim Start, bei der Landung oder bei sonstigen Manövern zu ermöglichen.

6. Fluggerät nach einem der Ansprüche 1 bis 5, **dadurch gekennzeichnet,** dass das Fluggerät mit zwei Auftriebskörpern (2, 3) ausgeführt ist, die entlang der Mittelachse des Fluggerätes hintereinander liegend, gegenläufig rotierend angeordnet sind.

NACHGEREICHT

7. Fluggerät nach einem der Ansprüche 1 bis 5, **dadurch gekennzeichnet,** dass das Fluggerät mit zwei gegenläufig rotierenden Auftriebskörpern (2, 3) ausgeführt ist, deren Mittelachse parallel nebeneinander liegen.

8. Fluggerät nach einem der Ansprüche 1 bis 5, **dadurch gekennzeichnet,** dass das Fluggerät mit vier Auftriebskörper (2, 3, 4, 5) ausgeführt ist, wobei jeweils zwei Auftriebskörper gegenläufig rotieren und parallel angeordnet sind.

9. Fluggerät nach einem der Ansprüche 1 bis 8, **dadurch gekennzeichnet,** dass mittels individuell verstellbarer Rotorblätter (8) bei Nenndrehzahl Auftriebskräfte und Seitenkräfte erzeugt werden können.

10. Fluggerät nach einem der Ansprüche 1 bis 9, **dadurch gekennzeichnet,** dass mittels individuell verstellbarer Rotorblätter (8) bei Nenndrehzahl im Schwebezustand unterschiedliche Schwerpunktlagen ausgeglichen werden können.

11. Fluggerät nach einem der Ansprüche 1 bis 10, **dadurch gekennzeichnet,** dass mittels der individuell verstellbaren Rotorblätter (8) bei Nenndrehzahl ein vertikaler Steigflug, ein Schwebezustand, eine langsame Vorwärts- bzw. Rückwärtsbewegung, eine Drehbewegung gegen bzw. im Uhrzeigersinn und ein vertikaler Sinkflug ausgeführt werden kann.

12. Fluggerät nach einem der Ansprüche 1 bis 11, **dadurch gekennzeichnet,** dass die Auftriebskörper (8) mit Abdeckungen (40, 41) versehen sind, ausgeführt als kompakte Abdeckungen oder als ein System von Lamellen, die einerseits einen ungehinderten Luftdurchlass gewährleisten und für eine hohe Reisegeschwindigkeit, wo der Wirkungsgrad der Auftriebskörper begrenzt ist, die Strömungsverluste reduzieren.

13. Fluggerät nach einem der Ansprüche 1 bis 12, **dadurch gekennzeichnet,** dass die Auftriebskörper seitlich eine Schutzverkleidung (6) aufweisen, die einen ungehinderten Luftdurchlass gewährleisten, im Bedarfsfall jedoch den rotierenden Auftriebskörper gegen Kollision mit einem festen Hindernis schützen.

14. Fluggerät nach einem der Ansprüche 1 bis 13, **dadurch gekennzeichnet,** dass der Auftriebskörper im Wesentlichen aus einer Drehachse (7), zwei Endscheiben (z. B. 2a, 2b) und Rotorblättern (8) besteht.

15. Fluggerät nach einem der Ansprüche 1 bis 14, **dadurch gekennzeichnet,** dass oberhalb der Pilotenkanzel keine rotierenden Aggregate vorhanden

NACHGEREICHT

sind und im Bedarfsfall der Pilot das Fluggerät mittels Schleudersitz sicher verlassen kann.

16. Fluggerät nach einem der Ansprüche 1 bis 15, **dadurch gekennzeichnet,** dass oberhalb des Fluggerätes keinerlei rotierende Aggregate vorhanden sind, sodass ein spezielles Aufklärungsgerät (43) vertikal in die Höhe geschossen und wieder eingebracht werden kann.

17. Fluggerät nach einem der Ansprüche 1 bis 16, **dadurch gekennzeichnet,** dass die Rotorblätter derart angestellt werden können, dass bei einem Totalausfall eines Antriebsaggregates oberhalb einer kritischen Höhe, der Auftriebskörper im Sinkflug des Fluggerätes in Autorotation versetzt werden kann und eine sichere Landung des Fluggerätes möglich ist.

18. Fluggerät nach einem der Ansprüche 1 bis 7, **dadurch gekennzeichnet,** dass der Auftriebskörper als Querstromrotor ausgeführt ist.

19. Fluggerät nach einem der Ansprüche 1 bis 18, dadurch gekennzeichnet, dass zwei Querstromrotoren gegenläufig rotierend hintereinander angeordnet sind.

20. Fluggerät nach einem der Ansprüche 1 bis 19, **dadurch gekennzeichnet,** dass in jeweils einem äußeren Querstromrotor ein zweiter kleinerer Querstromrotor mit gegenläufiger Drehrichtung eingeschrieben ist.

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e-mail: patent@babeluk.at

NACHGEREICHT

Recherchenbericht zu **A 673/2003**
Technische Abteilung 2A

österreichisches patentamt

Klassifikation des Anmeldungsgegenstands gemäß IPC[8]:		
B64C 29/00 (2006.01); ***B64C 39/00*** (2006.01)		
Klassifikation des Anmeldungsgegenstands gemäß ECLA:		
Recherchierter Prüfstoff (Klassifikation): B64C		
Konsultierte Online-Datenbank: EPODOC, WPI, TXTnn		
Dieser Recherchenbericht wurde zu den am **5. Mai 2003** eingereichten Ansprüchen **1-23** erstellt.		

Kategorie*)	Bezeichnung der Veröffentlichung: Ländercode, Veröffentlichungsnummer, Dokumentart (Anmelder), Veröffentlichungsdatum, Textstelle oder Figur soweit erforderlich	Betreffend Anspruch
X	US 1 761 053 A (RYSTEDT) 3. Juni 1930 (03.06.1930) *Beschreibungsseite 2, Fig.2-4;*	1,2,4,6-19
Y		21-23
A		3,5,20
	--	
Y	US 6 007 021 A (TSEPENYUK) 28. Dezember 1999 (28.12.1999) *Beschreibungsspalten 2-5, Ansprüche, Fig.1,5,6;*	21-23
A		1-20

Datum der Beendigung der Recherche: 13. März 2006	☐ Fortsetzung siehe Folgeblatt	Prüfer(in): Dipl.-Ing. NEUBAUER

*) **Kategorien** der angeführten Dokumente:

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A Veröffentlichung, die den **allgemeinen Stand der Technik** definiert.

P Dokument, das **von Bedeutung** ist (Kategorien **X** oder **Y**), jedoch **nach dem Prioritätstag** der Anmeldung **veröffentlicht** wurde.

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& Veröffentlichung, die Mitglied der selben **Patentfamilie** ist.

Document is not available for CA146228 (S)

US00D709430S

(12) **United States Design Patent** (10) **Patent No.: US D709,430 S**
Schwaiger (45) **Date of Patent: ** Jul. 22, 2014**

(54) **AEROPLANE**

(75) Inventor: **Meinhard Schwaiger**, Linz (AT)

(73) Assignee: **IAT 21 Innovatice Aeronautics Technologies GmbH**, Linz (AT)

(**) Term: **14 Years**

(21) Appl. No.: **29/425,942**

(22) Filed: **Jun. 28, 2012**

(51) **LOC (10) Cl.** **12-07**

(52) **U.S. Cl.**
USPC **D12/319**; D12/16.1; D12/330; D21/447

(58) **Field of Classification Search**
USPC .... D12/16.1, 319–322, 324–327, 330, D12/333–345; D21/436, 437, 441–449, D21/451, 430; 244/30, 35 R, 36, 55, 1 R, 244/158.1, 158.9, 153 R, 154, 171.8, 171.1; 446/61, 230–233; 342/62–65
See application file for complete search history.

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Primary Examiner — Caron D Veynar
Assistant Examiner — Martie K Holtje
(74) *Attorney, Agent, or Firm* — Greer Burns & Crain Ltd.

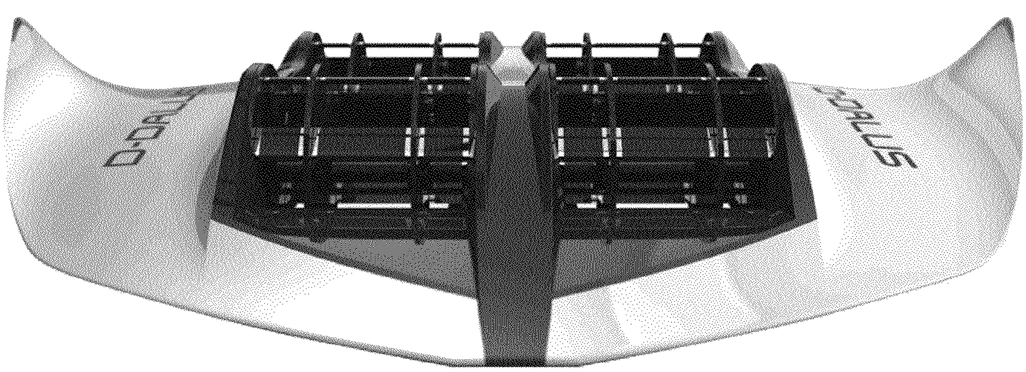
(57) **CLAIM**

The ornamental design for an aeroplane, as shown and described.

DESCRIPTION

FIG. **1** is a top front perspective view of an aeroplane showing my new design;
FIG. **2** is a left side elevational view, the right side being a mirror image thereof;
FIG. **3** is a top plan view thereof; and,
FIG. **4** is a top rear perspective view thereof.
The portions of the bottom of the aeroplane, not shown, form no part of the claimed design.

1 Claim, 4 Drawing Sheets



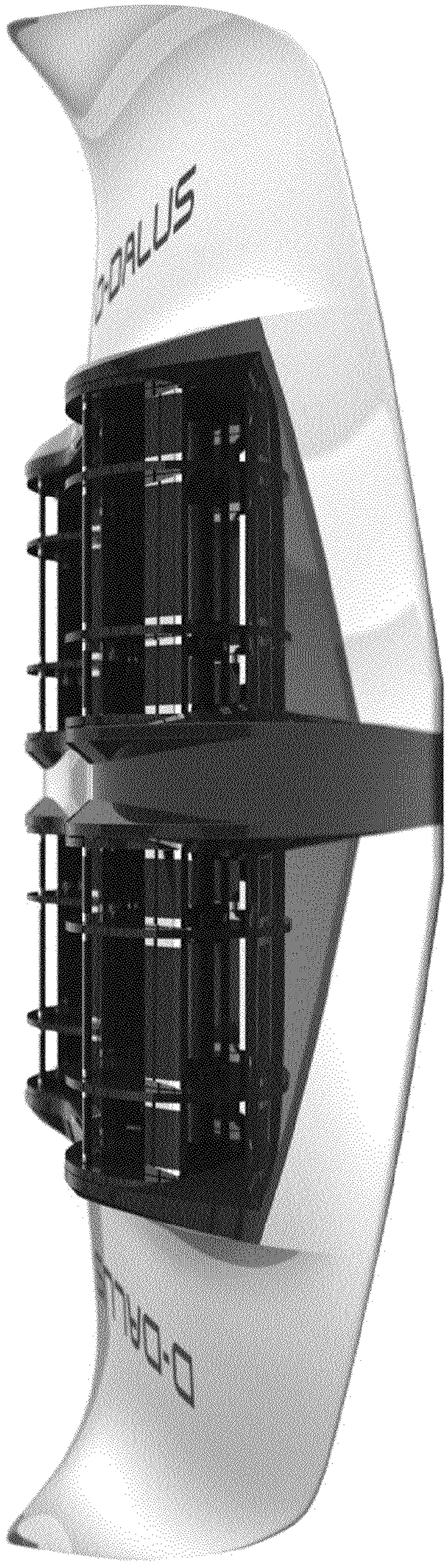


FIG. 1

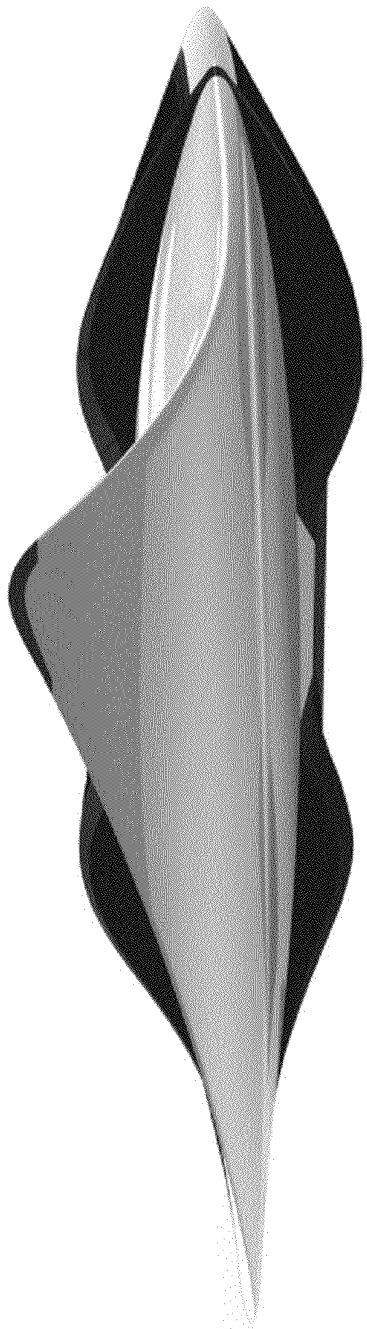


FIG. 2

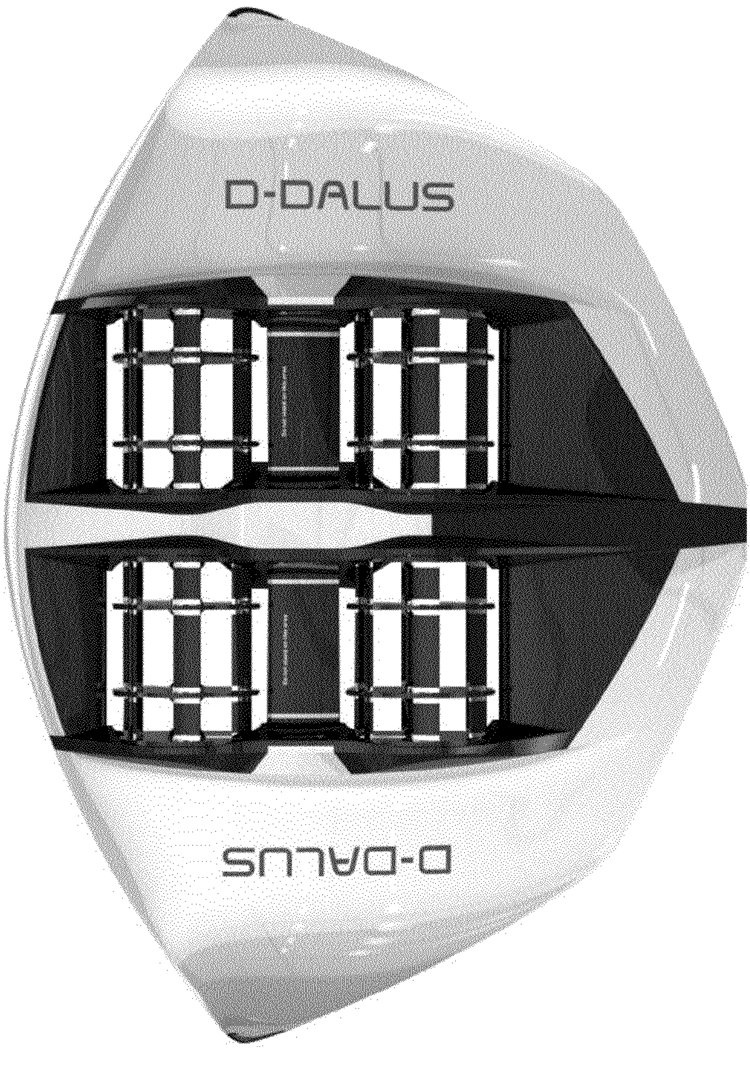


FIG. 3

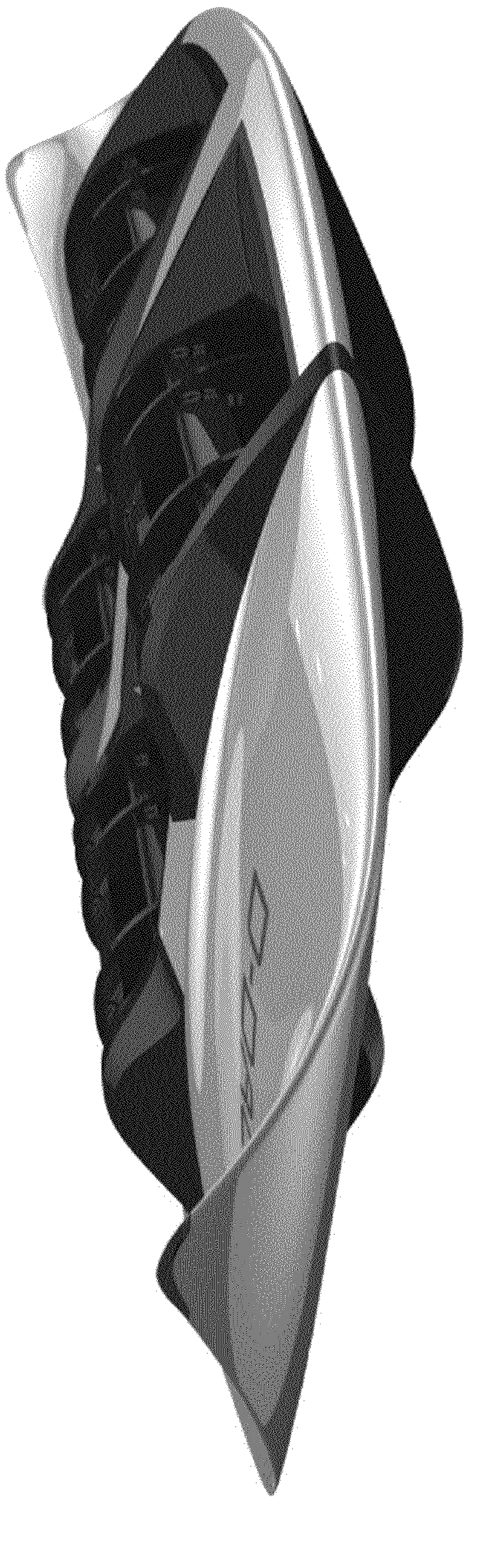


FIG. 4

April 14, 1936. A. B. GARDNER 2,037,377

CONSTRUCTION FOR AIRCRAFT

Original Filed Jan. 14, 1929 5 Sheets-Sheet 1

Fig. 1.

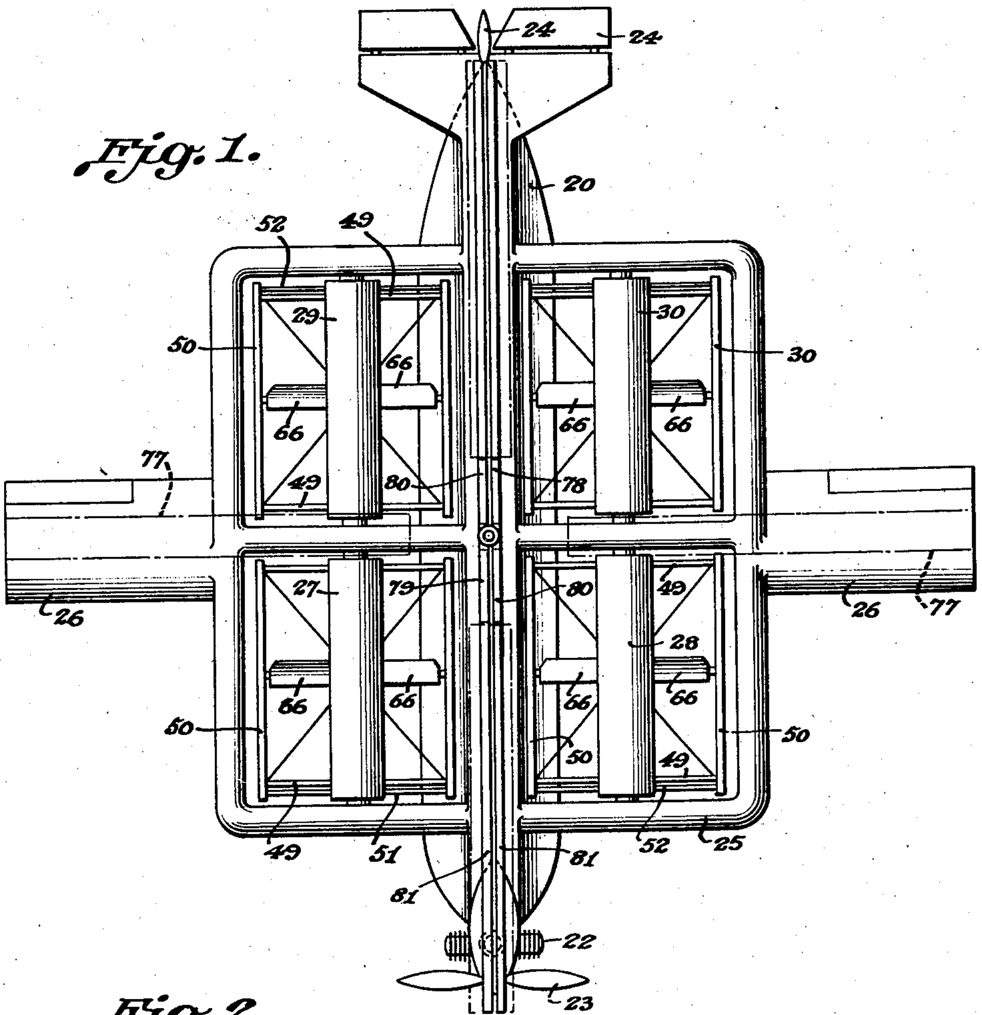
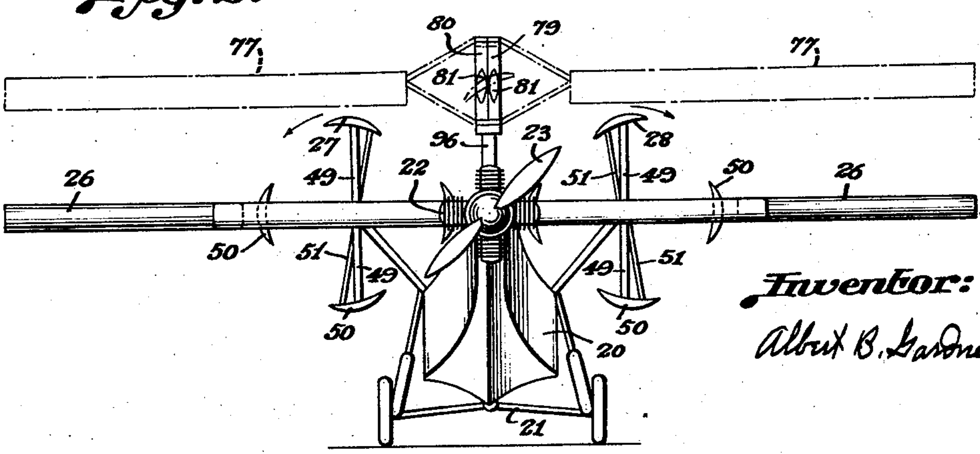


Fig. 2.



Inventor:
Albert B. Gardner

April 14, 1936. A. B. GARDNER 2,037,377

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Fig. 3.

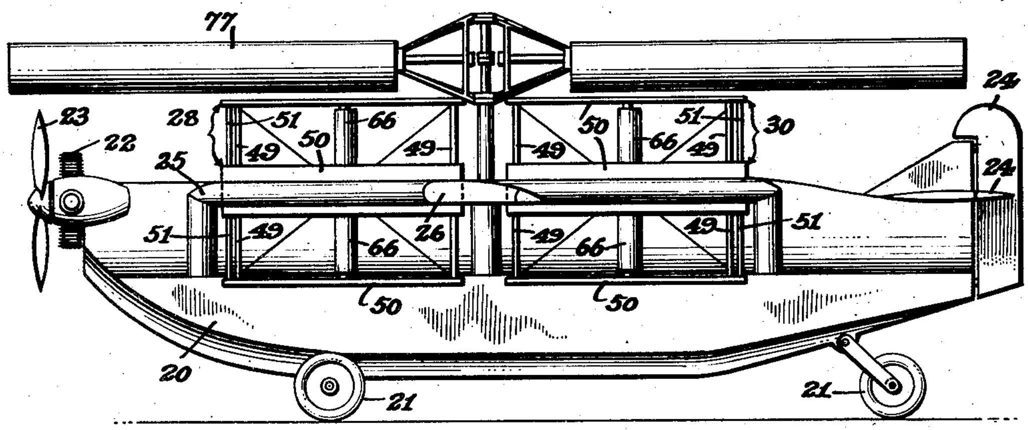
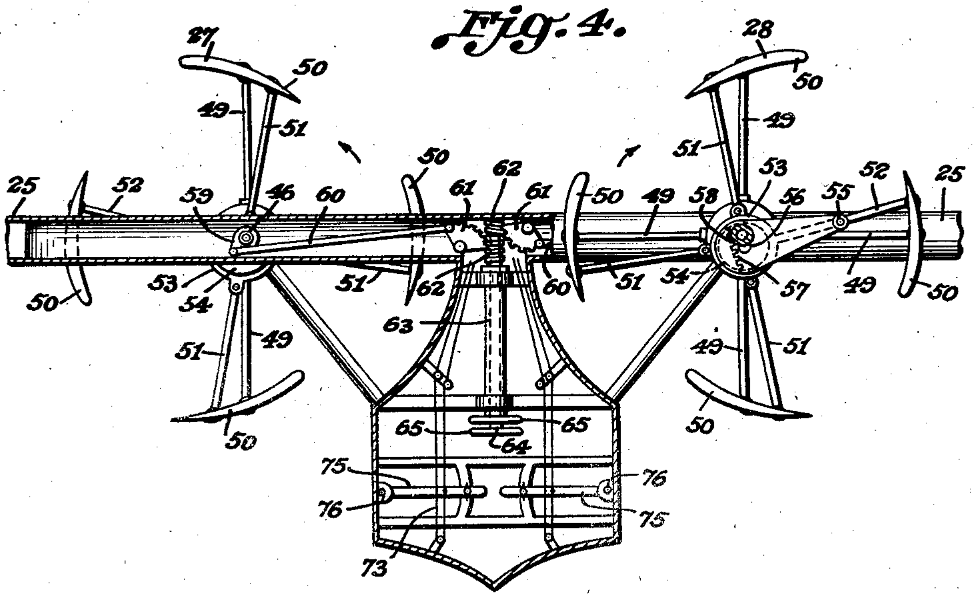


Fig. 4.



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Albert B. Gardner

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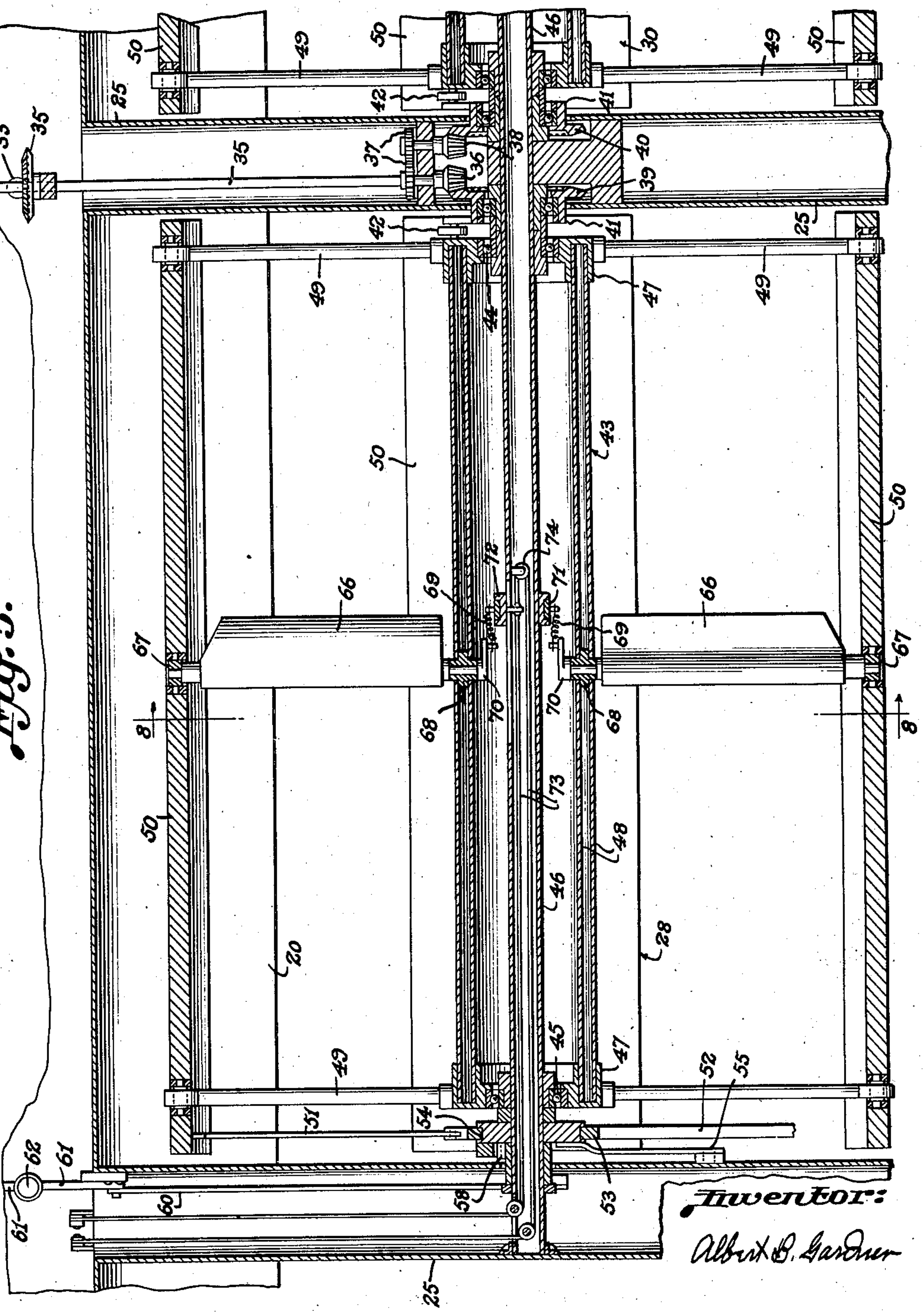
Fig. 5.



Inventor:
Albert B. Gardner

April 14, 1936. A. B. GARDNER 2,037,377

CONSTRUCTION FOR AIRCRAFT

Original Filed Jan. 14, 1929 5 Sheets-Sheet 4

Fig. 6.

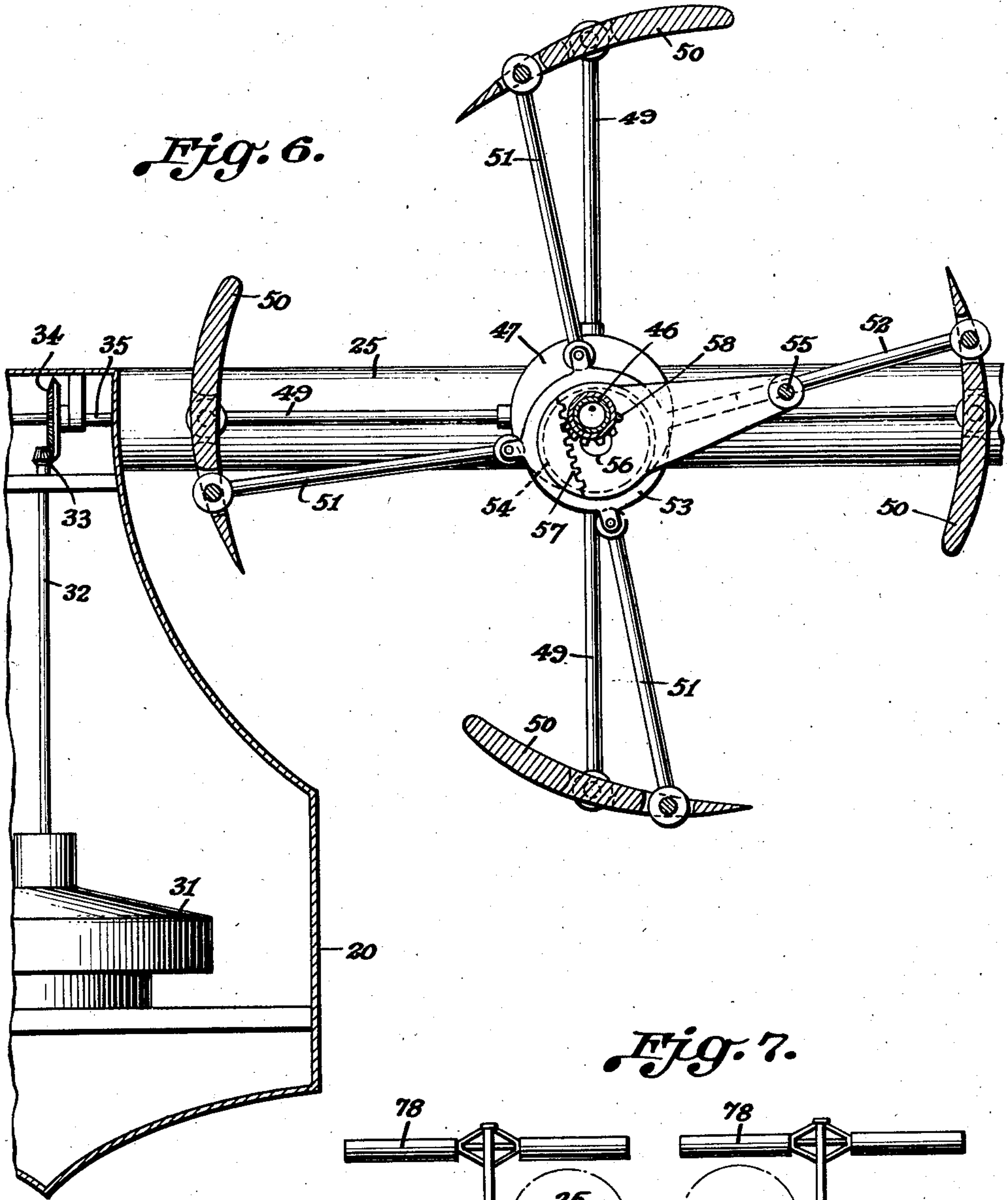
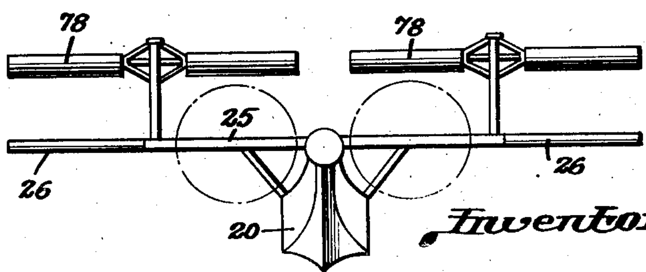


Fig. 7.



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April 14, 1936. A. B. GARDNER 2,037,377

CONSTRUCTION FOR AIRCRAFT

Original Filed Jan. 14, 1929 5 Sheets-Sheet 5

Fig. 8.

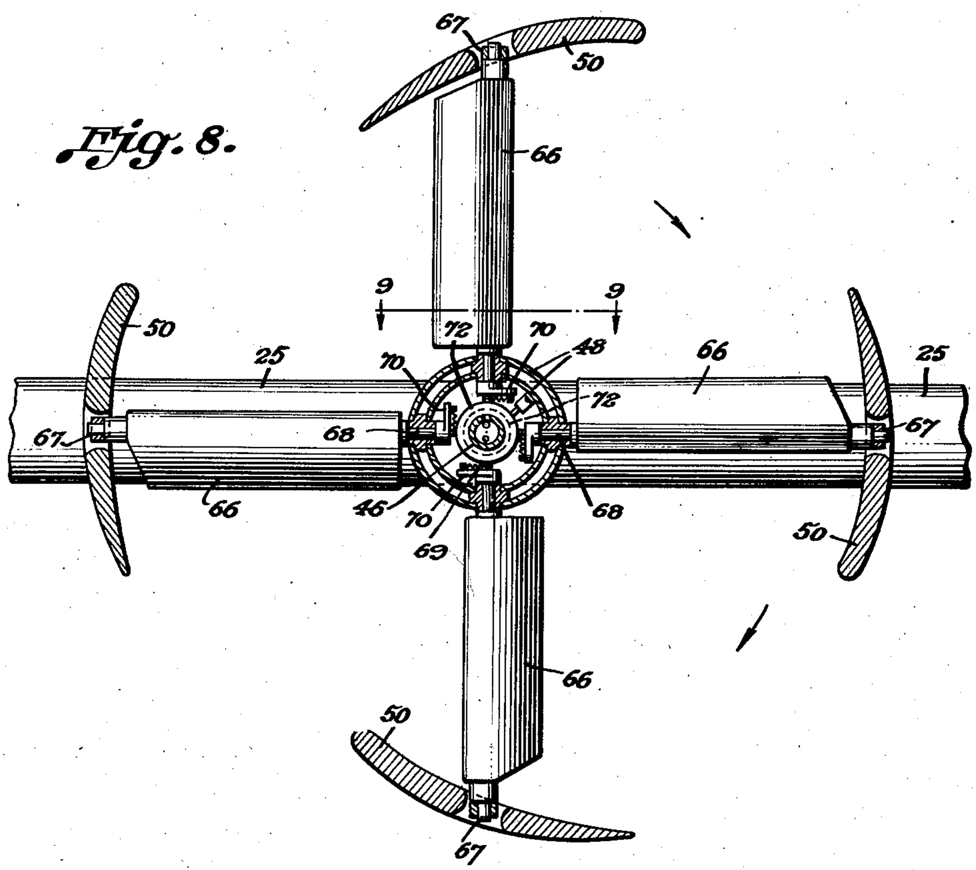
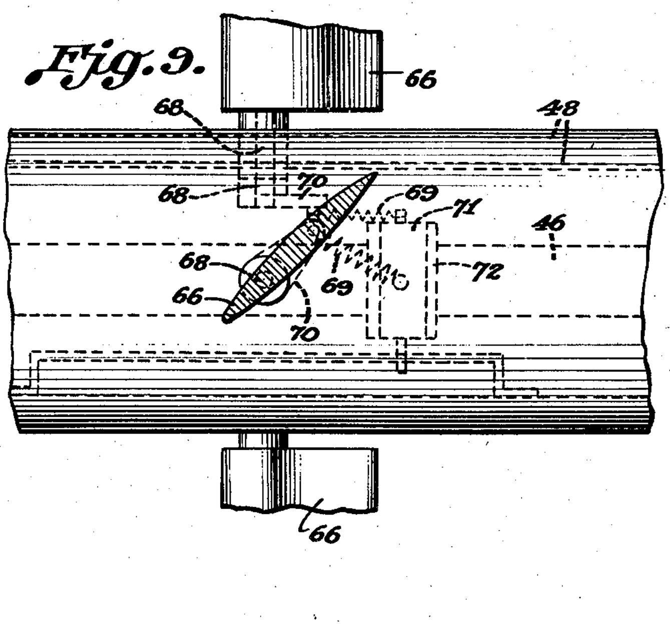


Fig. 9.



Inventor:

Albert B. Gardner

Patented Apr. 14, 1936

2,037,377

UNITED STATES PATENT OFFICE

2,037,377

CONSTRUCTION FOR AIRCRAFT

Albert B. Gardner, Racine, Wis.

Original application January 14, 1929, Serial No. 332,269. Divided and this application June 15, 1934, Serial No. 730,847

33 Claims. (Cl. 244—16)

This invention relates to aircraft and, more specifically, to aircraft of the so-called heavier-than-air type.

This invention also relates to, and the features thereof are fully described in the drawings and specifications of, former application Serial Number 332,269, filed January 14, 1929, now Patent 1,975,098 dated October 2, 1934, of which this application is a division.

One of the objects of this invention is to provide a practical construction of the above nature which shall be simple and dependable. Another object is to provide a construction of the above nature characterized by efficient action. Other objects are to provide a construction of the above nature which shall be readily adaptable to meet conditions of use, easily controlled, characterized by a high degree of safety in performance, economical of power, and adapted to maintain its original efficiency throughout the hardest use. More specifically, the object of this invention is to provide a practical construction of the above nature wherein the craft is sustained in the air by means of a plurality of lifting units disposed to rotate in twin or twin-tandem formation, the axes of which units are disposed in a substantially parallel relation to the longitudinal axis of the fuselage, each unit comprising, in combination, a drive shaft, a plurality of wing-like lifting vanes carried by said shaft and positioned in spaced circumferential relation thereto, the leading and trailing edges of any one of said vanes following, nearly, in the same path, in their respective orbits, varying only to the extent and by reason of the angle of air incidence created by the varying and changeable eccentricity between their respective axes, an eccentric pivotally disposed and operatable during flight to vary the maximum amount of eccentricity between the axes of the lifting unit and said eccentric along a fixed line, and wherein the pivots of these eccentrics in any twin-disposed units are positioned at one side of a horizontal line passing transversely through the axes of said units so as to provide an angle-of-dihedral effect between said twin units during any lifting epoch to establish an inherent lateral stability in the craft. These units also provide a governing action to control the power input of the motor, being that the sustaining medium is constantly varying, because of the usual atmospheric distribution conditions, necessitating a constant change in the speed of the motor to maintain a constant lifting force, especially when encountering air-pockets whereupon the load is suddenly removed from the motor because of a lack of stability in the sustaining medium, the motor will automatically accelerate in speed and provide the necessary amount of lifting force to maintain the desired altitude and in this regard, being that this aircraft provides its own relative wind speed as a component of lift it will maintain a relatively low-cost high-speed operation at higher altitudes than are possible of negotiation with the conventional type of aircraft, also because the craft, operated "tail high", will convert the drag due to incidence into a forward thrust component.

Further in regard to the aforementioned "forward thrust component", it can be readily seen that the axes of the twin arranged lifting units are disposed in pivotal relation coaxially with shaft 35, Fig. 5 of drawings, therefore, the axes of the twin units may be positioned in angular relation to a plane passing horizontally through the fore and aft axis of the fuselage without adding any feature to the construction, nor destroying the transverse dihedral lifting action of the twin units the means for the provision of which is one of the important novel features of this invention. The axes of the lifting units may be positioned at a forward tilted angle in aircraft constructed for the highest economical operation, and at a rearward tilted angle in aircraft constructed for high speed service wherein the cost of operation is a secondary consideration.

In explanation of the foregoing paragraph it is well to set forth that during sustained flight of an aircraft having this type of revolvable wings, the factors for producing lift, such as, the angle of air incidence of the wings, the wing cross section, the wing curves, and relative chord, are always in relation to the circular, or spiral, path of travel of any given point in the wing; this path is constantly changing in accordance with the variation in the forward speed of the aircraft and the rotative speed of the lifting unit, and there is a certain relation between these two last mentioned speeds at which the most economical operation is reached. Where higher speeds of aircraft service is required, the positioning of the axes of the lifting units at a rearward angle compensates in a measure for the loss of lift due to operating speeds at which said spiral path approaches a near parallel relation to the fore and aft axis of the wing, thereby keeping the rotative speed of the lifting unit and consequent resistance to turn, down to a minimum.

Regarding the provisions for safety, more specifically, one of the objects of this invention is to eliminate as much as practicable the human element in stabilization which is accomplished in this invention by the fixed transverse dihedral lifting effect, simple, dependable adjustment, along pre-established non-changeable lines only, to effect longitudinal equilibrium and simple means for quickly and positively causing auto-rotation of the lifting units in event of power failure in mid-air. Auto-rotation of the units is accomplished by the manipulation of a single actuating device, the handwheels 65, by means of which the eccentrics of all lifting units may be quickly reversed after which the action upon the relative, wind due to the more or less perpendicular descent of the craft, will recurrently and constantly develop kinetic energy as each wing-like vane enters, again and again, the lifting epoch of the orbital paths of their travel. This kinetic energy and consequent lifting effect may be greatly increased at the time of alighting or whenever desirable by quickly returning the vanes to their original lifting angle. Other objects are to provide stream-line means for supporting the stress in the wing-like vanes, at intermediate points along their longitudinal axes, against the strains due to centrifugal force and the tension and compression strains due to lift, means for controlling the horizontal position of the craft during hovering flight and means for slowing down the speed of the craft. Regarding economy: because of compactness, this craft has lower internal strain components, requires less stress elements, and is much lighter in weight, and because the lifting vanes are very thin the structural resistance is low per unit of lift.

Inherent longitudinal stabilization may be provided by the application of the automatic stabilizing device described in the drawings and specifications of former application Serial Number 443,139, filed April 10, 1930, now Patent 1,972,336 dated Sept. 4, 1934, and the craft thus provided with inherent stability will maintain an even keel and constant altitude under the usual atmospheric distribution conditions without the attention of the pilot.

In short, the main object of this invention is to provide a construction of the above nature which, with the addition of a device to provide automatic longitudinal stability, will eliminate, almost entirely, the human factor of stabilization and withal, an aircraft which will be economical in operation and fly at a high rate of speed at higher altitudes than the present conventional types. Other objects will be in part obvious and part pointed out hereinafter.

The invention accordingly consists in the features of construction, combination of elements, and arrangement of parts as will be exemplified in the structure to be hereinafter described and the scope of the application of which will be indicated in the following claims.

In the accompanying drawings, in which are shown one or more of various possible embodiments of the several features of this invention,

Figure 1 is a plan of the entire apparatus;

Fig. 2 is a front elevation of the apparatus shown in Fig. 1;

Fig. 3 is a side elevation of the same;

Fig. 4 is a front elevation of a pair of lifting devices and associated parts;

Fig. 5 is a plan of two lifting devices partially in section in order to show the parts more clearly;

Fig. 6 is a sectional elevation of a lifting device showing driving and adjusting mechanism;

Fig. 7 is a diagrammatic front elevation of apparatus comprising another embodiment of certain features of the invention;

Fig. 8 is a sectional elevation taken substantially along the line 8—8 of Fig. 5; and

Fig. 9 is a sectional plan taken along the line 9—9 of Fig. 8.

Similar reference characters refer to similar parts throughout the several views of the drawings.

Referring now to Fig. 2 of the drawings in detail, there is shown at 20 a body or fuselage which is mounted upon running gear 21 of any desired type. At the forward end of the fuselage is a motor 22 driving a propeller 23 of the usual form.

At the rear end of the fuselage is the usual apparatus 24 for vertical and horizontal steering of the craft. This is controlled in the usual way.

Mounted upon the fuselage is a frame 25 provided with laterally extended wings 26 at each side adapted to exercise the usual lifting function to some substantial extent when traveling through the air. These wings are not essential to the success of this invention but are shown as a possible embodiment to provide means for sustaining flight in event of power failure in mid-air.

Recurring to frame 25, it will be seen, as shown in plan, that this frame is provided with four lifting devices 27, 28, 29 and 30. Each of these devices is substantially identical in construction, and it is to be noted that many of the advantages of this invention will be gained with a single pair of these lifters, although for best action a greater number of them is now considered preferable.

Taking up now the construction of these lifting units, and having reference first to Fig. 6 of the drawings, there is shown at 31 an engine of any desired type driving the shaft 32 which, through bevel gears 33 and 34, drives the cross shaft 35. As best shown in Fig. 5 of the drawings, the shaft 35 drives directly a bevel pinion 36 and, through the spur gears 37, drives likewise a bevel gear 38. These pinions 36 and 38 respectively drive the bevel gears 39 and 40 which form the primary driving elements of the lifting units 28 and 30 respectively. It is understood that the shaft 35 extending in the opposite direction crosswise of the machine drives by similar means lifting units 27 and 29. The action of the bevel gear 39 and parts driven thereby, being substantially identical with that of the corresponding parts in the other lifting units, will alone be described in detail. This gear, acting through the sleeve-like extension 41 and link connection 42, drives a rotary frame 43 journaled by suitable ball bearings at 44 and 45 upon a central non-rotary tube 46. This frame comprises fittings or spiders 47 connected by the longitudinal tubes 48 and each provided with four radial arms or spokes 49.

Recurring to Fig. 6 of the drawings, each of the arms 49 has pivotally secured at its outer end a lifting vane 50 which is likewise pivoted to the opposite arm 49 of the lifting device in such a manner that the vane may rock about a line substantially central thereof and parallel to the central tube 46. These vanes, as shown in the drawings, are of stream-line form and are pivotally connected at points adjacent their rear edges by means of the links 51 and 52 with a central fitting 53 journaled upon an eccentric 54. The link 52 is rigidly connected at its inner end with the eccentric ring 53, whereas the remaining links 51 are pivotally connected thereto. The eccentric

54 is pivoted at 55 to the frame of the machine, as shown in Fig. 5 of the drawings, and is provided with an arcuate slot 56 through which the tube 46 passes. Formed on this eccentric is a gear segment 57 meshing with and controlled by a mutilated pinion 58. As the latter part is rotated, it is seen that the eccentric is swung about the pivotal connection 55 and its eccentricity varied, as desired, along a fixed line of action passing through the axes of eccentric 54 and the central tube 46. It is also seen that the pivotal connection 55 is positioned on a line at one side of a horizontal line passing transversely through the axes of the central tubes 46 of any twin-arranged lifting units, and that the amount of this offset in the position of said pivotal connection 55 may be such as to provide an inclination of the mean direction of thrust, during the lifting epoch of vanes 50, toward the upper end of a line passing vertically through the longitudinal axis of the fuselage thus providing a transverse dihedral effect to provide an inherent transverse stabilization of the craft.

The swinging of the pinions 58, which may be journaled upon the central tube 46, is brought about as shown in Fig. 4 of the drawings by cranks 59 connected by links 60 with worm wheel segments 61 meshing with worms 62 formed in the case of each pair of lifting devices respectively upon a rotary tube 63 and an inner shaft 64 controlled by hand-wheels 65. It will thus be seen that the pitch or inclination of the lifting vanes may be adjusted as desired, and the lifting effect with a given speed of rotation may be correspondingly varied. It will also be seen that the lifting vanes are substantially streamline in their action, lifting by the lateral element of their travel and substantially feathering in their up-and-down movement. It is also seen that were the arcuate slot 56 extended an equal distance each side of the axis of the eccentric 54 a downward as well as an upward thrust may be provided, therefore by one movement of hand-wheels 65 all eccentrics could be simultaneously and quickly reversed to cause auto-rotation of the lifting units in event of power failure in mid-air.

It is also to be noted that by a suitable adjustment of the above parts the rate and time of change of incidence to the air may be altered. For example, denoting the positions of these planes in their travel by analogy to the hands of a clock, 12 and 6 o'clock being on a line passing through the axes of the central tube 46 and its eccentric 54, they may be so arranged that at the nine-o'clock and three-o'clock positions they move substantially edgewise, and from the half past ten- to half past one-, as well as from the half past four- to half past seven-positions, they maintain a substantially constant incidence at the most effective angle. Their change from this angle of incidence to and from their angles of what might be termed zero incidence occurs from the half past seven- to the half past ten-positions and from the half past one- to the half past four-positions. The angle of incidence, of course, has reference to the circle denoting the path of travel of the vanes.

At the center of each lifting device, or at frequent intervals in lifting units of great length, there is preferably provided a feathering strut the stream-line fairing of which provides modified propeller vanes 66 each having a universal pivotal connection as shown at 67 in Fig. 8 of the drawings at their outer ends with one of the lifting vanes 50. Aligned with the pivotal connection 67 is a pivotal connection 68 at the inner ends of the vanes 66. The journals at each end of vanes 66 to be equipped with means (for example a ball-bearing of the so-called deep-groove type) to support end thrust caused by centrifugal force or the load due to lift. The axis of the pivots is near the forward edge of the vane so that it tends to move toward a plane transverse to the axis about which the corresponding lifting device rotates, this tendency being resisted in each case by a spring 69 connected by a crank 70 with the propeller vane. In this manner, as the speed of rotation of the propeller vane increases, its pitch automatically becomes less. The springs 69 are all connected with a ring 71 seated in a flanged collar 72 which is non-rotatable but is slidably mounted upon the inner tube 46. This collar 72, and with it the tension of the springs 69, is adjustable by means of a wire 73 passing over a pulley 74 and having its ends controlled as shown in Fig. 4 of the drawings by a hand lever 75 pivoted at 76. In this manner the action of the propeller vanes 66 is manually controlled so that their automatic variation of pitch may be governed as desired.

It is to be noted that by allowing free movement of cable 73, or positioning the collar 72 at a central point in relation to the spiral path traversed by vane 66 at any given speed of the craft, the struts will offer the least possible resistance to turn and produce the least possible disturbance of the air especially were the vanes of a spiral form as in an ideal propeller proportioned for the cruising speed at which the craft is to operate. It is also to be noted that by moving the hand lever farther, the corresponding collar 72 is moved to such an extent that the pitch of the blades or vanes is reversed, and thus any of these propellers may be at any desired time reversed and reversed to any desired degree of pitch. This action, of course, brings about a corresponding reversal of thrust of the propeller and a corresponding gain in flexibility of control of the entire craft.

It will thus be seen that there is provided apparatus which is of a simple and dependable character and which is nevertheless susceptible of complete adjustment in all particulars to meet the varying conditions of use. The primary lifting elements are of essentially efficient character and may be utilized for substantially vertical ascent or descent. In the forward travel of the machine, however, the ordinary vanes aid in a lifting effect and the propeller at the nose of the machine, as well as those of the lifting devices, contributes to a high speed of travel through the air. The automatic adjustment of the vanes governed as herein described tends to regulate the effect of the propellers by giving an increased thrust in proportion to the speed as the speed diminishes. The inherent stability of the craft, provided in this invention by the fixed transverse dihedral effect established by the proper positioning of the pivotal supports of the eccentrics controlling the angle of incidence of the rotary wings, is of exceptional advantage for safety because no degree of skill or alertness of the pilot can serve as a substitute for inherent stability in the craft itself. In short, the apparatus herein described attains the various objects of the invention and is well adapted to meet the conditions of the hardest practical use.

As many possible embodiments may be made of the above invention and as many changes might be made in the embodiment above set forth, it is to be understood that all matter hereinbefore set forth or shown in the accompanying drawings is to be interpreted as illustrative and not in a limiting sense.

I claim:

1. In an aircraft having a supporting rotor including an axle normally extending substantially parallel to the line of flight and a plurality of blades mounted parallel to and spaced from said axle and rigid struts connecting each blade adjacent each end thereof to said axle, whereby upon the revolving of said blades about the axis of the rotor and their translation along the line of flight their effective aspect ratio and effective lift vary, and a rigid strut supporting each of said blades intermediate said end struts to thereby effectively support the stresses due to said variation in the effective aspect ratio and effective lift of said blades.

2. In an aircraft having a supporting rotor including an elongated frame disposed for rotation on an axis substantially parallel to the line of flight including a plurality of lifting blades extending along said frame and connected adjacent each end of each blade to the respective end of said frame, said blades disposed longitudinally fore and aft whereby upon the revolving of said blades about said axis and their translation along the line of flight their effective aspect ratio and effective lift vary, and rigid means supporting each of said blades intermediate said end connections to thereby effectively support the stresses due to said variation in the aspect ratio and lift.

3. An aircraft having twin arranged pairs of rotatable lifting units disposed for rotation on axes disposed longitudinally fore and aft, each including a plurality of pivotally supported revolvable wings, and eccentric devices for each unit for controlling the amount of air incidence of the wings, including pivotal supports for the eccentric devices, the pivots of said supports fixedly disposed in spaced relation to and on the same side of a horizontal line passing transversely through the axes of the pair of lifting units, whereby the reaction line of a pair of lifting units lie at an angle to each other.

4. In an aircraft as claimed in claim 3, and adjusting means for said supports.

5. In an aircraft as claimed in claim 3, and rack and pinion adjusting means for said supports.

6. In an aircraft as claimed in claim 3, and adjusting means for said supports including self locking means.

7. In an aircraft as claimed in claim 3, including reciprocatively operatable means for coincidently increasing the lifting action of the pair of lifting units at one end of the aircraft over that of the pair at the other end, to thereby effect longitudinal equilibrium during flight.

8. In an aircraft as claimed in claim 3, including reciprocatively operatable means for coincidently increasing the lifting action of all of the lifting units on one side of the aircraft over that of all of those on the other side, to thereby effect lateral equilibrium during flight.

9. In an aircraft as claimed in claim 3, including reciprocatively operatable means for adjusting all of the eccentric supports coincidently, to thereby control the amount of the combined lifting effect of all of the lifting units in constant altitude flight.

10. In an aircraft as claimed in claim 3, including reciprocatively operatable means for adjusting all of the eccentric supports coincidently, to thereby control the amount of the combined lifting effect of all of the lifting units in constant altitude flight, and self locking means for holding said eccentric supports in any adjusted position.

11. In an aircraft as claimed in claim 3, including reciprocatively operatable means for quickly and positively adjusting the air incidence of all of the pivotally supported revolvable wings, during their lifting epoch, coincidently from a lifting angle to a gliding angle, to thereby cause auto-rotation of said lifting units to sustain the aircraft in slow vertical descent.

12. In an aircraft as claimed in claim 3, and streamline feathering struts for supporting the stress of said wings at intermediate points in their length against the strains due to lift and centrifugal force.

13. In an aircraft as claimed in claim 3, and streamline feathering struts for supporting the stress of said wings at intermediate points in their length against the strains due to lift and centrifugal force, the streamline fairing of which struts provide propeller vanes.

14. In an aircraft as claimed in claim 3, and streamline feathering struts for supporting the stress of said wings at intermediate points in their length against the strains due to lift and centrifugal force, the streamline fairing of which struts provide propeller vanes, and means controllable by pressure for varying the pitch of said vanes, to thereby control the directional position of the aircraft during hovering flight, or vertical ascent, and descent.

15. In an aircraft as claimed in claim 3, in which the streamline fairing of said struts provide modified propeller vanes, and means controllable by pressure for varying the direction of thrust of said vanes from a forward, or neutral, to a rearward, to thereby cause a brake action on the air for slowing down the forward speed of the aircraft.

16. An aircraft having a plurality of pivotally supported revolvable wings forming rotatable lifting units disposed in twin formation for rotation on axes disposed longitudinally fore and aft, each unit including an eccentric device for controlling the amount of air incidence of the wings, including a pivotal support for each of the eccentric devices, the pivots of said supports fixedly disposed in spaced relation to and on the same side of a horizontal line passing transversely through the axes of the pair of lifting units, whereby the reaction lines of the pair of lifting units lie at an angle to each other.

17. In an aircraft as claimed in claim 16, the further feature residing in an adjustable support for the eccentric device rotatably disposed coaxially with the lifting unit.

18. In an aircraft as claimed in claim 16, the further feature residing in a worm and segment adjusting means for said supports.

19. An aircraft having a plurality of pivotally supported revolvable wings forming rotatable lifting units disposed in twin formation for rotation on axes disposed longitudinally fore and aft, each unit including an eccentric device for controlling the amount of air incidence of the wings, and means for adjusting said eccentric devices upward and to one side, whereby the reaction lines of the pair of lifting units lie at an angle to each other.

20. An aircraft as claimed in claim 19, and means for adjusting the eccentric devices independently of each other, to thereby effect equilibrium of the aircraft.

21. An aircraft as claimed in claim 19, and means for adjusting all of the eccentric devices simultaneously to a reverse position, to thereby effect auto-rotation of the lifting units.

22. An aircraft as claimed in claim 19, and adjusting means including self locking means.

23. In an aircraft, a body, a rotatable lifting device, means for effecting rotation of said lifting device, including an axle mounted longitudinally fore and aft on said body, an elongated frame surrounding said axle and mounted for rotation thereon, a plurality of lifting blades mounted on and substantially parallel to said frame, struts supporting each blade from said frame adjacent the ends thereof, and a rigid strut connecting each blade to said frame intermediate said end struts.

24. An aircraft as claimed in claim 23, and streamline fairing for said struts.

25. An aircraft as claimed in claim 23, and pivotal supports for said struts.

26. An aircraft as claimed in claim 23, streamline fairing for said struts, and pivotal supports for said fairing disposed adjacent the leading edge thereof, to thereby cause the strut to feather into the relative wind due to flight and/or the rotation of the lifting device.

27. An aircraft as claimed in claim 23, streamline fairing for said struts, pivotal supports for said fairing, and means responsive to pressure for controlling the radial position of the streamline fairing of said struts.

28. In an aircraft, a body, a plurality of rotatable lifting devices disposed in twin formation for rotation on axes disposed longitudinally fore and aft, means for effecting rotation of said lifting devices, including axles mounted on said body, each lifting device including an elongated frame surrounding one of said axles and mounted for rotation thereon, a plurality of lifting blades mounted on and substantially parallel to said frame, struts supporting each blade from said frame, means for controlling the lifting effect of said blades, and means for adjusting the last mentioned means upward and to one side, whereby the reaction lines of the twin pair of lifting devices lie at an angle to each other.

29. In an aircraft having a supporting rotor including a frame disposed for rotation on an axis normally parallel to the line of flight including a plurality of lifting airfoils extending along said frame and connected adjacent each end of each airfoil to the respective end of said frame whereby upon the revolving of said airfoils about said axis and their translation along the line of flight their effective aspect ratio and effective lift vary, rigid means supporting each of said airfoils intermediate said end connections to thereby effectively support the stresses due to said variation in the aspect ratio and lift, and said frame constructed cylindrical in form to thereby facilitate the supporting of said airfoils intermediate said end connections.

30. In an aircraft as claimed in claim 29, and means for preventing the free flow of air through said frame whereby a substantial amount of air is impounded within said frame and whereby upon the translation of said frame along the line of flight and its rotation on its axis the air displaced and thrown off by said respective actions of said frame with its impounded air momentarily increases the density of the air, and relative wind speed, immediately surrounding said airfoils to thereby increase their lifting effect.

31. In an aircraft as claimed in claim 29, and said frame constructed cylindrical in form with a large portion of its outer walls substantially closed whereby the condition of the air immediately surrounding said airfoils is effectively controlled to thereby increase the lifting effect of said airfoils.

32. In an aircraft as claimed in claim 29, and a lifting airfoil connected to and extending from each side of said aircraft to sustain the aircraft in slow descent in event of the failure of the rotor in a like functioning.

33. In the combination as claimed in claim 29, a fuselage to which said rotor is pivotally connected and disposed for adjustment about a horizontal transverse axis, a tractor propeller disposed on the fuselage forward said rotor whereby upon adjusting said rotor to a position wherein its fore and aft axis lies at an angle to the line of airflow from said propeller and its translation along the line of flight the lifting air-foils become bathed in said air-flow or the relative wind due to flight or both, to thereby effect auto-rotation of said rotor.

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United States Patent [19]

Tsepenyuk

[11] **Patent Number: 6,007,021**

[45] **Date of Patent: Dec. 28, 1999**

[54] **FLYING APPARATUS FOR A VERTICAL TAKE OFF AND LANDING**

[76] Inventor: **Mikhail Tsepenyuk**, 269 Olean Prwy, H 2F, Brooklyn, N.Y. 11218

[21] Appl. No.: **08/993,306**

[22] Filed: **Nov. 18, 1997**

[51] **Int. Cl.**[6] **B64C 27/22**

[52] **U.S. Cl.** **244/9**; 244/19; 244/70; 416/111; 416/126

[58] **Field of Search** .... 244/9, 10, 19, 244/20, 70, 6, 7 R; 416/126, 178, 111; 440/93

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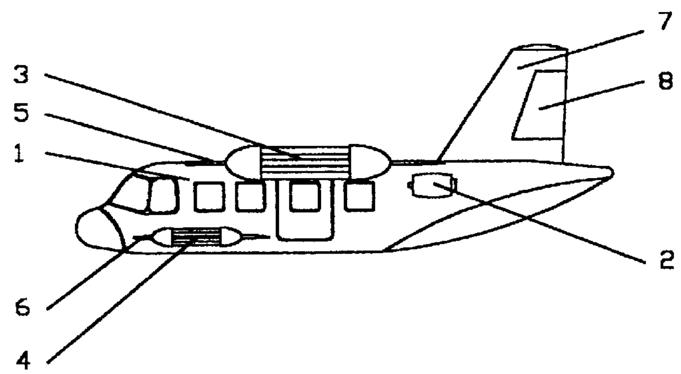
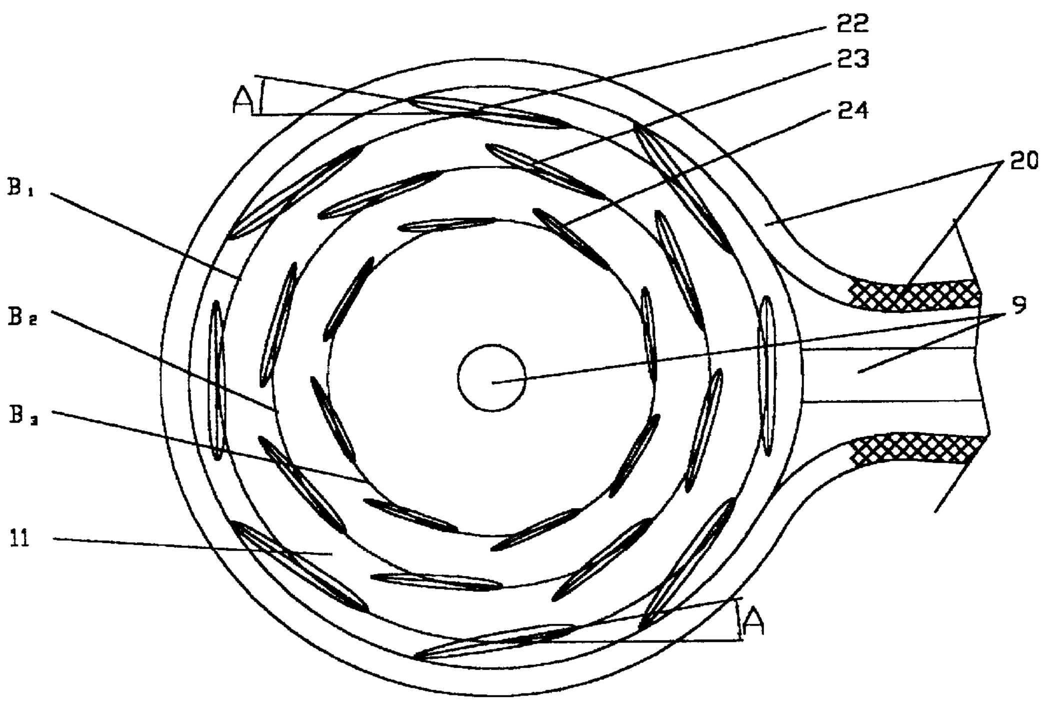
Primary Examiner—Galen L. Barefoot
Attorney, Agent, or Firm—Ilya Zborovsky

[57] **ABSTRACT**

A flying apparatus has a body; power means; and lifting force generating units, the lifting force generating units being arranged parallel to a plane of symmetry of the body and turnable in a vertical plane, each of the lifting force generating units is formed as a rotor including a plurality of aerodynamic blades arranged uniformly on a disk and at equal distances from an axis of rotation so as to be turnable.

9 Claims, 6 Drawing Sheets





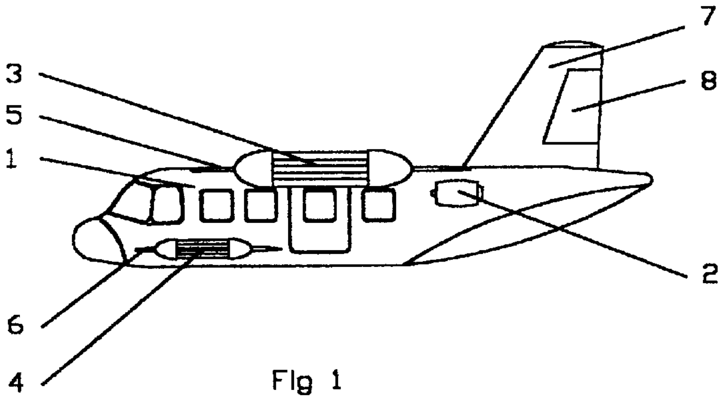


Fig 1

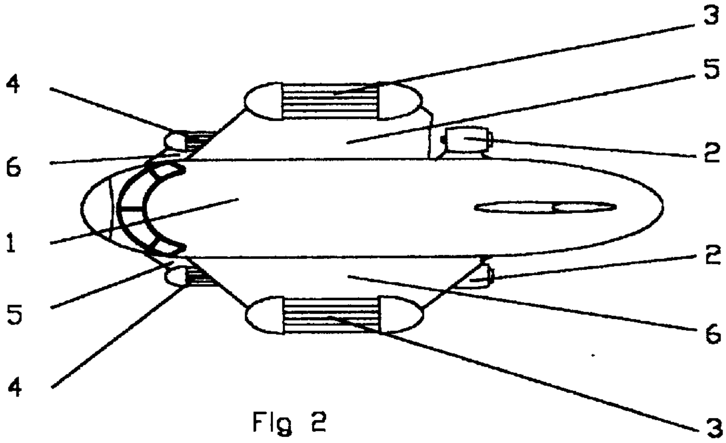


Fig 2

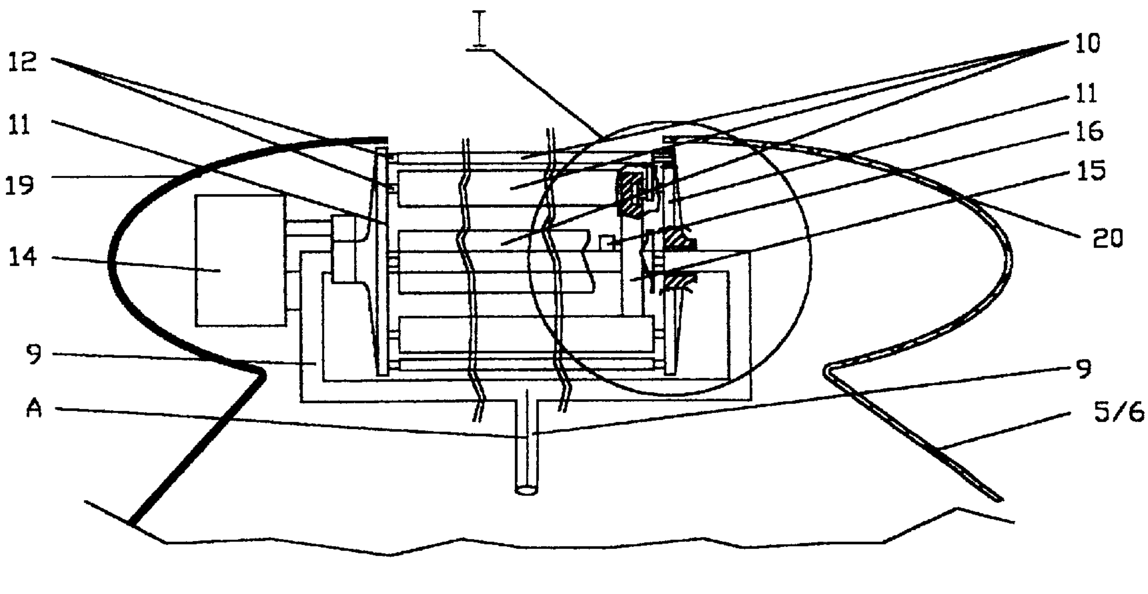


Fig 3

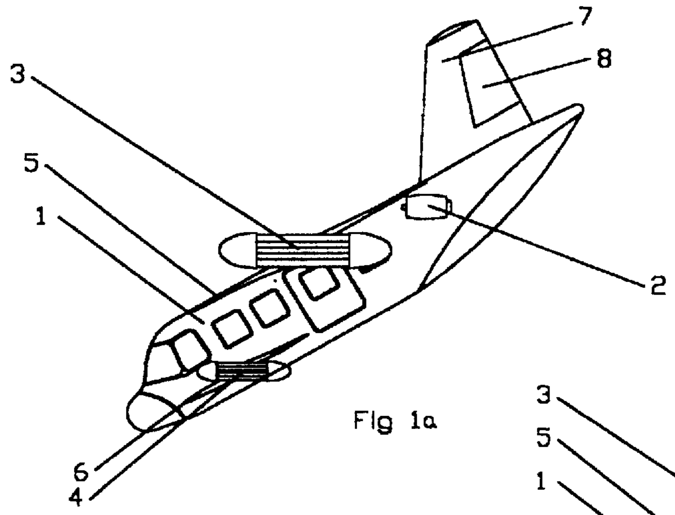


Fig 1a

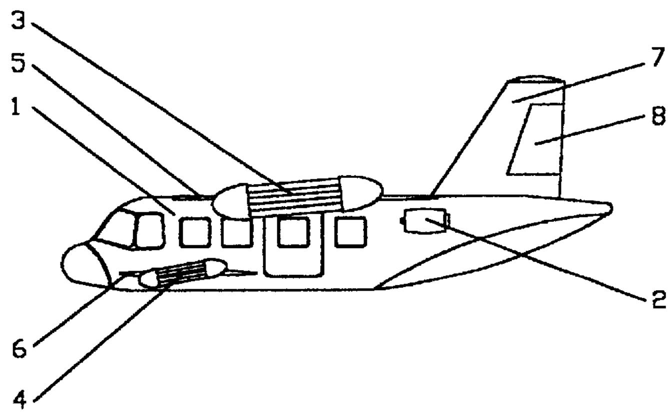


Fig 1b

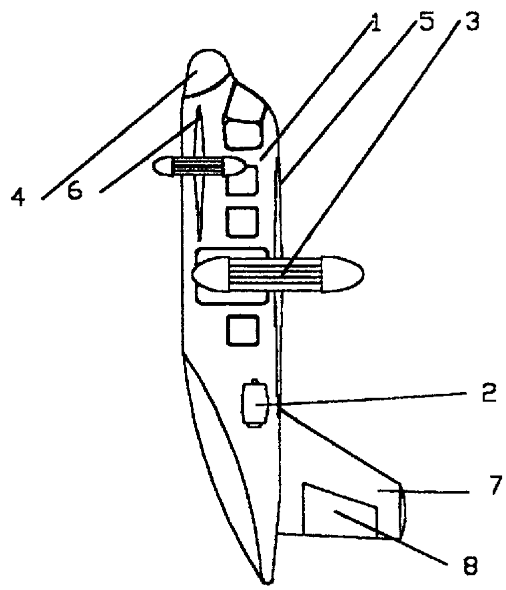


Fig 1c

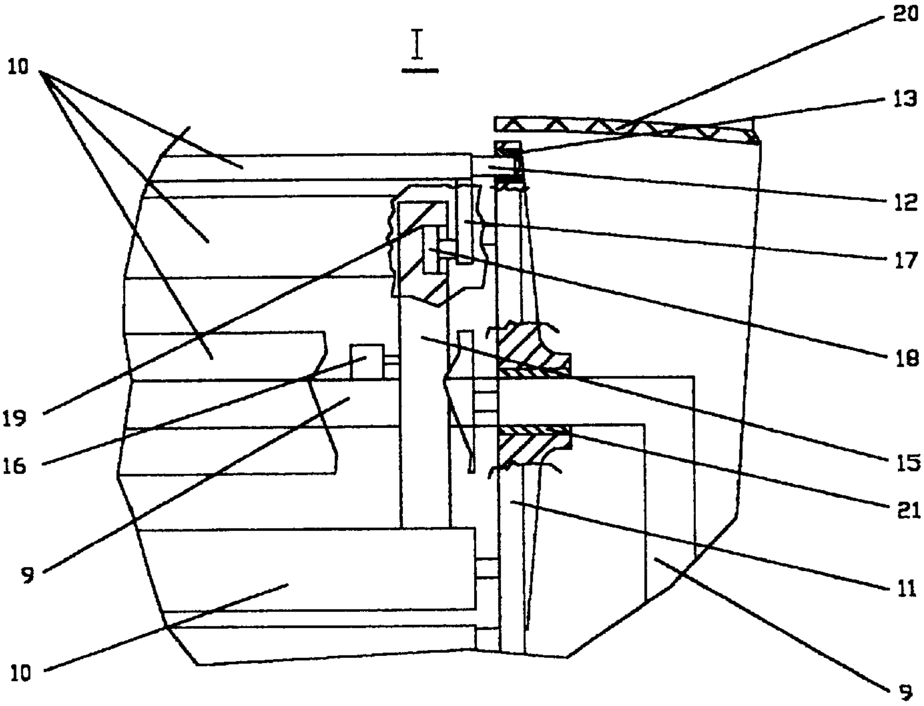

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Fig 4

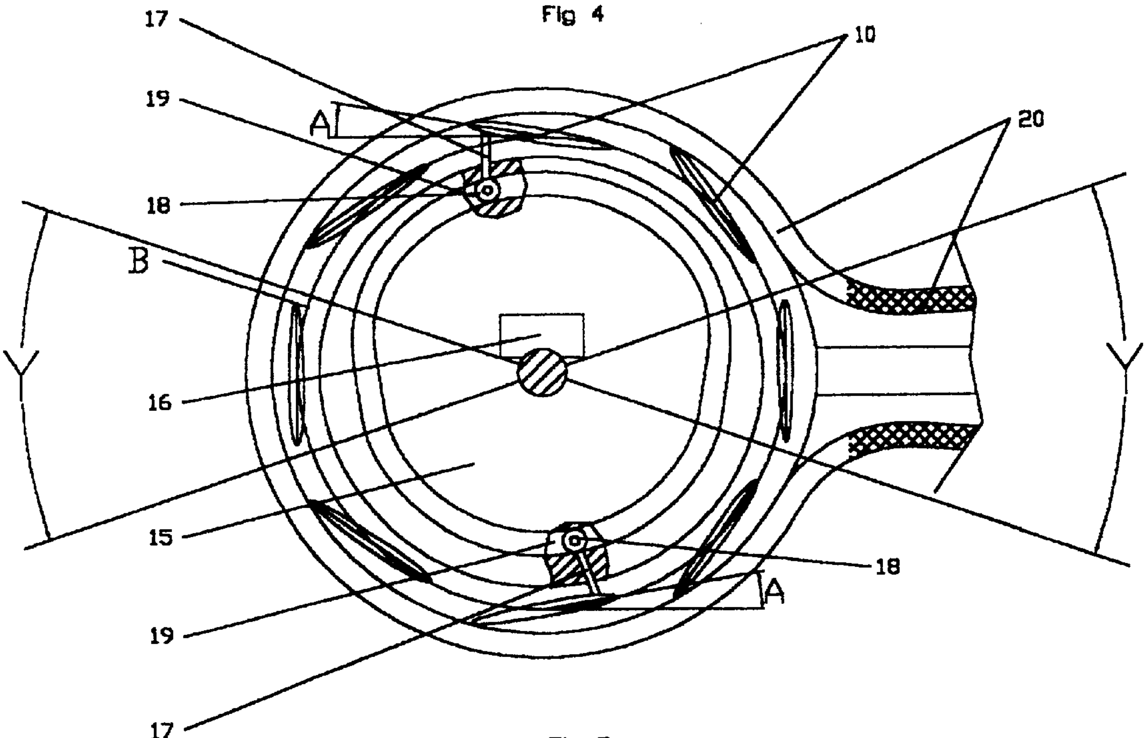
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Fig 5

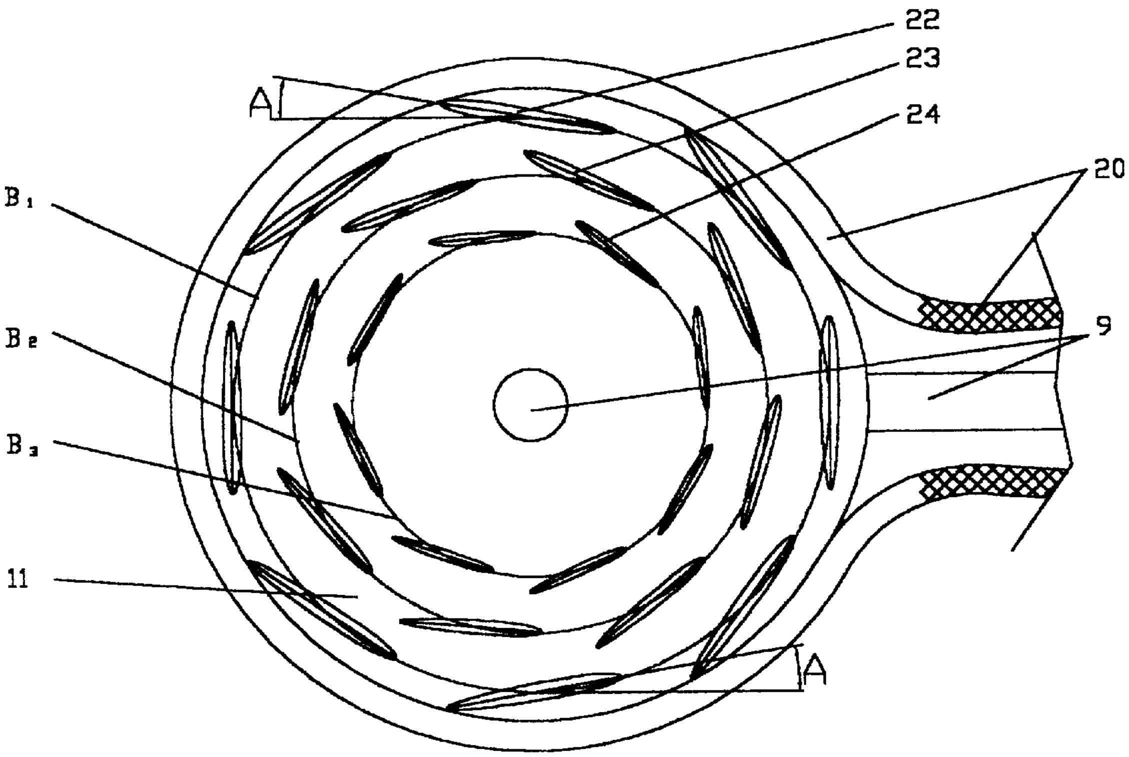

Fig 6

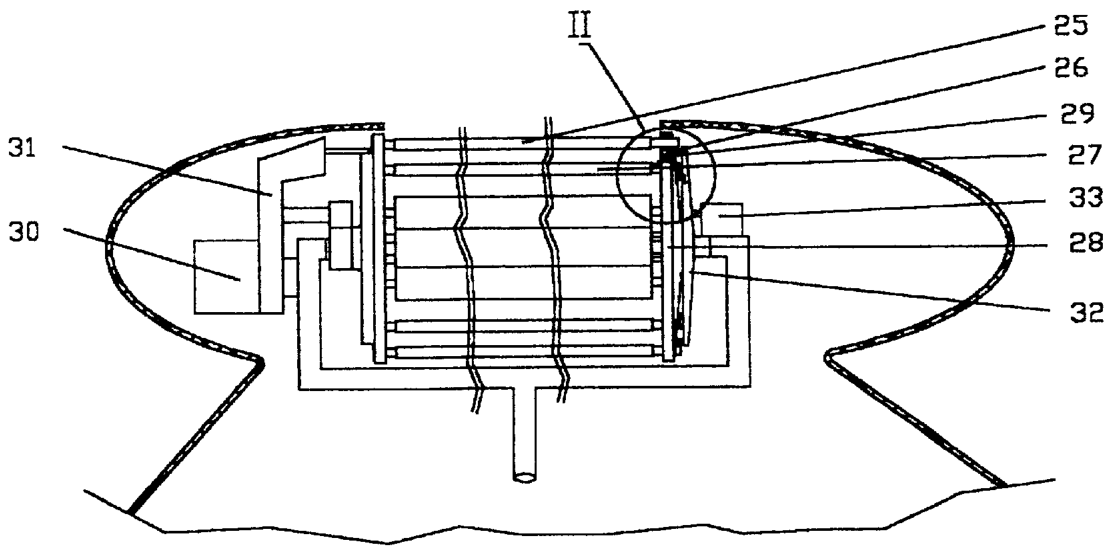

Fig 7

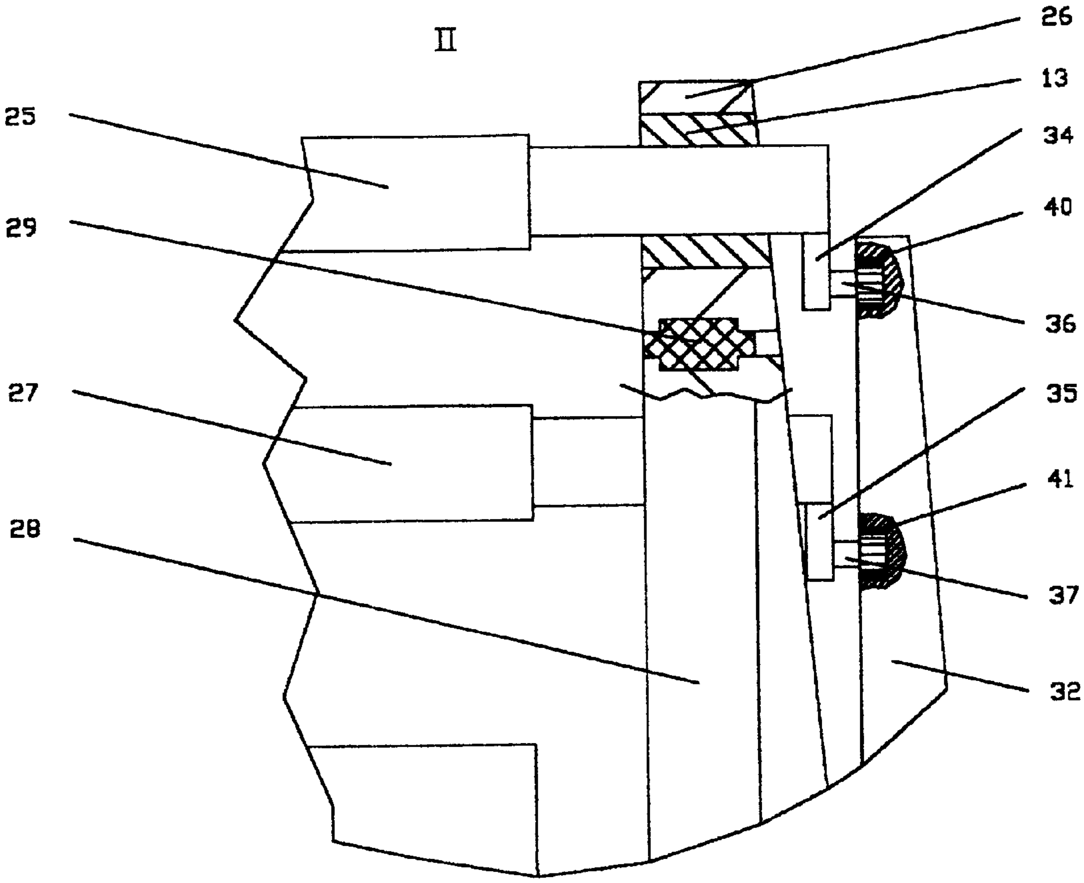

Fig 8

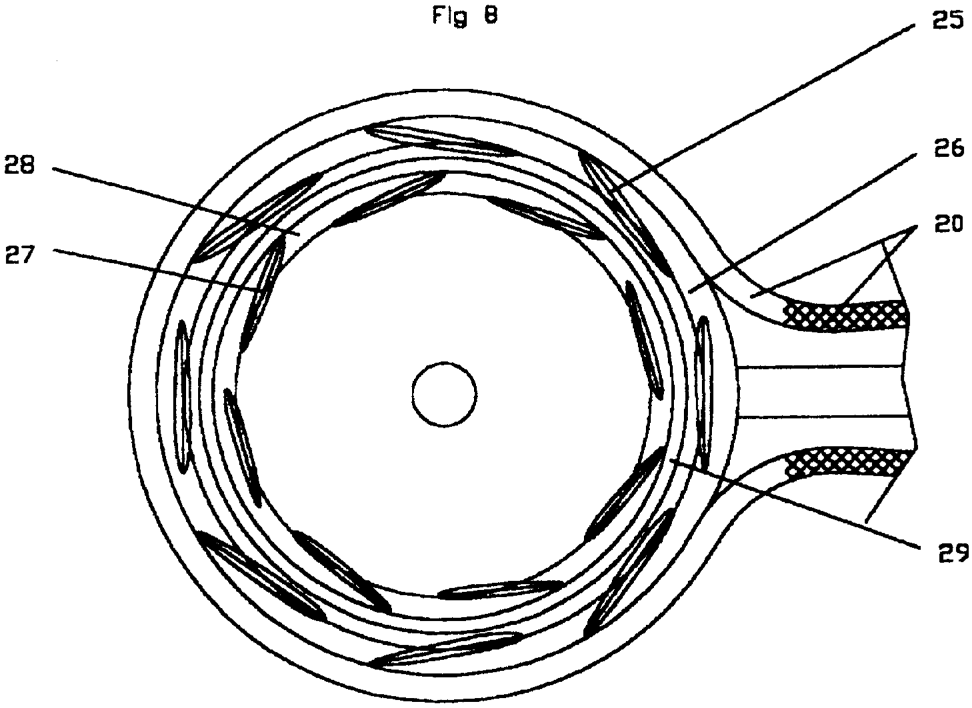

Fig 9

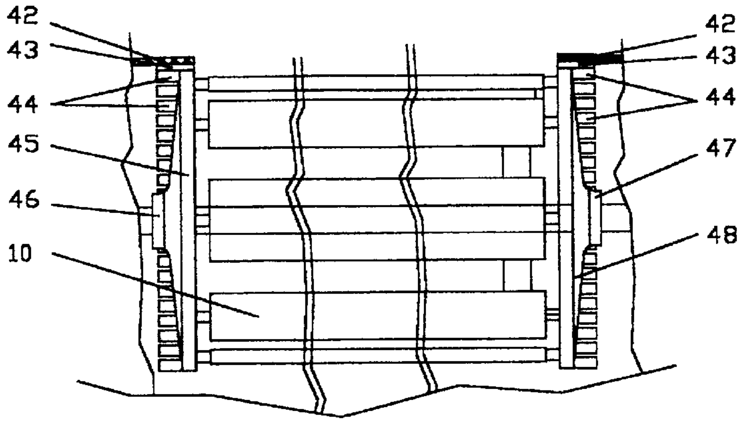

Fig 10

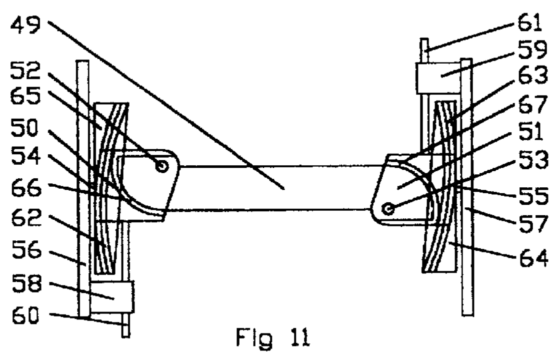

Fig 11

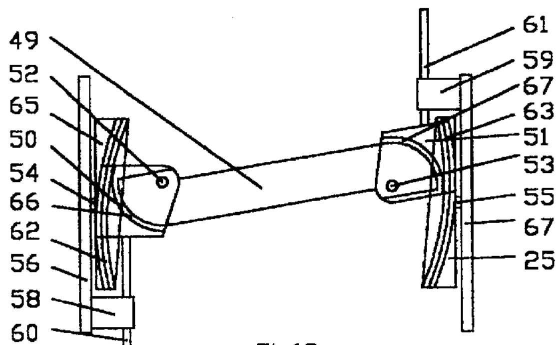

Fig12

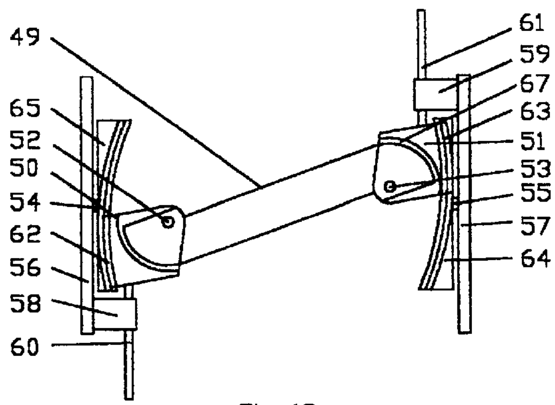

Fig 13

FLYING APPARATUS FOR A VERTICAL TAKE OFF AND LANDING

BACKGROUND OF THE INVENTION

The present invention relates to a flying apparatus for vertical take-off and landing.

The existing flying apparatus of the above mentioned type use the principle of throwing away air and therefore generating a reactive lifting force. Helicopters are built on this principle, and they are the closest as to the construction to the apparatus of the present invention. A known helicopter includes a body, lifting force generating units formed as a aerodynamic blades which are rotatable in a plane parallel to the ground surface, or in other words in a plane which is perpendicular to the symmetry plane of the body. The aerodynamic blades form a so-called carrying screw which, when rotating, throws the air stream downwardly to create a reactive lifting force. Helicopters are widely used because of their highly efficient performance, simple construction and convenience to use. However, the helicopters have the following disadvantages. The principle of generating a lifting force by throwing down the airstream with a carrying screw makes difficult performing operations on low altitudes, in a mode of suspension, and on the ground. Also, they are characterized by an aerodynamic crisis of the carrying screw which occurs at the speed of horizontal flight 80–100 m/sek. With this relatively low speed, the lifting force of the carrying screw lowers. Therefore, all existing helicopters have a limited speed of horizontal flight.

SUMMARY OF THE INVENTION

Accordingly, it is an object of present invention to provide a flying apparatus of the above mentioned general type, which avoids the disadvantages of the prior art.

In keeping with these objects and with others which will become apparent hereinafter, one feature of present invention resides, briefly stated, in a flying apparatus in which the lifting force generating units are arranged parallel to a plane of symmetry of the body and are turnable in a vertical plane, and they are formed as rotors including aerodynamic blades having a symmetrical profile and arranged on a disk at equal distances from a rotary axis and capable of turning.

When the flying apparatus is designed in accordance with the present invention, it eliminates the disadvantages of the prior art and provides for highly advantageous results.

The novel features which are considered as characteristic for the present invention are set forth in particular in the appended claims. The invention itself, however, both as to its construction and its method of operation, together with additional objects and advantages thereof, will be best understood from the following description of specific embodiments when read in connection with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. **1**a–**1**c and **2** are side views and a plan view of a flying apparatus in accordance with the present invention;

FIGS. **3**, **4** and **5** are views showing sections of a lifting force generating unit of the inventive flying apparatus;

FIG. **6** is a view showing a section a lifting force generating unit with three aerodynamic blades;

FIGS. **7**, **8**, **9**, and **10** are views showing a double-rotor lifting force generating unit in a longitudinal and transverse cross-section; and

FIGS. **11**, **12** and **13** are views showing three positions for changing the aero shape of the aerodynamic blades of the lifting force generating unit.

DESCRIPTION OF PREFERRED EMBODIMENTS

A flying apparatus for a vertical take-off and landing shown in FIGS. **1** and **2** has a body **1**, a power unit **2**, lifting force generating units of a rotor type **3** and **4** arranged on FIGS. **5** and **6** and having an aerodynamic profile in a cross-section, a keel **7** with a turning rudder **8**. The lifting force generating unit with one rotor is shown in FIGS. **3**, **4** and **5** and has aerodynamic blades **10** which have a symmetrical aerodynamic profile and are arranged on disks **11** through axles **12**. The axles **12** pass through centers of gravity of the aerodynamic blades **10**. The axles **12** are mounted on disks so as to be able to rotate, through corresponding bearings **13**. The aerodynamic blades **10** are arranged uniformly on the circumference B as shown in FIG. **5**. The disks **11** are mounted on a mounting unit **9** so that they can turn in bearings **21**. The mounting unit **9** is mounted in the body **1**, not shown in the drawings, so that it can turn relative to an axis A. The lifting force generating unit includes a motor **14** which is arranged on the mounting unit **9** and connected with the disk **11**, and through the disk **11** with the rotor. The mater **14** can be of any type, but preferably it is formed as an electric motor.

The aerodynamic blades **10** have a mechanism for setting an attack angle, which includes a cam disk **15**, a unit **16** for turning the cam disk, and a rod **17** connected to the blade **10** with a roller **18** which cooperates with a profiled groove **19** of the cam disk **15** so that the aerodynamic blades are set with a positive attack angle in any point of the circumference, with the exception of a zone Y where the rearrangement of the aerodynamic blades **10** takes place. The mechanism for setting an attack angle can have a different design, which can provide a positive attack angle of the aerodynamic blades **10** in any point of the circumference.

The lifting force generating units shown in FIGS. **3**, **4** and **5** are provided with aerodynamic streamliners **20** which merge into the fins **5** and **6**.

The single rotor lifting force generating unit shown in FIG. **6** has aerodynamic blades **22**, **23** and **24** located on different circumferences B**1**, B**2** and B**3** of the disks **11**. Therefore, the aerodynamic blades **22**, **23**, **24** are arranged at different distances from the rotary axis.

The areas of the aerodynamic blades **22**, **23**, **24** and the aerodynamic profile of their cross-sections are not necessarily identical, and their magnitudes are determined from their application.

The lifting force generating unit is also provided with a mechanism for setting the attack angle which is not shown in the drawings and can be the same as described above for the single-rotor lifting force generating unit.

The multi-rotor lifting force generating unit shown in FIGS. **7**, **8**, **9** includes aerodynamic blades **25** and **27** arranged on the disks **26** and **28** similarly to the single-rotor lifting force generating unit. This unit is illustrated as a double-rotor lifting force generating unit. The disk **26** is arranged on the disk **28** through bearings **28**. The disks **26** and **28** are connected with a motor **30** through a reducer **31**. The lifting force generating unit is also provided with a mechanism for setting an attack angle similar to the above described. It includes a cam disk **32** which is turnable by a motor **33**. Rods **34** and **35** are connected with the aerodynamic blades correspondingly **26** and **28**, and through rollers **38** and **39**, with profiled grooves **40** and **41**. The profiled grooves **40** and **41** have different sizes which correspond to the sizes of the corresponding rotor. The roller **38, 39** are arranged on rods **34** and **35** through axles **36** and **37**.

In the single-rotor or multi-rotor lifting force generating unit, instead of the motor **14** of FIG. **3** or motor **30** of FIG. **7**, electromagnetic coils are arranged as shown in FIG. **10**. The electromagnetic coils **43** are arranged on aerodynamic streamliners **42**, while electromagnetic coils **44** are arranged on disks **45**. In order to supply electric current to the electromagnetic coils **44**, commutators **46** and **47** are provided.

The single-rotor or multi-rotor lifting force generating unit is provided with a mechanism for changing an arrow angle of the aerodynamic blades shown in FIGS. **11, 12** and **13**.

For this purpose the aerodynamic blades are composed of three parts including a middle part **49** and two end parts **50** and **51** which are connected with one another by hinges **52** and **53**, and radial guides **66** and **67** formed inside the end parts **50** and **51**. The end parts **50** and **51** are connected by further radial guides **62** and **63** with carriages **64** and **65**, which, through axles **54** and **55**, are connected so as to turn with the disks **56** and **57**. The carriage **64** and **65** is connected with the mechanism for setting the attack angle, not shown in the drawings. The end parts **50, 51** of the aerodynamic blades are connected through a rod **60** and **61** with a reciprocating mechanism **58** and **59**.

The flying apparatus for a vertical take-off and landing with a rotor-type lifting force generating unit shown in FIGS. **1** and **2** flies in the following manner.

After turning on and setting the power unit **2** to a nominal operational mode, the energy generated by the power units **2** is supplied to the motors **14** of FIG. **3** or motors **30** of FIG. **7**, or to the electromagnetic coils **43** and **44** of FIG. **10**. They start turning the disks **11** with the aerodynamic blade **10** shown in FIGS. **3, 4, 10** or with the aerodynamic blades **22, 23, 24** of FIG. **6**, or the disks **26** and **28** with the aerodynamic blades **25** and **27** of FIG. **9**. During rotation of the aerodynamic blades **10**, or **22, 23, 24**, or **25, 27**, the attack angle of each aerodynamic blade is positive in any point of their trajectory, with the exception of the zone Y for resetting. The position of the aerodynamic blades is provided by the mechanism for setting the attack angle, since during rotation of the blades, rods **17** with the rollers **18** of FIGS. **3, 4** or rods **34** with the rollers **38** and rods **35** with the rollers **39**, the rollers **18** or the rollers **38** move along the profiled grooves **19** of the cam disk **15** of FIG. **3, 4** or along the profiled grooves **40, 41** of the cam disk **32**. The profiled grooves **19** and **44, 41** are formed so that they provide the above mentioned value of the attack angle. Thereby the mechanism for setting the attack angle in each of the above described constructions orients the aerodynamic blades in any point of the trajectory to the positive attack angle, so that during rotation of the aerodynamic blades **10** of FIG. **3** or **22, 23, 24** of FIG. **6**, or **25, 27** of FIG. **9** a lifting force is generated. A sum of the lifting forces of all aerodynamic blades constitutes the lifting force of the lifting force unit **4, 5** of FIG. **1**.

The lifting force is increased with the increase of number of revolutions, and therefore when the rotary speed of the aerodynamic blades is increased to reach a lifting force which exceeds the weight of the flying apparatus, the flying apparatus vertically takes off from the ground and reaches a desired altitude.

The lifting force of the lifting force generating unit can be expressed as follows:

$$Y=\sum Yi=\sum (2\ \sin\varphi_i+k_i\cos\varphi_i)C_{yi}\rho s_i\frac{\pi^3 Di^2 n^2}{2}$$

wherein φ is an angle between centers of gravity of aerodynamic blades with an apex in a rotary point and located on one setting diameter D;

K_i is a coefficient depending on the number of blades;

Cy is a coefficient of a lifting force of a utilized aerodynamic profile at the given deck angle;

ρ is an air density;

S_i is an area of the aerodynamic plane;

D_i is a setting diameter of the aerodynamic blades;

n is a number of revolutions of a rotor.

From the above presented expressions, it can be seen that the greater the number of blades, the lower the amplitude of fluctuation of lifting force. However, if the aerodynamic blades **10** of FIGS. **3, 4, 5** are located on the same setting circumference close to one another, then any of the aerodynamic blades **10** will be in a stream generated by a forward aerodynamic blade.

Therefore the single-rotor lifting force generating unit with a single setting circumference of FIGS. **3, 4, 5** has a limited number of aerodynamic blades **10** and has a limited lifting force.

In order to obtain the lifting force generating unit with a greater specific lifting force, the aerodynamic blades **22, 23, 24** can be installed as shown in FIG. **6** on the disks **11** from different setting circumferences B1, B2, B3 . . . Bi. With this construction is possible to have a great number of aerodynamic blades which are sufficiently spaced from one another.

The same result can be obtained with the use of a multi-rotor lifting force generating unit shown in FIGS. **7, 8, 9**. In this construction it is also possible to provide a great number of aerodynamic blades **25, 27**, etc. Since the rotation of each rotor and aerodynamic blades is performed in different directions, there is no twisting of the airstream.

After the take-off and gaining required altitude, the flying apparatus can maneuver without a traveling speed. Maneuvering is performed by changing or inclining a lifting force generated by the lifting force generating units **4, 5** in FIG. **1** and **2**. By turning the lifting force generating units around the axis A of the element **9** in FIG. **3**, it is possible to obtain a component of the lifting force, directed forwardly or rearwardly so as to move forward and rearward with high speed. By turning the cam disk **15** with the mechanism **16** of FIGS. **3, 4, 5**, it is possible to obtain a component of the lifting force directed laterally, so as to move the flying apparatus sideways. It should be mentioned that with simultaneous turning of the lifting force generating units around the axis A of the element **9**, turning of the cam disks **15** and changing the rotary speed of the rotors, the lifting force is changed and the flying apparatus can assume any position relative to the ground.

The horizontal flight of the flying apparatus is performed by the pulling force which is generated in the power units **2** of FIGS. **1, 2**, while the lifting force is generated by the lifting force generating units **3, 4** and partially by the fins **5, 6** having an aerodynamic profile in their cross-section.

Inclined flight can be performed by increasing or reducing the rotary speed of the lifting force generating units **4** and as a result by increasing or reducing the lifting force. The turning of the flying apparatus is performed by the turning rudder **8** located on the keel **7**, in condition of high horizontal speeds.

High horizontal speeds and high load capacity of the flying apparatus of the present invention can be obtained with the use of the mechanism for turning of a row orientation of the aerodynamic blades of FIGS. **11**, **12**, **13**. At low speeds of the horizontal flight, the oncoming airstream, despite the streamliners **20** moves along the aerodynamic blades and causes a tearing off of the stream from the blades with resulting reduction of the lifting force. At high rotary speeds M of the aerodynamic blades, when their linear speeds approach 0.6–0.8 M, also the tearing off of the airstream takes place. In this case, the mechanism for changing the arrow orientation of the blades of FIGS. **11**, **12**, **13** can be utilized. The mechanism for changing an attack angle, and more particularly the lifting force generating unit with the aerodynamic blades and changing aero orientation operates in the following manner.

When critical parameters of movement of aerodynamic blades **40**, **50**, **51** of FIGS. **11**, **12**, **13** are reached, the reciprocating mechanism **59** is turned on. The rods **61** move the end part of the blades **51**, which moves along the radial guide **63** of the carriage **64** and turns relative to the hinge **53** so as to simultaneously turn the middle part of the aerodynamic blades **49** to form the aero angle of the blade as shown in FIG. **12**. The movement of the end part of the aerodynamic blade **50** is performed in the same manner, for which purpose the reciprocating mechanism **58** with the rod **60** is used as shown in FIG. **13**. The movement of the end parts of the aerodynamic blades **50**, **51** is performed both simultaneously and successively.

The flying apparatus for vertical take-off and landing of FIGS. **1** and **2** has higher maneuverability and higher speed than the helicopters. Moreover, the aerodynamic blades of the lifting force generating units do not throw the airstream downwardly, which makes this flying apparatus especially suitable during saving works in the mode of suspension above a target as well as maneuvering at the low altitudes.

It will be understood that each of the elements described above, or two or more together, may also find a useful application in other types of constructions differing from the types described above.

While the invention has been illustrated and described as embodied in flying apparatus for a vertical take off and landing, it is not intended to be limited to the details shown, since various modifications and structural changes may be made without departing in any way from the spirit of the present invention.

Without further analysis, the foregoing will so fully reveal the gist of the present invention that others can, by applying current knowledge, readily adapt it for various applications without omitting features that, from the standpoint of prior art, fairly constitute essential characteristics of the generic or specific aspects of this invention.

What is claimed as new and desired to be protected by Letters Patent is set forth in the appended claims:

1. A flying apparatus, comprising a body; power means; and lifting force generating units, said lifting force generating units being arranged parallel to a vertical plane of symmetry of said body an turnable in a vertical plane, each of said lifting force generating units is formed as a rotor including a plurality of aerodynamic blades arranged uniformly on a disk and at equal distances from an axis of rotation so as to be turnable, said aerodynamic blades having axes of rotation located parallel to said vertical plane of symmetry of said body and being tunable about an axis extending perpendicular to said plane, said aerodynamic blades having a symmetrical aerodynamic profile, said aerodynamic blades being located at different distances from an axis of rotation of said rotor and on different circumferences and have different aerodynamic areas and also are located with an offset.

2. A flying apparatus, comprising a body; power means; and lifting force generating units, said lifting force generating units being arranged parallel to a vertical plane of symmetry of said body and turnable in a vertical plane, each of said lifting force generating units is formed as a rotor including a plurality of aerodynamic blades arranged uniformly on a disk and at equal distances from an axis of rotation so as to be turnable, said aerodynamic blades having axes of rotation located parallel to said vertical plane of symmetry of said body and being turnable about an axis extending perpendicular to said plane, said aerodynamic blades having a symmetrical aerodynamic profile, each of said lifting generating units including at least two rotors which are rotatable in different directions and each provided with said aerodynamic blades, an area and number of aerodynamic blades of one rotor being different from an area and a number of dynamic blades of the other rotor.

3. A flying apparatus, comprising a body; power means; and lifting force generating units, said lifting force generating units being arranged parallel to a vertical plane of symmetry of said body and turnable in a vertical plane, each of said lifting force generating units is formed as a rotor including a plurality of aerodynamic blades arranged uniformly on a disk and at equal distances from an axis of rotation so as to be turnable, said aerodynamic blades having axes of rotation located parallel to said vertical plane of symmetry of said body and being turnable about an axis extending perpendicular to said plane, said aerodynamic blades having a symmetrical aerodynamic profile, each of said lifting force generating units including at least two said rotors which are coaxial with one another, so that said aerodynamic blades of said rotors together with said rotors rotate in different directions and have different number of revolutions.

4. A flying apparatus as defined in claim **3**, wherein each of said lifting generating units includes at least two rotors which are rotatable in different directions and each provided with said aerodynamic blades.

5. A flying apparatus as defined in claim **4**, wherein an area and number of aerodynamic blades of one rotor is different from an area and a number of aerodynamic blades of the other rotor.

6. A flying apparatus as defined in claim **3**, wherein said disks of said lifting force generating units are provided with electromagnetic coils and means for supplying electric current to said electromagnetic coils.

7. A flying apparatus as defined in claim **3**; and further comprising aerodynamic streamliners provided with electromagnetic coils and means for supplying electric current to said electromagnetic coils.

8. A flying apparatus as defined in claim **4**, wherein said electrodynamic blades have a changeable aerodynamic profile.

9. A flying apparatus as defined in claim **8**, wherein each of said aerodynamic blades is composed of three parts hingedly connected with one another and guided in guides, said parts of each of said aerodynamic blades including two end parts which are connected through said guides and axles with said disks, said end parts of each of said aerodynamic blades being reciprocatingly moveable.

* * * * *

United States Patent [19]

Sharpe

[11] **4,194,707**

[45] **Mar. 25, 1980**

[54] **LIFT AUGMENTING DEVICE FOR AIRCRAFT**

[76] Inventor: **Thomas H. Sharpe,** 502 Dorr Ave., Belvedere, S.C. 29841

[21] Appl. No.: **861,269**

[22] Filed: **Dec. 16, 1977**

[51] **Int. Cl.**² **B64C 29/00;** B64C 39/00

[52] **U.S. Cl.** .... **244/9;** 244/12.3; 244/12.5; 244/208; 244/53 B; 416/108; 416/111

[58] **Field of Search** .... 244/9, 10, 11, 13, 19, 244/20, 21, 22, 23 D, 39, 206, 110 B, 12 S, 12.1, 53 B, 12.3, 208; 416/108, 110, 111

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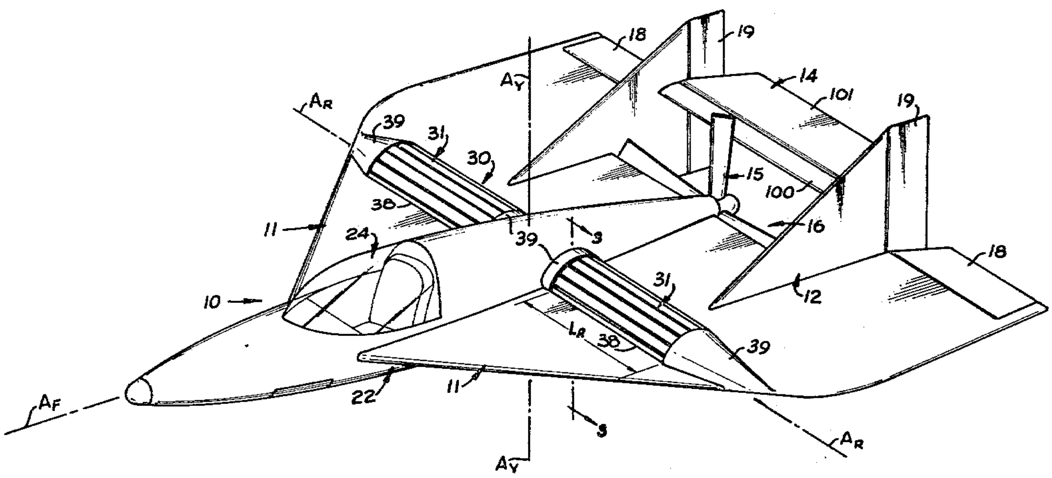
Primary Examiner—Galen L. Barefoot

Attorney, Agent, or Firm—B. J. Powell

[57] **ABSTRACT**

A lift augmenting device to provide a vertical take-off capability in aircraft which includes a pair of rotor assemblies with independently individually pivoted rotor vanes so that the attitude of the vanes can be changed at different positions along the circumferential rotational path of the vanes as they rotate with the rotor assemblies to pump air therethrough and selectively generate lift on the aircraft.

9 Claims, 9 Drawing Figures



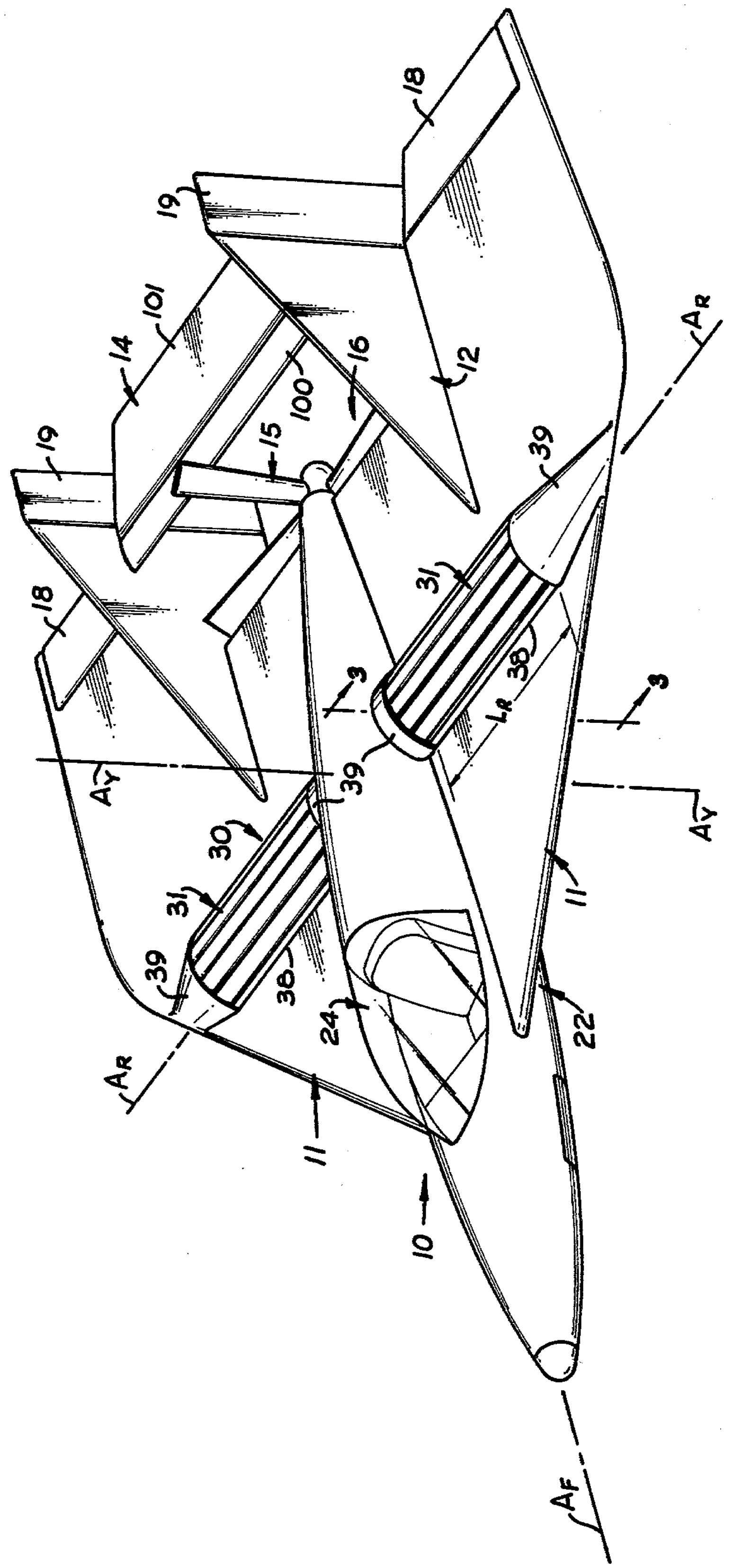

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FIG 1

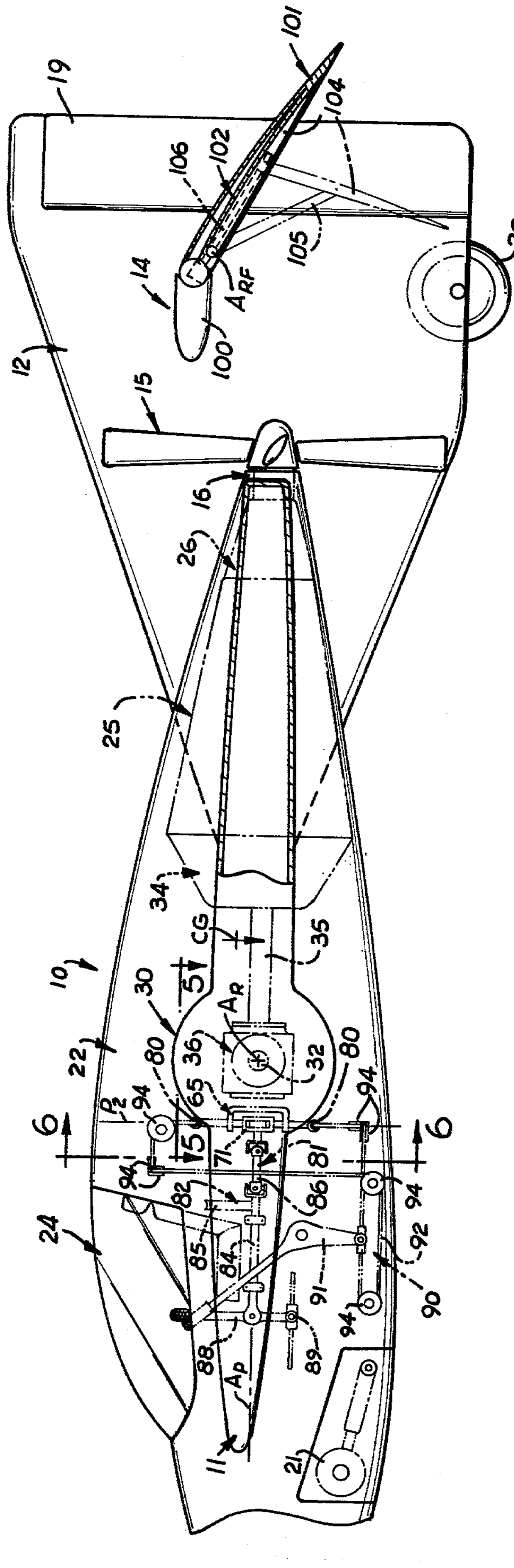

Fig 2

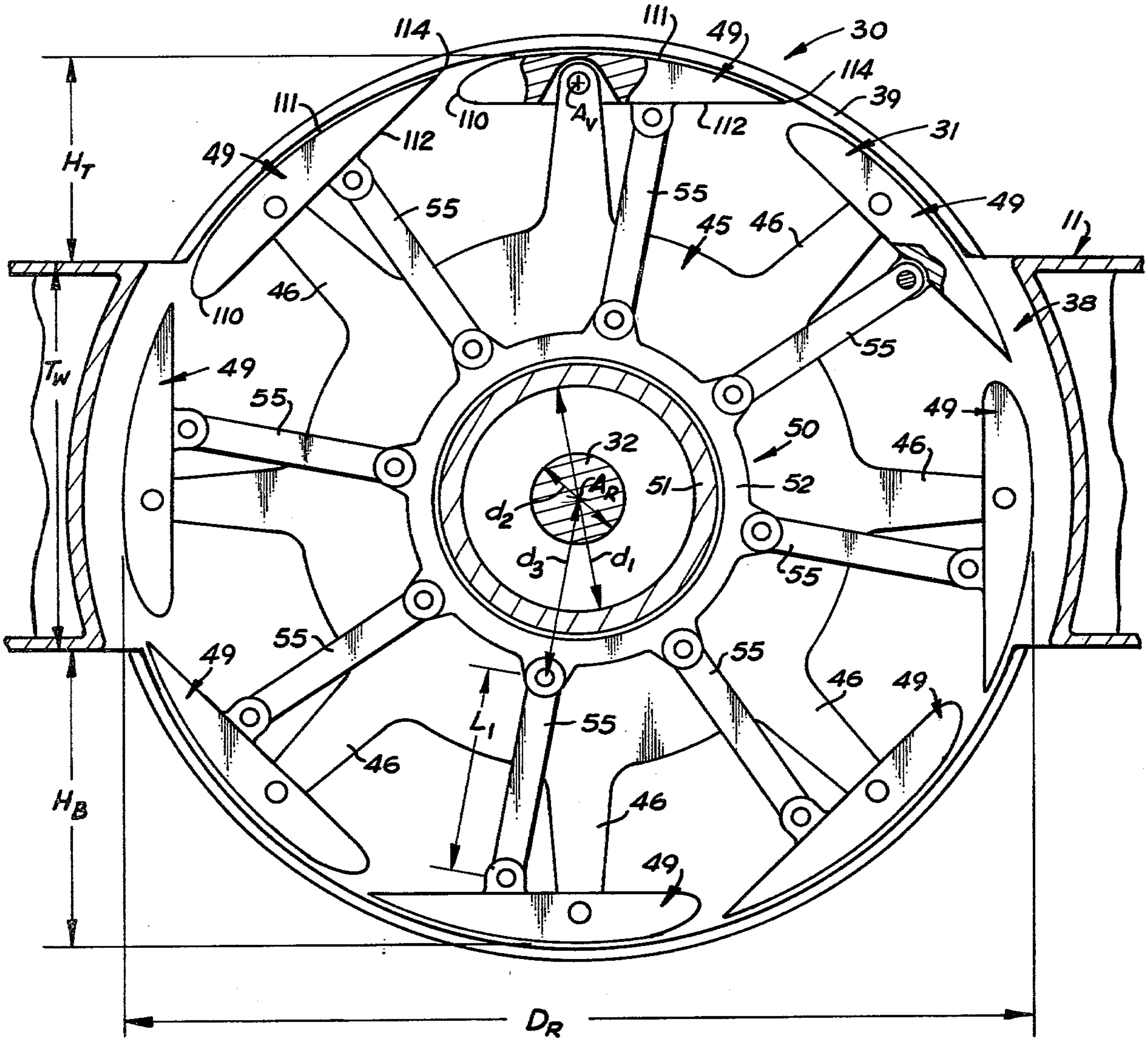
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Fig 3

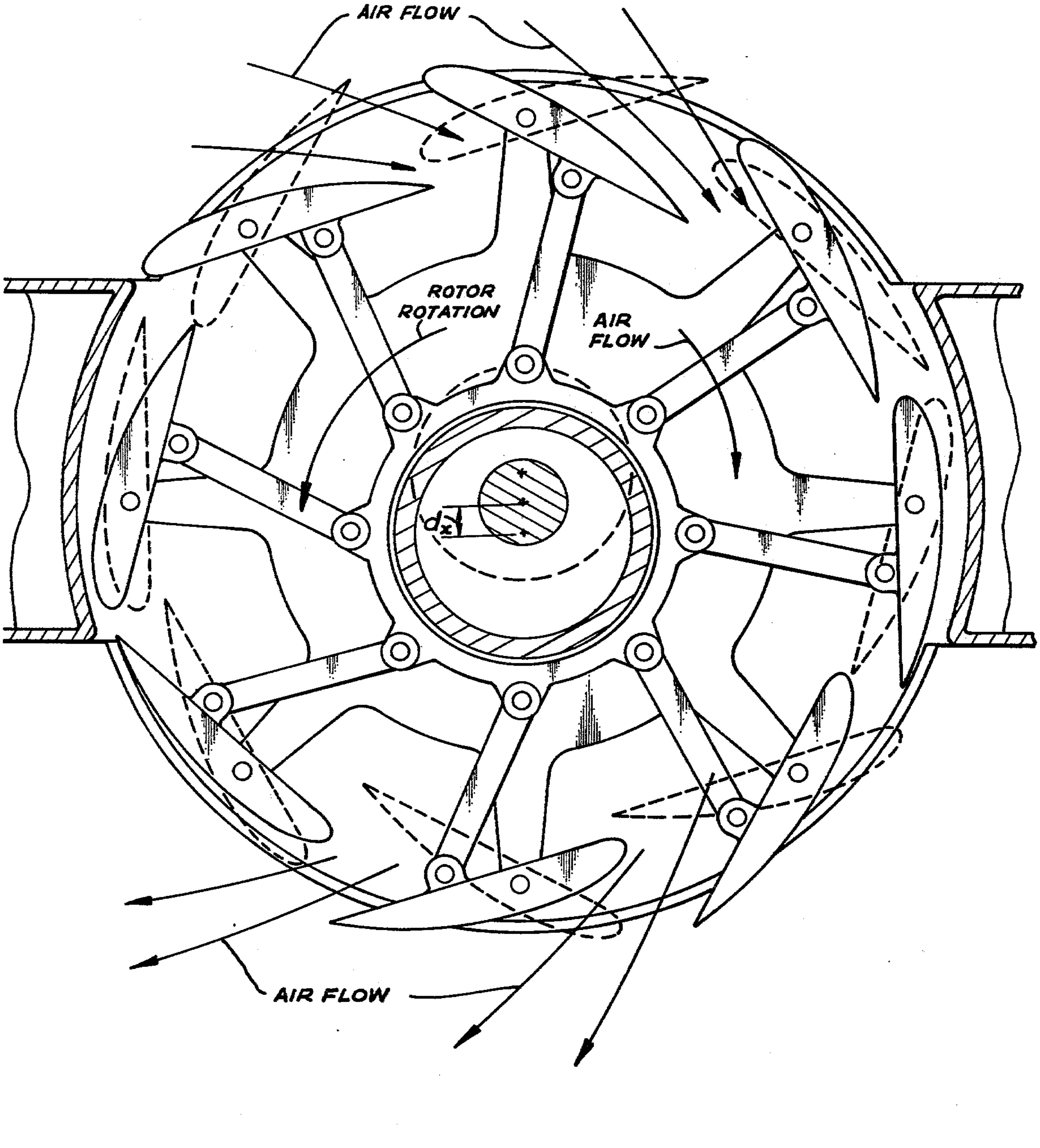

Fig 4

Fig 5

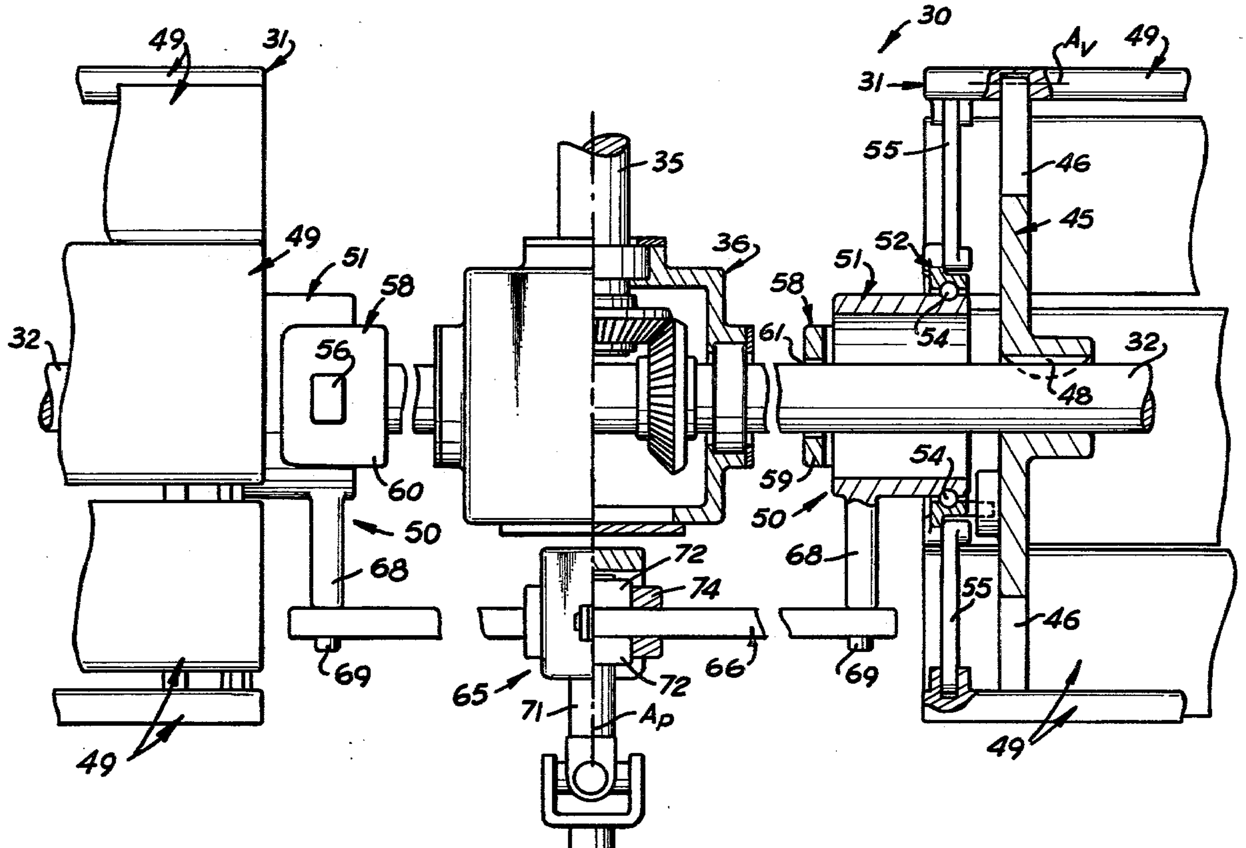
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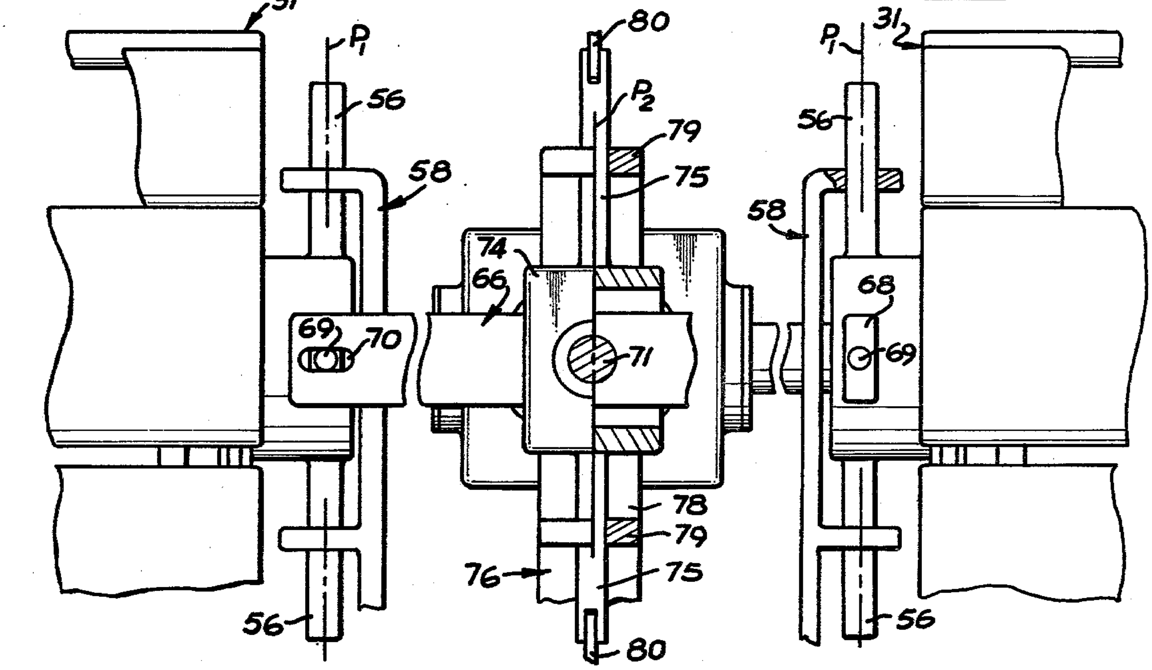
Fig 6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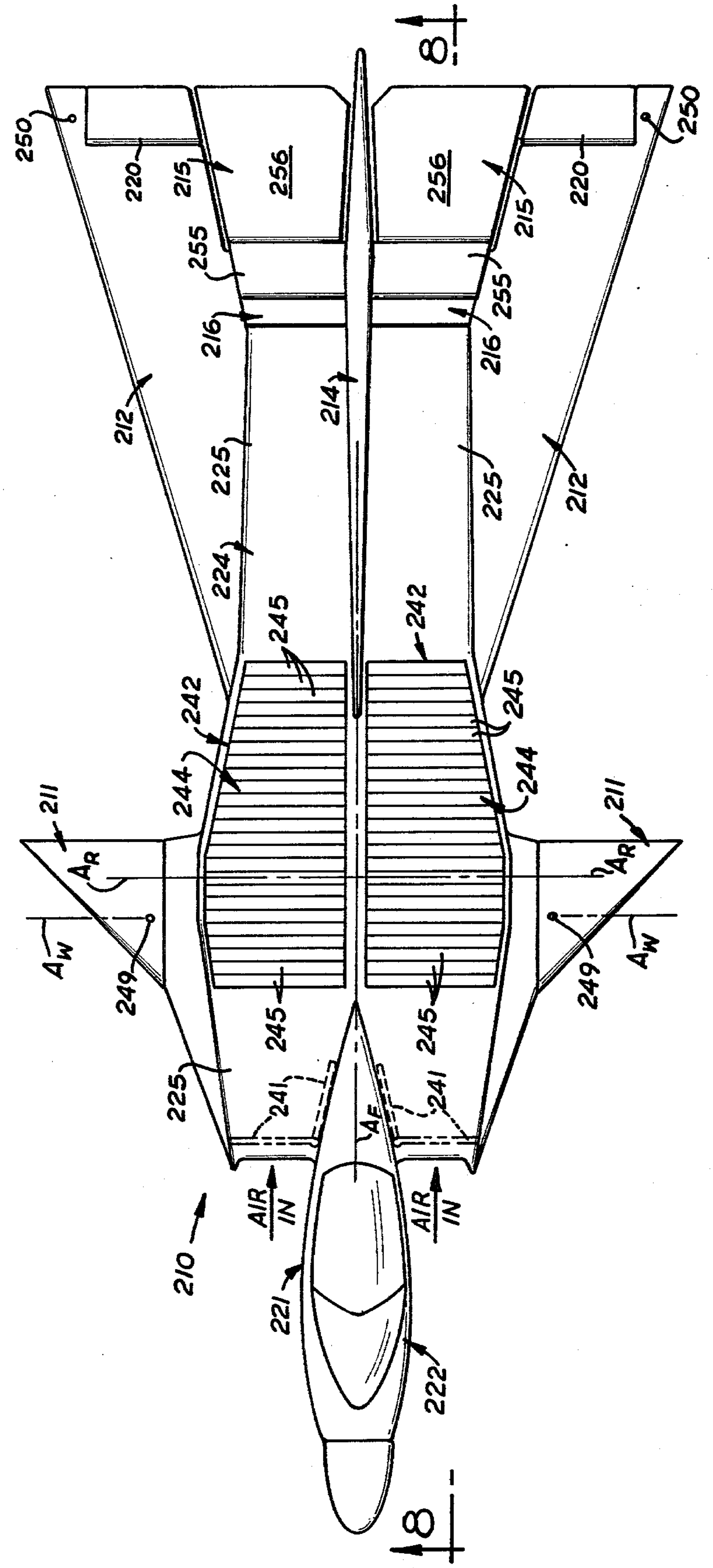
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FIG 7

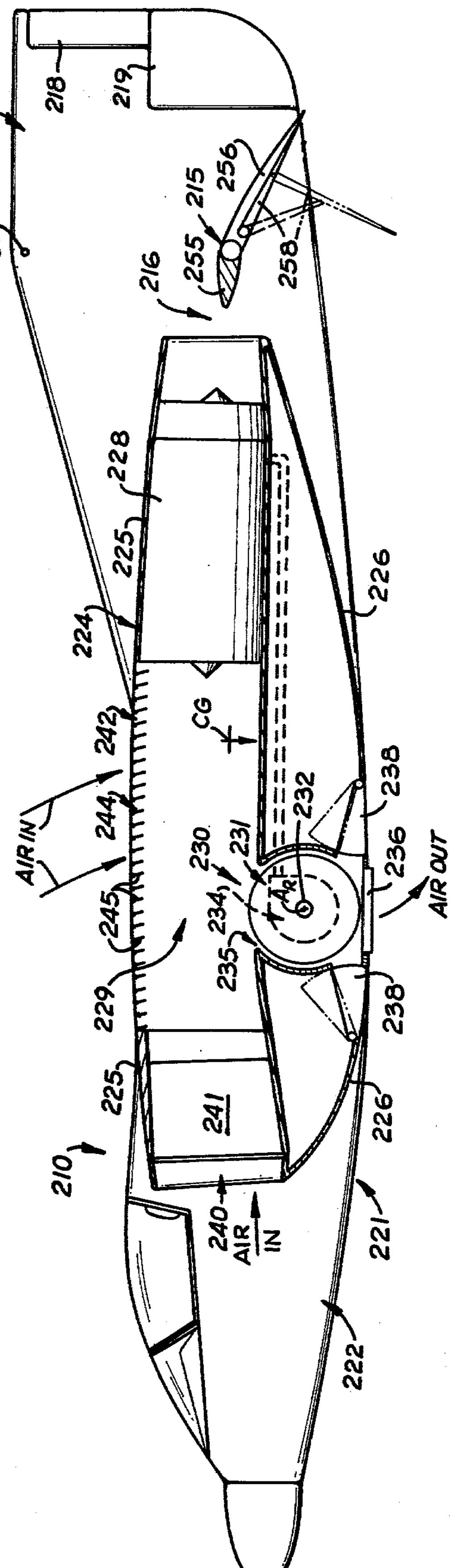
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Fig 8

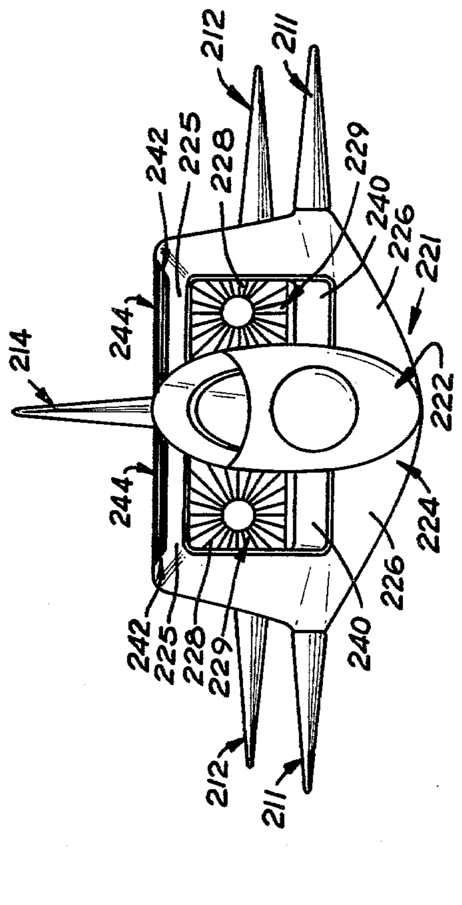
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Fig 9

LIFT AUGMENTING DEVICE FOR AIRCRAFT

BACKGROUND OF THE INVENTION

Various devices have been suggested in the past for augmenting the lift on an aircraft either to reduce the required wing area or to decrease the required forward speed of the aircraft during take-off and landing. Such devices have not enjoyed widespread success due primarily to the fact that such devices have had difficulty in providing adequate control over the aircraft at low speed, especially when vertical take-offs and landings were attempted. One type of suggested lift augmenting device uses rotors positioned in the wings. Examples of this type of lift augmenting device are shown in U.S. Pat. Nos. 2,344,515 and 3,065,928. These rotors are fixed vanes in the rotors making it difficult to vary the flow of air through the rotors.

SUMMARY OF THE INVENTION

These and other problems and disadvantages associated with the prior art are overcome by the invention disclosed herein by the provision of rotor assemblies on opposite sides of the aircraft flight axis in communication with the air above and below the aircraft. The vanes on the rotor assemblies are each individually pivoted so that the rotor vanes can be pivoted in one direction to draw air into the rotor assembly while the vanes in communication with the air above the aircraft and can be pivoted in the opposite direction to discharge air from within the rotor assembly while the vanes are in communication with the air below the aircraft to exert lift on the aircraft. The vanes on both the rotor assemblies can be simultaneously oriented in the same sense and degree of pivoting or can be pivoted in the opposite sense. This allows the rotor assemblies to be selectively controlled so as to give the aircraft a vertical take-off and landing capability.

These and other features and advantages of the invention will become more fully understood upon consideration of the following description and the accompanying drawings wherein like characters of reference designate corresponding parts throughout the several views and in which:

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view of an aircraft embodying the invention;

FIG. 2 is a partial side view of the aircraft of FIG. 1 with some of the internal components thereof shown in phantom lines;

FIG. 3 is a cross-sectional view taken generally along line 3—3 in FIG. 1 showing the construction of the rotor assembly;

FIG. 4 is a view similar to FIG. 3 showing different operational positions of the rotor vanes in the rotor assembly;

FIG. 5 is a view taken generally along line 5—5 in FIG. 2 showing the drive connection between the rotor assemblies;

FIG. 6 is a view taken generally along line 6—6 in FIGS. 2 and 5;

FIG. 7 is a top plan view of a second aircraft embodying the invention;

FIG. 8 is a view taken generally along line 8—8 in FIG. 7; and,

FIG. 9 is a front view of the second aircraft.

These figures and the following detailed description disclose specific embodiments of the invention; however, it is to be understood that the inventive concept is not limited thereto since it may be embodied in other forms.

DETAILED DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS

As seen in FIG. 1, the invention is embodied in an aircraft **10** with delta wings **11**, a pair of vertical stabilizers **12**, and an elevator **14** extending between the vertical stabilizers **12**. The forward flight of the aircraft **10** is powered by a propeller **15** in a cutout **16** in wings **11** between the vertical stabilizers **12** and forwardly of elevator **14**. The elevator **14** is located so that a portion of the rearwardly directed airflow generated by the propeller **15** is directed across the elevator **14** as will become more apparent. The rear edges of the wings **11** outboard of the vertical stabilizers are provided with conventionally operating ailerons **18** and the vertical stabilizers **12** are provided with conventionally operating rudders **19**. Rear landing wheels **20** are mounted in the bottom of the vertical stabilizers and a retractable nose wheel **21** is provided in the forward portion of the fuselage **22** as seen in FIG. 2. An appropriate pilot cockpit **24** is provided in the forward portion of fuselage **22**. The fuselage **22** has a longitudinal flight axis A_F along which the aircraft **10** moves in forward flight. The fuselage **22** further mounts an engine **25** shown by phantom lines in FIG. 2 forwardly of the propeller **15** for driving same.

The aircraft **10** is provided with a lift augmenting means **30** mounted in the wings **11** on opposite sides of the fuselage **22** as seen in FIG. 1. The lift augmenting means **30** includes a pair of rotor assemblies **31**, one being rotatably mounted in each wing **11**. The rotor assemblies **31** are rotatably mounted about a common rotational axis A_R (FIGS. 1–5) normal to the flight axis A_F on a common drive shaft **32** (FIGS. 3–5) which is driven by the engine **25** through a transmission **34** (FIG. 2), transfer drive shaft **35** (FIGS. 2 and 3) and right angle drive **36** (FIGS. 2–4). Each of the rotor assemblies **31** has an effective length L_R and a nominal diameter D_R best seen in FIGS. 1 and 3 and both are located equadistant from the flight axis A_F of the aircraft as will become more apparent. Each of the rotor assemblies **31** is mounted in a rotor cutout **38** in each of the wings **11** where the wings **11** have an effective thickness T_W which is less than the diameter D_R of the rotor assemblies **31**. Thus, it will be seen that each rotor assembly **31** projects above and below the wings **11** so that the rotor assemblies **31** are in communication with the air above and below the aircraft. Each of the rotor assemblies **31** project above the wings **11** the height H_T and project below the wings **11** the height H_B. It will be further noted that the height H_B is greater than the height H_T as will become more apparent. The common drive shaft **32** mounting the rotor assemblies **31** is appropriately journaled in the wings **11** so that the drive shaft **32** and rotor assembly **31** can rotate about the rotor axis A_R. Appropriate fairings **39** are provided at the outboard and inboard ends of the rotor assemblies **31** to streamline the exposed ends of the rotor assemblies **31**. It will be noted that the rotor assemblies **31** are rotated in the same direction so that the top of the rotor assemblies projecting above the wings **11** are moving toward the front of the fuselage **22** or counterclockwise as seen in FIG. 3. Because more of the rotor assemblies **31** are exposed more below the wings **11** than above the wings **11**, the natural flow of the air flowing above and below the wings **11** will try to rotate the rotor assemblies **31** in this same direction.

Each of the rotor assemblies **31** includes a pair of spaced apart support arbors **45** mounted on the common drive shaft **32** at the opposite ends of the rotor assemblies **31** as best seen in FIGS. 3–5. Each of the support arbors **45** is provided with a plurality of radially extending support arms **46** which are equally spaced circumferentially around the arbors **45**. While different numbers of support arms **46** may be provided on the arbors **45**, eight such support arms are illustrated in the figures. It will be seen that each of the support arbors **45** is keyed to common drive shaft **32** through a key **48** as best seen in FIG. **4** so that the support arbors **45** are rotated with the drive shaft **32**. The support arms **46** individually pivotally mount a plurality of rotor vanes **49** at the outboard ends of the support arms **46**, with the rotor vanes **49** having a length about equal to the effective length L_R of the rotor assemblies **31** and oriented generally parallel to the rotor axis A_R. It will thus be seen that each of the rotor vanes **49** is pivotally connected to the support arms **46** about a separate vane pivot axis A_V so that each of the rotor vanes **49** may be individually pivoted over a limited range about the vane pivot axes A_V parallel to the rotor axis A_R. This allows each of the rotor vanes **49** to be individually positioned relative to the support arms **46** about the vane pivot axes A_V.

A vane positioning drive mechanism **50** is provided at the inboard end of the rotor assembly **31** inboard of the inboard support arbor **45** as best seen in FIGS. 3–5 to selectively pivot the rotor vanes **49** about the vane pivot axes A_V. The vane positioning drive mechanism **50** includes generally an inner annular race member **51** having an inside diameter d_1 which is significantly larger than the outside diameter d_2 of the common drive shaft **32** as best seen in FIG. 3. Because of the differences in inside diameter of the race member **51** and outside diameter of the shaft **32**, it will be seen that the inner race member **51** can be shifted about the common drive shaft **32** for a limited amount of movement without interference between the race member **51** and the drive shaft **32**. The annular race member **51** rotatably mounts thereon just inboard of the inboard support arbor **45** an outer annular positioning ring **52** through bearings **54** between the positioning ring **52** and inner race member **51**. This allows the race member **51** to be held rotationally stationary while the outer positioning ring **52** is free to rotate about the inner race member **51** on the bearing **54**. The outer positioning ring **52** is pinned to each of the rotor vanes **49** through a positioning link **55** so that the relative pivotal position of the rotor vanes **49** with respect to the vane pivot axes A_V can be controlled by appropriate movement of outer positioning ring **52** by the race member **51**. It will be seen that each of the positioning links **55** is pinned to each of the rotor vanes **49** a distance d_3 from the vane pivot axis A_V and that each of the positioning links **55** has the same length L_1 so that, when the positioning ring **52** is concentric about the rotor axis A_R, all of the rotor vanes **49** will have the same relative rotational position about the individual vane pivot axes A_V with each of the vanes **49** being oriented generally normal to a radial line connecting the vane pivot axis A_V with the rotor axis A_R. It will further be seen that when the inner race member **51** is moved diametrically of the rotor axis A_R, the rotor vanes **49** adjacent one end of this diametrical path of movement will be pivoted in one rotational direction while those rotor vanes **49** adjacent the opposite end of the diametrical path of movement will be pivoted in the opposite direction. In this particular application, it will be seen that the inner race member **51** is provided with a pair of diametrically opposed guide bars **56** extending radially outwardly from the inboard end of the inner race member **51** along diametrically opposed paths. These guide bars **56** are slidably received in a U-shaped guide **58** which is provided with a central upstanding web **59** and outwardly projecting legs **60**. The U-shaped guide member **58** is attached to the frame work inside the fuselage **22** and is positioned so that the buide bars **56** are slidably carried in the legs **60** of the U-shaped guide **58** so that the inner race member **51** is diametrically movable with respect to the rotor axis A_R along a diametrical path P_1 shown on FIG. 3 which is normal both to rotor axis A_R and the flight axis A_F. An appropriate clearance passage **61** is provided through central web **59** of the U-shaped guide **58** through which the common rotor drive shaft **32** concentrically extends so that the shaft **32** can rotate without the U-shaped guide **58** rotating.

A drive mechanism controller **65** is provided for selectively moving the inner race members **51** along the positioning paths P_1 to selectively change the rotational position of the rotor vanes **49**. The drive mechanism controller **65** includes basically a common drive bar **66** which is connected at its opposite ends with one of the driving projections **68** fixedly mounted on each race member **51**. The connections between the drive bar **66** and driving projection **68** are slip-pin joint connections which allow the drive bar **66** to shift with respect to the drive pin **69** on the driving projection **68** as they extend through the slots **70** in opposite ends of the drive bar **66** as will become more apparent. The drive bar **66** is fixedly mounted on a positioning shaft **71** which is in turn rotatably journaled on bearings **72** in a positioning housing **74**. The positioning **74** is provided with diametrically opposed guide bars **75** which are in turn mounted on a U-shaped guide **76** fixedly carried by the aircraft frame structure. The U-shaped guide **76** is provided with a central upstanding web **78** and a pair of forwardly projecting legs **79** which slidably receive guide bar **75** therethrough. The U-shaped guide **76** is positioned so that the positioning housing **74** is movable along a path P_2 parallel to the inner race member paths P_1 and normal to the flight axis A_F. It will further be noted that the positioning housing **74** about a positioning axis A_p which is centered between the inner annular race members **51** and oriented generally parallel to the flight axis A_F. Thus, the positioning housing **74** can be selectively moved along the path P_2 while the positioning shaft **71** can be selectively rotated about the positioning axis A_p independently of the position of the positioning housing **74** along the path P_2.

The projecting ends of the guide bar **75** are provided with appropriate attachment eyes **80** best seen in FIGS. **2** and **6** so that an appropriate vane attitude control mechanism can be attached to the guide bar **75** to selectively position the positioning housing **74** along the path P_2. It will further be noted that, as long as the rotational position of the positioning shaft **71** about the positioning axis A_p remains the same, movement of the positioning housing **74** along the path P_2 will cause the same amount of movement of the inner race members **51** in the same direction along the paths P_1 to simultaneously change the relative rotational positions of the rotor vanes **49** of each of the rotor assemblies **31** with the vanes **49** of both rotor assemblies **31** being changed in the same manner. On the other hand, if the positioning housing **74** is maintained in the same position along the path P_2, rotation of the positioning shaft **71** will cause one of the inner race members **51** to be shifted along the path P_1 in one direction while the opposite inner race member **51** will be shifted a like amount in the opposite direction along its path P_1. This causes the vanes **49** of one of the rotor assemblies **31** to be shifted directly opposite to the way the vanes **49** of the other rotor assembly **31** is shifted.

Referring now specifically to FIG. 2 and also to FIG. 5, it will be seen that the positioning shaft **71** is controlled from the cockpit **24** by a vane attitude roll control **81**. The vane attitude roll control **81** is incorporated in the aircraft aileron control system **82**. Usually, the aircraft aileron control system **82** has a drive shaft **84** which mounts the aileron connection **85** to move the ailerons **18** in response to rotation of the drive shaft **84**. A transfer shaft **86** connects the drive shaft **84** on the aileron control system to the positioning shaft **71** so that rotation of drive shaft **84** rotates shaft **71**. When the aircraft is provided with a control stick **88** in the cockpit **24** as seen in FIG. 2, the drive shaft **84** usually serves as the pivot point for the control stick **88** and is rotated about its axis as the control stick **88** is moved laterally of the flight axis of the airplane. Thus, when the control stick **88** is moved laterally of the flight axis A_F by the pilot, the ailerons **18** will be appropriately pivoted by the aileron connection **85** to cause the plane to bank. At the same time, the movement of the control stick **88** laterally of the flight axis of the aircraft will also cause the positioning shaft **71** to rotate about the positioning axis A_p to correspondingly shift the vanes **49** on the two rotor assemblies **31** in the opposite sense to exert a like banking movement to the aircraft as will become more apparent. Movement of the control stick **88** along the flight axis A_F causes the elevator connection **89** thereon to move the elevator **14** in conventional manner.

A vane attitude lift control **90** is connected to the eyes **80** on the positioning housing **74** to selectively move the positioning housing **74** along the path P_2. The vane attitude lift control **90** is best seen in FIG. 2 and includes a vane lift control lever **91** pivotally mounted in the cockpit **24**. The vane lift control lever **91** is connected to vane control cable **92** appropriately trained over cable pulleys **94** so that the motion imparted to the vane control cable **92** moves the positioning housing **74** along the path P_2. The ends of the cable **92** are connected to the attachment eyes **80** so that movement of the cable in one direction by the control lever **91** will shift the positioning housing **74** along the path P_2 in a first direction while the movement of the cable in the opposite direction will shift the positioning housing **74** in the opposite direction. As seen in FIG. 2, pivoting the control lever **91** counterclockwise will raise the positioning housing **74** while pivoting the control lever **91** clockwise will lower the positioning housing **74**.

The elevator **14** includes a generally horizontal fixed section **100** as seen in FIGS. 1 and 2 to which is pivoted a movable elevator section **101** as best seen in FIG. 2. The elevator section **101** has a cutout **102** on the underside thereof in which is movably mounted a reversing flap **104**. The movable elevator section **101** is controlled in a conventional manner from the elevator connection **89** on the control stick **88**. The position of the reversing flap **104** is controlled by an appropriate mechanism such as a screw drive **106** which moves the pivot point of the reversing flap from a forwardmost position as illustrated in solid lines in FIG. 2 to a rearmost position as shown by phantom lines in FIG. 2. The pivotal position of the reversing flap **104** as seen in FIG. 2 is controlled by a fixed length positioning link **105** seen by phantom lines in FIG. 2 when the reversing flap **104** is in its lowered position. The positioning link **105** is pivoted about the fixed pivotal axis A_{RF} so that as the pivotal connection of the reversing flap **104** is shifted rearwardly along the cutout **102**, the positioning link **105** causes the reversing flap **104** to pivot downwardly toward the position shown by phantom lines in FIG. 2. This causes the thrust of the propeller to be reversed on the aircraft as will become more apparent.

The operation of the rotor assemblies **31** will be best understood by reference to FIG. 4. As seen in FIG. 4, the inner race member **51** has been shifted downwardly along the path P_1 the distance d_x. It will further be noted that each of the rotor vanes **49** has an airfoil cross sectional shape with a rounded leading edge **110**, with a curvilinear outboard side surface **111**, and a generally planar inboard side surface **112** that joins with the outboard side surface **111** to form a relatively sharp trailing edge **114**. When the rotor assembly **31** is in its neutral position, as seen in FIG. 3, it will be seen that the planar inboard side surfaces **112** are generally normal to the radius of the drive shaft **32**. When the annular inner race member **51** of the vane positioning mechanism **50** is shifted downwardly along path P_1 to the position shown in FIG. 4, it will be seen that those vanes **49** extending above the wings **11** will be pivoted clockwise while those vanes **49** projecting below the wings **11** will be pivoted counterclockwise. The vanes **49** passing through the rotor cutout in the wings **11** will generally be in the same position as when the rotor assembly **31** is in its neutral position. Thus, it will be seen that the leading edges **110** of the vanes **49** are pivoted outwardly from the rotor axis A_R as the vanes **49** move above the wings **11** while the leading edges **110** of the vanes **49** will be pivoted inwardly as the vanes **49** pass below the wings **11**. This serves to cause the vanes **49** of the rotor assembly **31** to draw air from above the wing into the interior of the rotor assembly **31** and then discharge this air outwardly below the wings **11** as shown by the air flow lines in FIG. 4. The net result is that the air pressure directly above the wing **11** is lowered while the air pressure immediately below the wing **11** is raised since the rotor assemblies **31** are pumping air from above to below the wings **11**. This causes a net lifting effect to be imparted to the aircraft due to the pumping action of the rotor assemblies **31**. When the rotor assemblies **31** and the vanes **49** are appropriately sized, the lifting effect generated by the rotor assemblies **31** will be sufficient to lift the aircraft **10**. Thus, it will be seen that the rotor assemblies **31** give the aircraft **10** a vertical takeoff capability when the vanes **49** are pivoted in the direction shown by solid lines in FIG. 4.

On the other hand, raising the inner race members **51** from the position shown by solid lines in FIG. 4 first through the neutral position seen in FIG. 3 and then toward the reversed position shown by dashed lines in FIG. 4. When the vanes are in the reversed position shown by dashed lines in FIG. 4, the leading edges **110** of the vanes **49** are pivoted inwardly as they pass above wing **11** and pivoted outwardly as they pass below the wing **11** so that air is pumped from below wing **11** through the rotor assembly 31 and then out above wing 11. This serves to reduce the lift on the aircraft in increasing its descent.

On the other hand, raising the inner race members 51 from the position shown by solid lines in FIG. 4 serves to pivot the vanes 49 first through the neutral position seen in FIG. 3 and then toward the reversed position shown by dashed lines in FIG. 4. When the vanes are in the reversed position shown by dashed lines in FIG. 4, the leading edges 110 of the vanes 49 are pivoted inwardly as they pass above wing 11 and pivoted outwardly as they pass below the wing 11 so that air is pumped from below wing 11 through the rotor assembly 31 and then out above wing 11. This serves to reduce the lift on the aircraft in increasing its descent.

The pilot is able to control the position of the vanes 49 to simultanously increase and decrease the lift of both rotor assemblies 31 using the lift control lever 91. As seen in FIG. 2, rotation of lever 91 clockwise will increase lift while rotation of lever 91 counterclockwise decreases lift. Because the control stick 88 also controls the rotational position of the positioning shaft 71 through the vane attitude roll control 81, the pilot moves the control stick 88 laterally of the flight axis A_F to vary the relative between the rotor assemblies 31. This allows the pilot to control the roll attitude of the aircraft about the flight axis A_F.

To use the vertical takeoff capability of the aircraft 10, the pilot starts the engine 25 and engages the rotor transmission as well as the propeller transmission 26. The rotor assemblies 31 are now being rotated in the direction shown in FIGS. 3 and 4 so that the vanes 49 have a forward component of motion as they pass above the wings 11. The propeller 15 will probably be of the variable pitch type and will usually be set at about the neutral position. The pilot then moves the lift control lever 91 clockwise as seen in FIG. 2 to pivot the vanes 49 toward their maximum lift position shown by solid lines in FIG. 4. As the engine 25 is speeded up, the rotor assemblies 31 generate a lift on the aircraft 10 to lift it off the ground. The roll attitude of the aircraft is controlled by the pilot by appropriately shifting the control stick 88 laterally of the flight axis A_F. The pitch attitude of the aircraft about the rotor axis A_R is controlled by the pilot by adjusting the pitch of the propeller 15 in known manner and by adjusting the position of the elevator 14 with fore and aft movement of the control stick 88. Lowering the elevator section 101 raises the rear end of the aircraft while raising section 101 lowers the rear end of the aircraft. When the rotor axis A_R is located forwardly of the center of gravity CG of the aircraft as seen in FIG. 2, the pitch of the propeller 15 and the position of elevator 14 is adjusted so that the force of the air from propeller 15 against the elevator 14 serves to lift the rear end of the aircraft. The pilot can also adjust the fore and aft movement of the aircraft by adjusting the position of the reversing flap 104. Thus, it will be seen that the aircraft can lift off the ground vertically, hover or move forwardly or rearwardly while hovering. The yaw attitude of the aircraft about the yaw axis A_y in FIG. 1 is controlled by the pilot by adjusting the pitch of the propeller 15 and the position of rudders 19.

When the aircraft has been lifted off the ground, the pilot can transfer gradually into full forward flight by increasing the pitch of the propeller 15. The rotor assemblies 31 continue to supply the lift necessary to maintain the aircraft airborne. As the aircraft gradually accelerates toward full flying speed, the lift setting of the vanes 49 can be gradually lowered by rotating the lift control lever 91 back toward its neutral position so that the vanes 49 reach their neutral position after the aircraft has reached full flying speed. Once the aircraft has reached full flying speed, the rotor assemblies can be disengaged from the engine 25 by rotor transmission 34 and stopped or allowed to free wheel. If the rotor assemblies 31 are allowed to free wheel, the greater exposure below the wings 11 will continue to rotate the rotor assemblies 31 in the direction shown in FIGS. 3 and 4. At full flying speed, the aircraft operates generally conventionally. For a vertical landing, the process is reversed.

If a loss of power in the engine 25 is experienced, the rotor assemblies 31 can be used to assist in the safe landing of the aircraft. If the rotor assemblies 31 are free wheeling sufficiently fast, the pilot can move the vanes 49 toward the lift position as the aircraft slows and use the rotational momentum of the rotor assemblies 31 to create the necessary lift to allow the aircraft to land at a slow speed or vertically. If sufficient altitude is available and the rotor assemblies 31 are not free wheeling fast enough, the pilot can speed up the rotation of the rotor assemblies by moving the lift control lever 91 toward its descent position to pivot the vanes 49 toward their descent positions shown by dashed lines in FIG. 4. The force of the air flowing from below the wings 11 through the rotor assemblies 31 to above the wings 11 speeds up the rotation of the rotor assemblies 31 to increase their rotational momentum. Then, as the aircraft approaches the ground, the vanes 49 can be shifted to their lift positions to cause the rotational momentum to create the necessary lift to allow the aircraft to safely land.

SECOND EMBODIMENT

A second embodiment of an aircraft embodying the invention is seen in FIGS. 7 and 8. The aircraft is designated generally by the numeral 210 and is designed for much higher speeds than aircraft 10. The aircraft 210 has a pair of forward wings 211 and a pair of aft wings 212. A vertical stabilizer 214 is provided between the aft wings 212 and a pair of elevators 215 are provided in exhaust cutouts 216 in the trailing portions of the aft wings 212. The vertical stabilizer 214 is provided with high and low speed rudders 218 and 219 while the trailing edges of the aft wings 212 are provided with ailerons 220. The aircraft 210 has a fuselage 221 with a forward cockpit section 222 that carries the pilot and a trailing propulsion section 224 which mounts the power plant. The upper and lower surfaces 225 and 226 of the propulsion section 224, while not shown as such, may be aerodynamically curved to generate lift. A pair of propulsion jet engines 228 are provided in the aft end of the propulsion section 224 of the fuselage and discharges the exhaust gases rearwardly therefrom over the elevators 215 in cutouts 216. The intakes to the engines 228 are connected to ducts 229 opening onto the leading end of the propulsion section 224 of the fuselage to supply air to the engines 228.

The lift augmenting device 230 is operatively communicating with the ducts 229 and with the air below the aircraft. The lift augmenting device 230 has a pair of rotor assemblies 231 mounted on common rotor shaft 232. The rotor assemblies 231 have the same construction as the rotor assemblies 31, and the specific construction thereof will not be repeated here. Also, because the controls for the rotor assemblies **231** is the same as the controls for the rotor assemblies **31**, their description will not be repeated. The common drive shaft **232** is driven by a fluid motor **234** powered by a bleed line from engines **228** rather than by a direct drive. The rotor drive shaft **232** is oriented on a rotor axis A_R normal to the longitudinal flight axis A_F of the aircraft. The rotor assemblies **231** are mounted in a pair of rotor cutouts **235** which extend from each duct **229** out through the bottom of the propulsion section **224** of the fuselage **221** so that the rotor assemblies **231** pump air back and forth between the ducts **229** and the bottom of the aircraft in accordance with the operation described for rotor assemblies **31**. The bottom of cutouts **235** below the rotor assemblies **231** can be selectively opened and closed by a set of shutter vanes **236** pivoted about axes generally normal to the rotor axis A_R and parallel to the flight axis A_F.

The exposure of the rotor assemblies **231** to the air below the aircraft can also be regulated by pairs of pivotable gates **238** on the forward and trailing edges of the cutouts **235**. The gates **238** are shown in their lowered positions by solid lines in FIG. **8** and in their raised positions by phantom lines.

The forwardly facing intake openings **240** to ducts **229** are provided with closure doors **241** which can be pivoted from an open position shown by dashed lines in FIG. **7** to a closed position shown by phantom lines in FIG. **7** to prevent the flow of air into the ducts **229** through the intake openings **240**. The propulsion section **224** of fuselage **221** is provided with a pair of intake cutouts **242** from the top of the aircraft **210** to the ducts **229** over the rotor assemblies **231**. The cutouts **242** are selectively closed by intake shutter assemblies **244** with shutter vanes **245** pivoted about vane axes normal to the flight axis A_F and parallel to the rotor axis A_R. This allows the rotor assemblies **231** to communicate with the air above the aircraft as will become more apparent.

The forward wings **211** are pivoted about axes A_W normal to the flight axis A_F and parallel to the rotor axis A_R. This allows the forward wings **211** to also act as ailerons to assist in controlling the banking of the aircraft. Each of the movable wings **211** is provided with upwardly and downwardly directed jet nozzles **249** that pivot with the wings **211** supplied with air from engines **228** to selectively generate a thrust from each to selectively control the roll attitude of the aircraft about flight axis A_F in combination with similar jet nozzles **250** in the aft wings **212** and jet nozzles **251** in the vertical stabilizer **214**. The jet nozzles **249** in the movable forward wings **211** can also be used to stabilize the aircraft forwardly and rearwardly along the flight axis A_F by rotating wings **211**.

The elevators **215** are each provided with a fixed section **255** and a movable section **256** similarly to elevator **14** on aircraft **10**. The movable sections **256** are also provided with reversing flaps **258** similar to elevator **14**. The elevators **215** operate similarly to the elevator **14**.

In operation, it will be seen that the second embodiment of the invention also has the vertical takeoff and landing capability similar to the first embodiment. When the aircraft **210** is to be started from a vertical takeoff position, it will be seen that the rotor assemblies **231** will be operated by the pilot from the pilot cockpit similarly to the rotor assemblies **31** in the first embodiment aircraft **10**. When this occurs, the rotor assemblies **231** will be pumping air from within the ducts **229** out through the bottom of the aircraft since the shutter vanes **236** below the rotor assemblies **231** are in their open position. In order to impress the pressure differential across the aircraft itself, the pilot, through appropriate controls, opens the shutter vanes **245** in intake shutter assemblies **244** closing cutouts **242** in the top of the propulsion section **224** while operating an appropriate closure mechanism to pivot the closure doors **241** at the intake opening **240** to ducts **229** to the position shown by phantom lines in FIG. **7** so that the closure doors **221** close the intake opening **240**. This places the air above the propulsion section **224** of the aircraft **210** in communication with the intake to the rotor assemblies **231** so that the air is now pumped from above the aircraft to below the aircraft by the rotor assemblies **231** to generate a lift on the aircraft. Where the rotor assemblies **231** are located forwardly of the center of gravity CG of the aircraft **210** as illustrated in FIG. **8**, the thrust generated by the jet engines **228** will be adjusted against the movable sections **256** of the elevators **215** so as to lift the rear end of the aircraft **210**. This will cause the aircraft to lift vertically for a vertical takeoff. The attitude of the aircraft can be adjusted by appropriately manipulating the rotor assemblies **231** in the manner explained for the first embodiment, and in addition, can be controlled using the jet nozzles **249** in the forward wings **211** and the jet nozzles **250** in the aft wings **212**. It will be noted that the jet nozzles **249** and **250** are connected to appropriate air bleed lines from the engines **228** and are provided with appropriate valves so that the pilot can control the thrust generated by the air flowing through the jet nozzles from the cockpit section **222** of the aircraft. The yaw attitude of the aircraft can be controlled using the low speed rudder **19** in the vertical stabilizer **214** in a manner described for the first embodiment of the invention and, in addition, by using the jet nozzles **251** in the vertical stabilizer **214** which is also connected by appropriate bleed lines and values to the jet engines **228**. The reversing flap **258** is used in a manner similar to that described for the first embodiment of the invention. The forward wings **211** may be rotated about their axes A_W so that the jet nozzles **249** therein can be used to control the fore and aft movement of the aircraft **210** along the flight axis A_F. After takeoff, the pilot can increase the thrust on the jet engines **228** and start propelling the aircraft forwardly alorg the flight axis A_F. As the speed of the aircraft increases so that the fore and aft wings **211** and **212** start producing lift, the pilot can vary the setting on the rotor assemblies **231** to reduce the airflow therethrough and/or can start opening the closure doors **241** closing the intake to the ducts **229** so that the air starts passing through the ducts to the intakes on the jet engines **228**. As the shutter vanes **245** in the shutter assembly **244** are moved toward a closed position, the intake of the air from above the aircraft into the ducts **229** can be regulated. When full forward flying speed is reached, the shutter vanes **245** can be completely closed as well as the shutter vanes **236** below the rotor assemblies **231** and the rotor assemblies **231** stopped from rotating or rotated in a neutral position so that aircraft operates relatively conventionally. Because of the aerodynamic inside shape of the ducts **229**, it may be desirable to not fully close the intake shutter vanes **245** so that air is continued to be drawn into ducts **229** through the shutter assemblies **244** as well as through the intake openings **240** to the ducts **229**. By leaving the shutter vanes **245** partly open, it will be seen that the flow pattern of the air through the ducts **229** can be more accurately controlled to maximize the amount of intake air passing into the intakes of the jet engines **228** from the ducts **229**. To make a vertical landing with the aircraft **210**, it will be seen that the procedure described will be reversed so that the forward flight of the aircraft along the flight axis A_F can be slowed and eventually stopped with the rotor assemblies **231** again supporting the weight of the aircraft for landing.

If a failure of the engines **228** is experienced, the rotor assemblies **231** can be manipulated similarly to that described for the first embodiment of the invention to speed up the free wheeling rotation of the rotor assemblies **231** to store sufficient rotational momentum therein to allow the rotor assemblies **231** to be reversed just prior to landing and permit safe landing of the aircraft. When this occurs, the gates **238** will usually be opened to increase the exposure of the rotor assemblies **231** to the air below the aircraft so as to rotate the rotor assemblies **231** sufficiently fast to store the required amount of rotational momentum to permit a safe landing.

I claim:

1. A lift augmenting device for an aircraft having a longitudinally flight axis along which the aircraft flies and a pilot cockpit and defining a pair of air intake ducts therein having forwardly facing air intakes thereto on opposite sides of the aircraft flight axis, said lift augmenting device comprising:

a pair of rotor assemblies positioned on opposite sides of the aircraft flight axis and rotatable about a common horizontal rotor axis generally normal to the aircraft flight axis, both of said rotor assemblies communicating with the air above and below the aircraft, one of said rotor assemblies operatively communicating with each of said air intake ducts for pumping air from within said intake duct through said rotor assembly to below the aircraft, each of said rotor assemblies including:

a plurality of rotor vanes circumferentially spaced about and rotatable with said rotor assembly, each of said rotor vanes individually pivoted about an individual vane pivot axis generally parallel to said rotor axis;

closure means for selectively closing each of said air intakes to said air intake ducts;

louver means for selectively connecting each of said air intake ducts to the air above the aircraft; and

vane control means for selectively controlling said rotor vanes on both of said rotor assemblies as said rotor vanes rotate with said rotor assemblies about said rotor axis to selectively change the lift imparted to the aircraft by said rotor assemblies; said vane control means including:

a pair of positioning drive mechanisms, one of said positioning drive mechanisms operatively associated with said rotor vanes of each of said rotor assemblies and including an inner race member rotatably fixed with respect to said common rotor axis and diametrically movable with respect to said common rotor axis along a positioning path generally normal to said rotor axis and the aircraft flight axis, an outer positioning ring rotatably mounted on said inner race member for rotation about said inner race member with said rotor assembly associated therewith, and a plurality of positioning links connecting said outer positioning ring individually with each of said rotor vanes on said rotor assembly so that shiting said inner race member along its positioning path causes said rotor vanes in communication with the air above the aircraft to pivot individually about their respective individual vane pivot axes in one pivotal direction while simultaneously causing said rotor vanes in communication with the air below the aircraft to pivot about their individual pivot axes in the opposite pivotal direction to selectively change the amount of air pumped from about the aircraft to below the aircraft and thereby change the lift imparted to the aircraft by said rotor means; and

a common drive mechanism controller operatively connecting said inner race members to selectively position said inner race members along their respective said positioning paths, said drive mechanism including first vane attitude control means selectively operated from the pilot cockpit for simultaneously moving both of said inner race members along said positioning paths in the same direction and second vane attitude control means selectively operated from the pilot cockpit for simultaneously moving said inner race members along their respective said positioning paths in opposite directions, said second vane attitude control means moving said inner race members independently of said first attitude control means.

2. A lift augmenting device for an aircraft having a longitudinal flight axis along which the aircraft flies and a pilot cockpit; defining a pair of air intake ducts therein on opposite sides of the aircraft flight axis having forwardly facing air intakes thereto and a rear end; and including forward propulsion means operatively associated with the rear ends of the air intake ducts for generating forward thrust to propel the aircraft forwardly along the aircraft flight axis; said lift augmenting device comprising:

a pair of rotor assemblies positioned on opposite sides of the aircraft flight axis and rotatable about generally horizontal rotor axes, one of said rotor assemblies communicating with each of said air intake ducts between the air intake thereto and the rear end thereof and with the air below the aircraft so that each rotor assembly can selectively pump air from within the duct to below the aircraft;

closure means for selectively closing the air intakes to the air intake ducts; and

louver means for selectively connecting each of the air intake ducts between the air intake thereto and the rear end thereof to the air above the aircraft so that, when said closure means closes the air intakes and said louver means connects the air intake ducts to the air above the aircraft, said rotor assemblies can pump air from above the aircraft through the air intake ducts to below the aircraft to generate lift on the aircraft.

3. The lift augmenting device of claim **2** wherein the center of gravity of the aircraft is located rearwardly of the lift forces generated by said rotor assemblies so that the rear end of the aircraft is urged downwardly when said rotor assemblies lift the aircraft and further including elevator flap means operatively associated with the forward thrust generating gas stream from the forward propulsion means so that said elevator flap means cooperates with the forward thrust generating gas stream to selectively impart a lifting force to the aircraft rearwardly of the center of gravity to assist in keeping the aircraft level during lifting.

4. The lift augmenting device of claim **3** wherein each of rotor assemblies includes a plurality of rotor vanes circumferentially spaced about and rotatable with said rotor assembly about said rotor axis, each of said rotor vanes oriented generally parallel to said rotor axis and individually pivoted about an individual vane pivot axis generally parallel to said rotor axis; and

vane control means operated from the pilot cockpit for selectively and individually pivoting each of said rotor vanes about its individual vane pivot axis as said rotor vanes rotate with said rotor means about said rotor axis to selectively change the lift imparted to the aircraft by said rotor assemblies.

5. A lift augmenting device for an aircraft having a longitudinal flight axis along which the aircraft flies, a pilot cockpit, a pair of generally horizontally oriented, opposed aerodynamic wings for lifting the aircraft when in forward flight along the flight axis, and forward propulsion means for generating forward thrust to propel the aircraft forwardly along the aircraft flight axis; said lift augmenting device comprising:

a generally vertically oriented rotor cutout defined through each of said wings;

a pair of rotor assemblies, one of said rotor assemblies rotatably mounted in each of said rotor cutouts about a generally horizontal rotor axis, each of said rotor assemblies projecting out of said cutout above the wing and below the wing so that said rotor assembly communicates with the air above the wing and the air below the wing; each of said rotor assemblies including a plurality of rotor vanes circumferentially spaced about said rotor assembly, each of said rotor vanes individually pivoted about a vane pivot axis generally parallel to said rotor axis; said rotor vanes spaced from said rotor axis so that each of said rotor vanes extends above the wing during a first portion of the rotation of said rotor vane about said rotor axis and extends below the wing during a second portion of the rotation of said rotor vane about said rotor axis; and

vane control means operated from the pilot cockpit for slectively pivoting each of said rotor vanes about its individual vane pivot axis as said rotor vanes rotate with said rotor assemblies, said vane control means including a pair of positioning drive mechanisms, one of said positioning drive mechanisms operatively associated with said rotor vanes of each of said rotor assemblies and each of said positioning drive mechanisms comprising:

an inner race member rotatably fixed with respect to said common rotor axis and diametrically movable with respect to said common rotor axis only along a positioning path generally normal to said rotor axis and the aircraft flight axis,

an outer positioning ring rotatably mounted on said inner race member for rotation about said inner race member with said rotor assembly associated therewith and for movement with said inner race member along said positioning path, and

a plurality of positioning links connecting said outer positioning ring individually with each of said rotor vanes on said rotor assembly so that shifting said inner race member upwardly along its positioning path causes said rotor vanes to be pivoted while moving above the wing to force air from above the wing into said rotor assembly, to be pivoted to a substantially neutral position while moving through said rotor cutout through the wing, and to be pivoted while moving below the wing to force air from within said rotor assembly to below the wing to generate only generally vertically oriented lift forces tending to lift the aircraft, the amount said rotor vanes are pivoted above and below the wing selectively variable by the amount of upward shifting of said inner race along its positioning path,

said vane control means further including a common drive mechanism controller operatively connecting said inner race members to selectively position said inner race members along their respective said positioning paths, said common drive mechanism operated from the pilot cockpit to selectively control the vertical lift on the aircraft by said rotor assemblies so that the vertical lift for the aircraft is provided by said rotor assemblies unit while the aircraft is moved sufficiently fast along its longitudinal flight axis by the forward propulsion means for the lift generated by the aerodynamic wings to keep the aircraft airborne.

6. The lift augmenting device of claim **5** wherein said drive mechanism controller includes first vane attitude control means selectively operated from the pilot cockpit for simultaneously moving both of said inner race members along said positioning paths in the same direction and second vane attitude control means selectively operated from the pilot cockpit for simultaneously moving said inner race members along their respective said positioning paths in opposite directions, said second vane attitude control means moving said inner race members independently of said first attitude control means.

7. The lift augmenting device of claim **5** wherein the center of gravity of the aircraft is located rearwardly of the lift forces generated by said rotor assemblies so that the rear end of the aircraft is urged downwardly when said rotor assemblies lift the aircraft and further including elevator flap means operatively associated with the forward thrust generating gas stream from the forward propulsion means so that said elevator flap means cooperates with the forward thrust generating gas stream to selectively impart a lifting force to the aircraft rearwardly of the center of gravity to assist in keeping the aircraft level during lifting.

8. The lift augmenting device of claim **5** further including power means for rotating said rotor assemblies in a direction so that said rotor vanes move forwardly with respect to the flight axis as said rotor vanes project above said wing and move rearwardly with respect to the flight axis as said rotor vanes project below said wing so that forward motion of the aircraft along its flight axis increases rather than decreases the pumping efficiency of said rotor assemblies generating vertical lifting forces on the aircraft.

9. The lift augmenting device of claim **8** wherein each of said rotor assemblies project below the wing a distance greater than the distance said rotor assembly projects above the wing so that, when said rotor vanes are adjusted to a neutral position completely around said rotor assembly, the air drag on said rotor assemblies while the aircraft is moving forwardly along its flight axis tends to rotate said rotor assemblies in the same rotational direction as when powered by said power means.

* * * * *

US005265827A

United States Patent [19]

Gerhardt

[11] **Patent Number: 5,265,827**

[45] **Date of Patent: Nov. 30, 1993**

[54] **PADDLE WHEEL ROTORCRAFT**

[75] Inventor: **Heinz A. Gerhardt**, Redondo Beach, Calif.

[73] Assignee: **Northrop Corporation**, Hawthorne, Calif.

[21] Appl. No.: **946,266**

[22] Filed: **Sep. 16, 1992**

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 716,431, Jun. 17, 1991, abandoned.

[51] **Int. Cl.**^{5} **B64C 29/00**

[52] **U.S. Cl.** **244/20**; 244/70; 244/9

[58] **Field of Search** 246/9, 19, 20, 17.19, 246/51, 17.21, 17.13, 70; 416/108, 111

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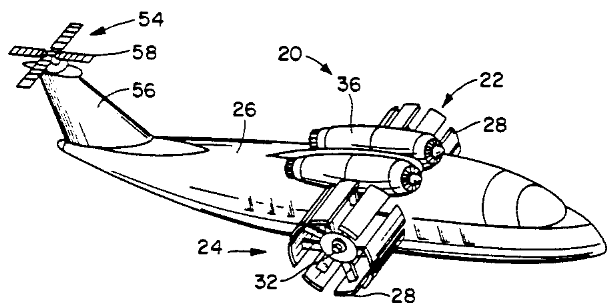
Primary Examiner—Galen Barefoot

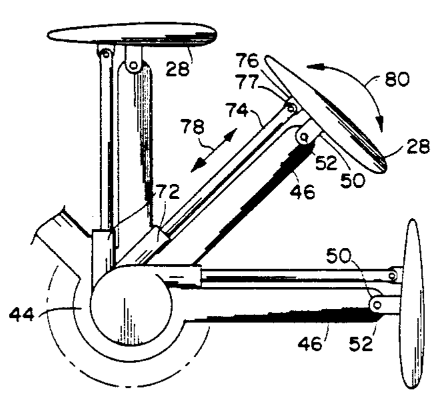
Attorney, Agent, or Firm—Terry J. Anderson; Robert B. Block; Karl J. Hoch, Jr.

[57] **ABSTRACT**

An aircraft having vertical takeoff and landing capability having at least first and second laterally extending paddle wheels rotatable on a central axis generally perpendicular to the longitudinal axis of the aircraft and between its nose and tail. Each of the paddle wheels has a plurality of blades pivoted by a system of linear actuators to a determined optimum blade pitch angle. One paddle wheel is positioned adjacent the port side of the aircraft and the other paddle wheel is positioned adjacent the starboard side. The pilot is able to operate the aircraft in all regimes of flight by differentially adjusting the pivot angle of each of the blades. In one embodiment utilizing only a pair of paddle wheels, differential operation of the blades provides lift, thrust, roll, and yaw control of the aircraft, while an aircraft pitch control rotor rotatable about a vertical axis distant from the paddle wheels is provided for controlling pitch of the aircraft. In another embodiment of the invention, the aircraft is provided with both forward and aft pairs of paddle wheels such that differential operation of the blades of the forward and aft paddle wheels provides pitch control of the aircraft without need of a separate pitch control rotor, while also providing lift, thrust, roll, and yaw control.

17 Claims, 3 Drawing Sheets





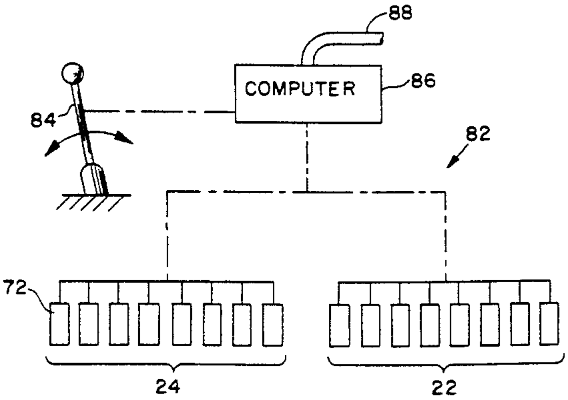


FIG. 1

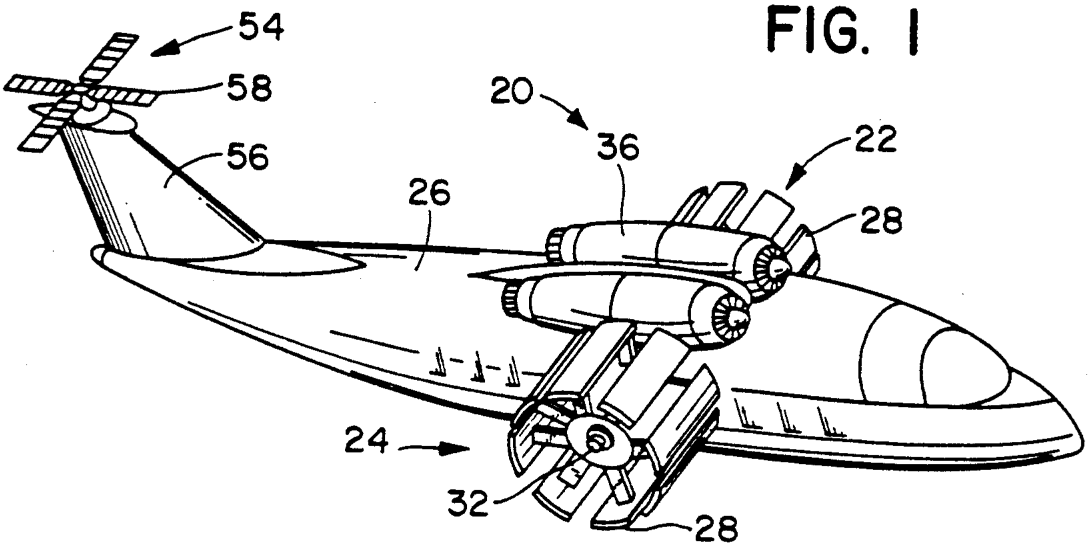


FIG. 2

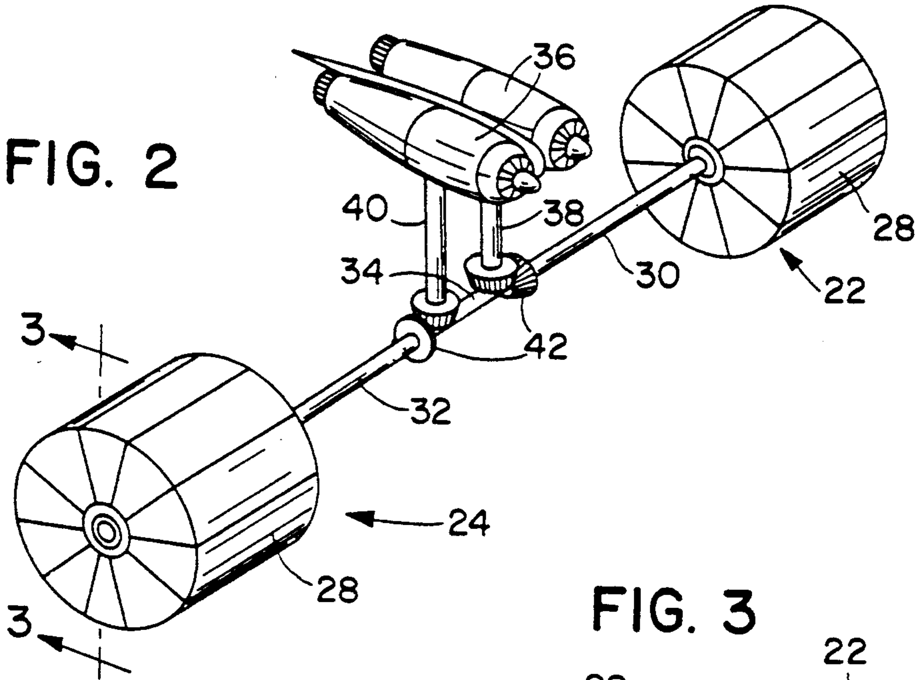


FIG. 3

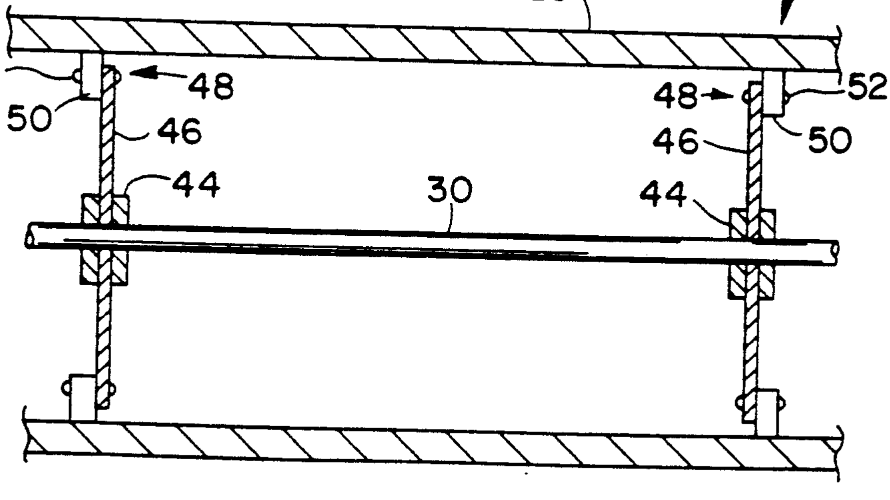


FIG. 4

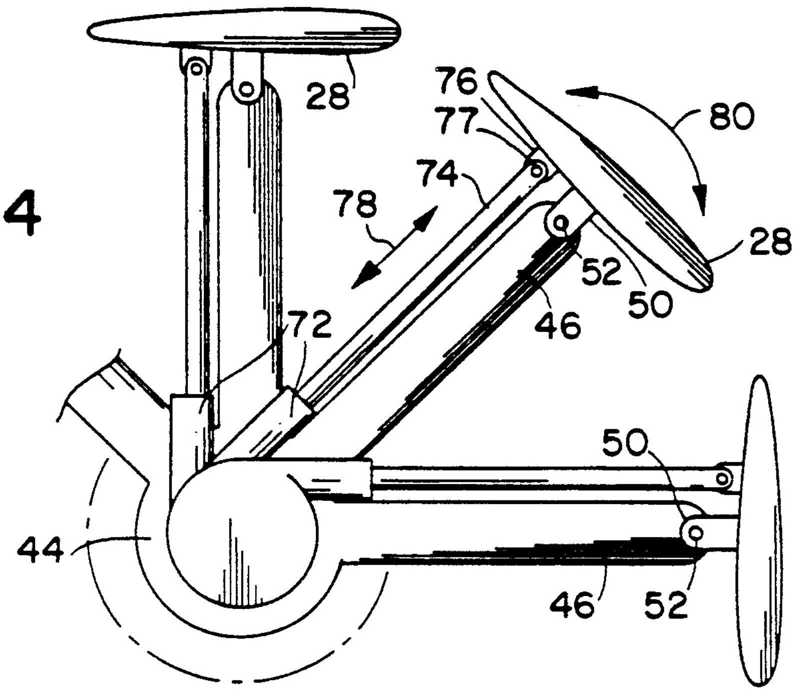


FIG. 5

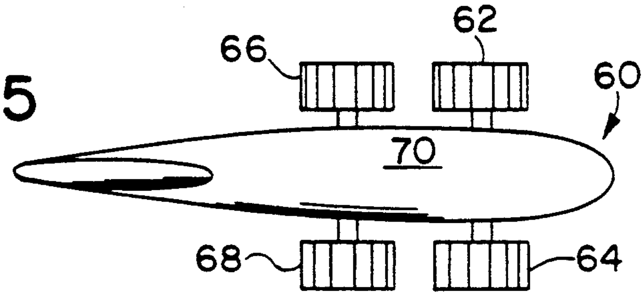
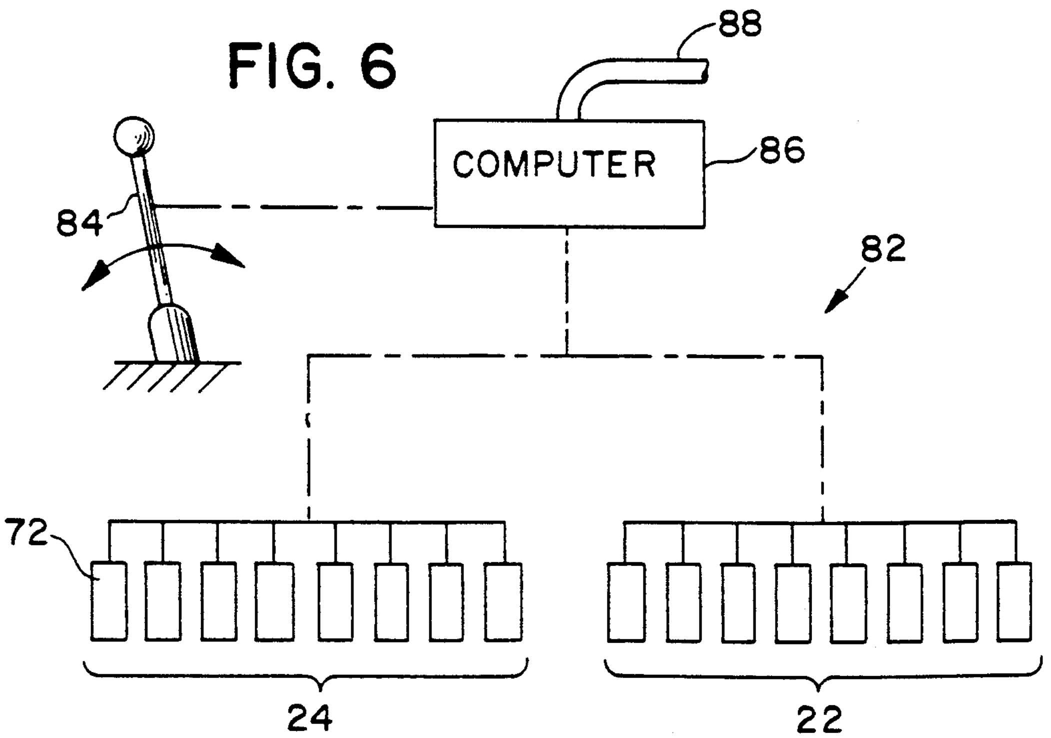


FIG. 6



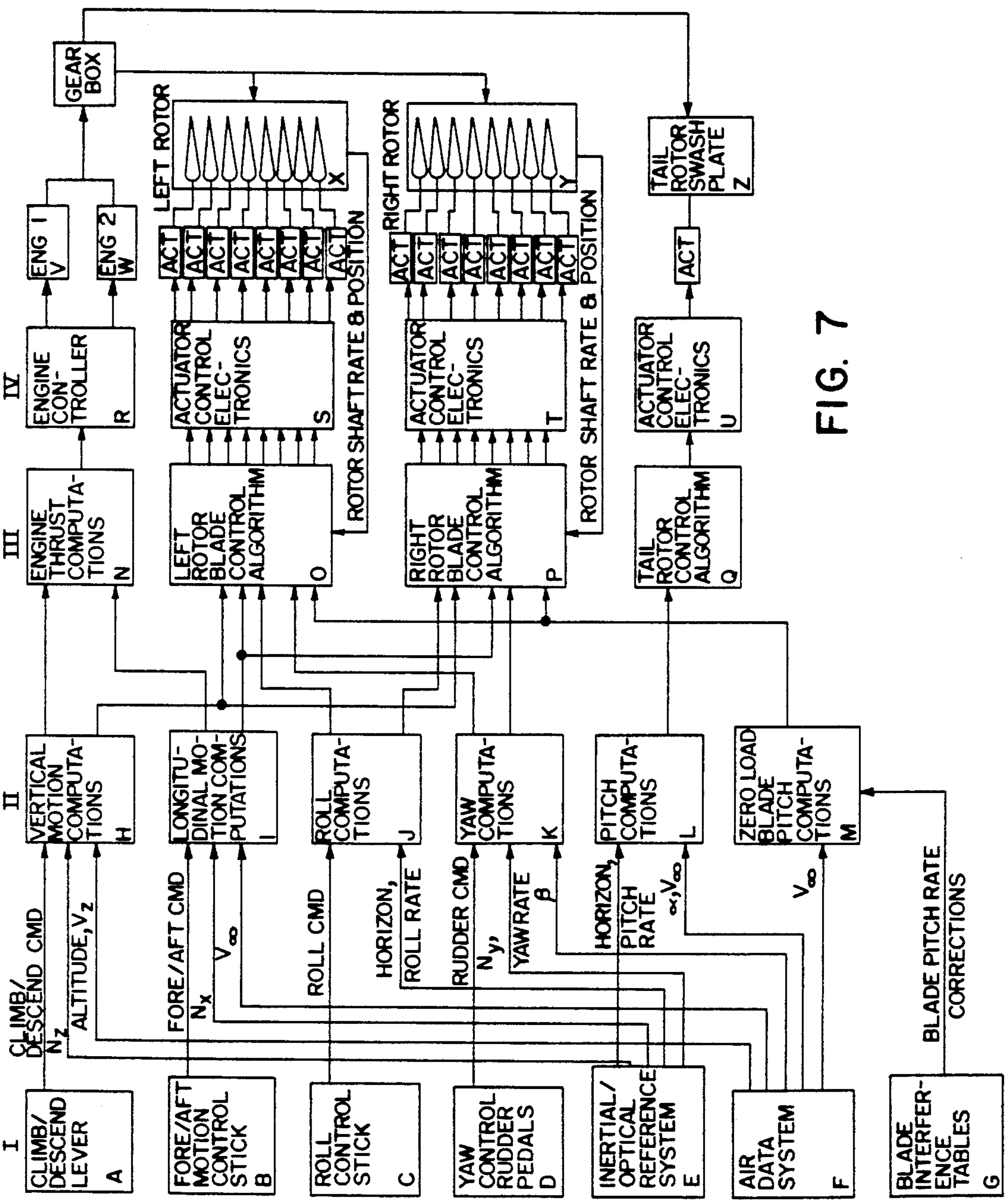

I
II
III
IV
CLIMB/ DESCEND LEVER A
FORE/AFT MOTION CONTROL STICK B
ROLL CONTROL STICK C
YAW CONTROL RUDDER PEDALS D
INERTIAL/ OPTICAL REFERENCE SYSTEM E
AIR DATA SYSTEM F
BLADE INTERFER- ENCE TABLES G
VERTICAL MOTION COMPUTA- TIONS H
LONGITU- DINAL MO- TION COM- PUTATIONS I
ROLL COMPUTA- TIONS J
YAW COMPUTA- TIONS K
PITCH COMPUTA- TIONS L
ZERO LOAD BLADE PITCH COMPUTA- TIONS M
ENGINE THRUST COMPUTA- TIONS N
LEFT ROTOR BLADE CONTROL ALGORITHM O
RIGHT ROTOR BLADE CONTROL ALGORITHM P
TAIL ROTOR CONTROL ALGORITHM Q
ENGINE CON- TROLLER R
ACTUATOR CONTROL ELEC- TRONICS S
ACTUATOR CONTROL ELEC- TRONICS T
ACTUATOR CONTROL ELEC- TRONICS U
ENG 1 V
ENG 2 W
LEFT ROTOR X
RIGHT ROTOR Y
TAIL ROTOR SWASH PLATE Z
GEAR BOX
ACT
ROTOR SHAFT RATE & POSITION
CLIMB/ DESCEND CMD
Nz
ALTITUDE, Vz
FORE/AFT CMD
Nx
V∞
ROLL CMD
HORIZON, ROLL RATE
RUDDER CMD
Ny,
YAWRATE
β
HORIZON, PITCH RATE
∝, V∞
BLADE PITCH RATE CORRECTIONS

FIG. 7

PADDLE WHEEL ROTORCRAFT

CROSS-REFERENCES TO RELATED APPLICATIONS

The application is a continuation-in-part of application Ser. No. 07/716,431, filed Jun. 17, 1991 now abandoned.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates generally to vertical takeoff and landing aircraft and, more particularly, to such aircraft which derive aerodynamic lift and thrust from opposed rotatable paddle wheel assemblies of airfoil-shaped blades in place of the wings and propellers or jet engines of a conventional airplane.

2. Description of the Prior Art

The history of the aircraft industry has been marked with innovations that have contributed in varying measure to the development of the present day aircraft, with each innovation recognizing or anticipating a changing need as ground transport gradually gave way to air transport. Early innovations in this development were directed to the range, speed and cargo capacity of the aircraft, with later innovations aimed at improved maneuverability and lift as aircraft size and weight increased and as urban areas mushroomed to lessen the adequacy of the city based airport.

With the obsolescence of the city-based airport, new airports of more adequate acreage were established in areas remote from the cities, at distances ranging from 10 to 50 miles and frequently necessitating more land travel time than flight time. Although aircraft accessibility was improved with the advent of air shuttle and land limousine services, the latter have provided but slight reductions in land travel time, and air shuttle service has remained generally out of the financial reach of the general public for use on a regular basis. With the advent of today's giant sized aircraft, even the remote area airports have required expansion, with runways being lengthened to satisfy their take off and landing requirements.

In recognition of the lift limitations of fixed wing aircraft and the cargo limitations of the helicopter, further innovation is required if present airport patterns are to be altered, with remote area airports ever expanding to accommodate commercial aircraft, and with city airports remaining the exclusive property of private and small commercial aircraft and helicopters.

In recent years, there has been more and more interest in the development of vertical takeoff and landing cargo and passenger carrying aircraft that have the capability of taking off and landing on either the shorter runways of the city airport or the longer runways of remote area airports, thereby preserving the utility of existing airports while at the same time bringing the ultimate destination of the traveler within more accessible and convenient reach, with land travel time reduced to its former more proportionate ratio. Tilt wing and tilt rotor concepts have generated particular interest as design compromises that have the vertical takeoff and landing advantages of the helicopter and approach the speed and range capability of conventional fixed wing aircraft. Such concepts have significant military potential as well as commercial.

In U.S. Pat. No. 1,754,977 to Bergman, an airplane is provided with rotatable assemblies of impeller blades having the shape of an inverted trough. As the impeller blades are rotated, shutter vanes pivotably suspended on each blade are opened or closed by air pressure to provide lift and thrust when closed, and to minimize drag when opened. The position of each impeller blade relative to its supporting assembly is controlled by a control eccentric to provide for vertical and horizontal motion of the aircraft.

In U.S. Pat. No. 2,123,916 to Rohrbach, an aircraft is provided with revolving assemblies of wings. The angle of incidence of the revolving wings is said to be controlled to the aerodynamically correct position relative to the incident airflow for all wing positions by an oscillation gear mechanism for all flight conditions.

In British Patent No. 480,750, a cyclogyro aircraft is provided with rotor assemblies each having a plurality of vanes distributed around the rotor axis. As the rotor rotates, the vanes are constrained to rotate relative to the rotor by an eccentric gear mechanism or, in another embodiment, a cam slot and pin follower, so that each vane is maintained at a substantially constant angle of attack relative to the resultant airstream. The gear or cam mechanism is adjustable to vary the phase, or angular disposition, of the vanes relative to the aircraft fuselage.

In U.S. Pat. 2,507,657 to Wiessler, an aircraft is equipped with rotors of pivotably mounted blades which operate in paddle wheel fashion. The cyclic variation of incidence of the blades and their initial relative inclination are controlled by supports which are journaled in a fixed axis. The fixed axis is slotted so that it may be positioned eccentrically relative to the rotor shaft. Screw mechanisms driven by motors vary the eccentricity of the fixed axis. The rotors may be held in fixed position when sufficient airspeed is attained, so that the blades act as conventional wings.

In U.S. Pat. No. 2,413,460 to Main, an airplane is provided with conventional wings and rotatable Cycloidal propellers disposed beneath the wings. Each propeller comprises an assembly of blades which are pivotably connected to spokes of the propeller. As the propeller rotates, the angles of incidence of the pivotably connected blades are controlled by a cam, roller, and linkage mechanism.

In U.S. Pat. No. 2,580,428 to Heuver, a cycloidal rotor for aircraft is described. The rotor provides lift and thrust as the rotor is rotated by the cycloidal motion of a series of airfoil members or blades relative to the rotor. Control of the airfoil motion, or pitch, is accomplished through a system of sprocket wheels, gear trains, linkages, eccentric pins, and levers.

In one interesting development disclosed in U.S. Pat. No. 4,210,299 to Chabonat, an aircraft is provided with a propulsion and lifting rotor comprising two diametrically opposed wings of aerofoil section located at respective sides of a fuselage at right angles to the rotor axis. Each of the wings is mounted for pivotal movement about a respective axis spaced from the axis of the rotor and lying parallel to the leading edge of the wing.

In one embodiment, a cam mechanism changes the angle of incidence of the blades both collectively and cyclicly. The cam preferably forms part of a set of cams keyed slidably on the cam shaft. By displacing the set of cams, it is possible to modify the pattern of incidence variation as a function of the speed of flight.

In another development, as disclosed in U.S. Pat. No. 4,194,707 to Sharpe, an aircraft is provided with rotor assemblies on opposite sides of its flight axis. The vanes on the rotor assemblies are each individually pivoted by means of a complex linkage system so that the rotor vanes can be pivoted in one direction to draw air into the rotor assembly while the vanes are in communication with the air above the aircraft and can be pivoted in the opposite direction to discharge air from within the rotor assembly while the vanes are in communication with the air below the aircraft to exert lift on the aircraft. The vanes on both the rotor assemblies can be simultaneously oriented in the same sense and degree of pivoting or can be pivoted in the opposite sense. This allows the rotor assemblies to be selectively controlled so as to give the aircraft a vertical takeoff and landing capability.

U.S. Pat. No. 4,482,110 to Crimmens, Jr., describes a composite aircraft in which a system of wing and blade airfoils rotate about the horizontal longitudinal axis of a lighter-than-air gas containment bag to provide lift and thrust for augmenting or opposing the aerostatic lift forces of the gas containment bag. Engines mounted on the airfoil components rotate the wing and blade airfoils and gas containment bag about the longitudinal axis of the gas containment bag. Each wing airfoil and engine assembly are rotatably mounted on a structural support, their rotation being controlled by a system of cylinders, pulleys, and cables such that, in forward flight when the cyclorotor does not rotate, the wings can be rotated to a point where the spanwise axis of the wings is perpendicular to the horizontal axis of the aircraft and thus provide lift in the manner normal to fixed wing aircraft. The angle of attack of each wing is further controlled by a system of cylinders, pulleys, and cables which rotate each wing about its spanwise axis. The angle of attack of the blade airfoils is also controlled by a system of cylinders, pulleys, and cables to rotate the blades about their spanwise axes, so that the blades provide propeller-like thrust for forward or rearward movement of the composite aircraft.

The positions of the wing and blade airfoils are controlled through an electronic control system which accepts input commands from the pilot, or a remote control operator, or an autopilot, and also input data as to aircraft altitude, attitude, heading, and ground relative positions, and generates cyclic and collective control signals for servo control of blade and wing airfoil positions.

And, in U.S. Pat. No. 5,100,080 to Servanty, a rotor for developing lift and propulsive forces for an aircraft is disclosed. The rotor comprises several rotatable profiled blades. The angle of incidence of each blade is controlled in real time as a function of the angular position of the blade in the rotor's rotation cycle and the flight conditions of the aircraft to produce the optimum lift and propulsion forces from each blade for the then-existing flight conditions.

In Servanty, a computational device is used to store physical configuration information about the rotor and blades, to measure and determine at each instant the aerodynamic conditions governing the production of lift and thrust by the blades and also the azimuthal position of each profiled blade, to generate control signals representative of the lift and drag forces desired for a particular flight condition, and to calculate the instantaneous geometric angle required for each blade as a function of the aforementioned stored parameters, determined values, and control signals. Control means are provided to position each blade at each instant to the instantaneous geometric angle calculated for that blade.

The movement of each profiled blade is obtained by combining an average movement, or cyclic angle of incidence, and a complementary movement, or additional angle of incidence. The average movement is produced by a "kinematic chain" which is common to the set of profiled blades and has a mechanical structure corresponding to the particular "law" chosen for the average movement, as for example a circular translation of each blade during one revolution of the rotor.

The "kinematic chain" comprises a flange connected to the rotor shaft, which supports the body of a rotary hydraulic actuator associated with each profiled blade, and a toothed wheel centered on the rotor shaft, which is coupled to a mechanical phase shifter and drives the bodies of the rotary hydraulic actuators as the rotor revolves to rotate the profiled blades according to the selected average cyclic "law" of incidence.

The complementary movement is obtained by a hydraulic system, powered by rotation of the rotor, which includes distributors and servo valves associated with each rotary actuator to provide hydraulic power to that actuator to generate the complementary movement in response to control signals from the calculating means.

In Servanty, the mechanical structure and configuration of the kinematic chain are defined by the particular cyclical variation of blade angle selected, and cannot be changed without massive redesign of the kinematic chain. Although the invention of Servanty thus provides for a relatively reduced amplitude of movement of the rotary actuators, it precludes operational flexibility of the rotor to adapt to conditions where other patterns of cyclic variation would be more effective for a particular flight condition, or where no pattern of cyclic variation is required for optimum performance. Additionally, the invention of Servanty requires a more complex implementation of the instantaneous blade geometric angle, Ψ, than the present invention since the angle is achieved by combining the average and complementary movements discussed above, rather than directly.

While the basic concepts presented in the aforesaid patents are desirable, the mechanisms employed to effect their operation are far too complicated to render them practical, have limited or no flexibility to adapt to differing flight conditions, and the extent of control achieved is minimal. It was in light of the prior art as just discussed that the present invention has been conceived. In short, it is an object of the present invention to provide an aircraft having the cargo capacity of the modern fixed wing aircraft and a lift comparable to the helicopter, such that existing city based and remote area airports may be utilized for vertical landings and takeoffs, enabling the traveler to embark and disembark in closer proximity to his or her home and destination. It is a further object of the present invention to provide such an aircraft in which cyclic variations of the individual blades of the paddle wheel assemblies of the aircraft are optimized for each flight condition and pilot command, and in which the blades are pivoted to their respective optimum angle of incidence by a system of controlled linear actuators which is more flexible and adaptable to differing flight conditions than the cam and gear mechanisms of the prior art.

SUMMARY OF THE INVENTION

To the aforementioned end, the present invention provides an aircraft having vertical takeoff and landing capability provided with at least first and second laterally extending paddle wheels rotatable on a central axis perpendicular to the longitudinal axis of the aircraft fuselage and between its nose and tail. Each of the paddle wheels has a plurality of blades with lateral axes parallel to the central axis and arranged in a cylindrical surface at equally spaced circumferential locations equidistant from the central axis. One paddle wheel is positioned adjacent the port side of the aircraft and the other paddle wheel is positioned adjacent the starboard side. The pilot is able to operate the aircraft in all regimes of flight by differentially adjusting the attitude of each of the blades relative to the cylindrical surface about its lateral axis.

In one embodiment utilizing only a pair of paddle wheels, differential operation of the blades provides lift, thrust, roll, and yaw control of the aircraft and an aircraft pitch control rotor rotatable about a vertical axis distant from the paddle wheels is provided for controlling pitch of the aircraft. In another embodiment of the invention, an aircraft may be provided with both forward pairs and aft pairs of paddle wheels such that differential operation of the blades to the forward and aft paddle wheels can effect pitch control of the aircraft without need of a separate pitch control rotor.

In this manner, a vertical takeoff and landing aircraft having superior capabilities in regard to payload, speed, and handling characteristics is provided. It is of simplified mechanical construction. At the same time, the airfoils of the paddle wheels can be controlled in complex patterns by means of a computer to achieve whatever flight pattern the pilot chooses.

The airfoils of the paddle wheels require a cyclic pitch actuation which refers to the fact that, as the paddle wheel revolves, the airfoil pitch angle needs to change as a function of vehicle speed and peripheral position of the airfoil. This is to ensure that, as a starting condition, the airfoils are brought into alignment with the local flow direction relative to the revolving blades, which is the vector sum of vehicle speed and the tangential velocity of the rotating wheel. Superimposed on these cyclic blade pitch deflections are deflections required to generate air loads on the blades as they rotate past specific positions on the wheel circumference. The blade airloads represent either lift or thrust depending on the direction of these forces. The magnitudes of the airfoil pitch angles at various peripheral positions need to be accurately and precisely controlled according to complex schedules which ensure the required production of lift and thrust at any flight condition, defined as a certain combination of airspeed, altitude, maneuvering load factor, acceleration and deceleration, and level, climbing, or descending flight path.

Satisfying a flight condition implies certain power settings, paddle wheel rotation rates and cyclically varying pitch settings. Each flight condition is associated with a specific advance ratio which relates the speed of flight to the tangential velocity of the rotating paddle wheel. The advance ratio, α, is commonly used in propeller and helicopter design theory and is defined by the following formula:

$$\lambda = \frac{V_{\infty}}{\pi n d}$$

where V_{∞} is the speed of travel of the vehicle measured in feet per second; n is paddle wheel revolutions per second; and d is diameter of the paddle wheel in feet. It follows that the vehicle speed must be measured continuously and a corresponding signal be used in setting the proper blade incidence.

It was previously noted that the construction in the U.S. Pat. No. to Chabonat, No. 4,210,299, utilizes a cam and follower arrangement for positioning its airfoils. In that instance, one particular cam shape would satisfy the cyclic blade pitch variations for one particular flight condition. However, many different cam shapes would be necessary to cover the operations at a sufficient number of flight conditions. Similar limitations and disadvantages are found in the inventions of the other references.

And, although the invention of Servanty, No. 5,100,080, provides some flexibility in this regard by superimposing a complementary blade angle movement upon the average cyclic angle of incidence for the blade produced by the kinematic chain, the flexibility of the Servanty invention is limited by the fixed mechanical configuration of the kinematic chain.

It is this lack of flexibility of mechanical cam and push rod systems, and the complexity of such systems, which the present invention overcomes. This is accomplished by providing a variable stroke linear piston and cylinder blade pitch actuation system, which is operated by computer signals of an electronic airfoil (blade) pitch control system which embodies the cyclic steering commands in mathematical form, instead of the mechanical systems of the prior art. The flight computer processes both the pilot steering commands and signals from an inertial and air data system to generate composite guidance commands for the blade pitch actuation mechanisms.

Other and further features, advantages, and benefits of the invention will become apparent in the following description taken in conjunction with the following drawings. It is to be understood that the foregoing general description and the following detailed description are exemplary and explanatory but are not to be restrictive of the invention. The accompanying drawings which are incorporated in and constitute a part of this invention, illustrate one of the embodiments of the invention, and, together with the description, serve to explain the principles of the invention in general terms. Like numerals refer to like parts throughout the disclosure.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a perspective view of a vertical takeoff and landing aircraft depicting one embodiment of the invention;

FIG. **2** is a perspective view of certain components illustrated in FIG. **1**;

FIG. **3** is a cross section view taken generally along line **3**—**3** in FIG. **2**;

FIG. **4** is a detail end elevation view of the paddle wheel illustrated in FIG. **3**;

FIG. **5** is a top plan view of another embodiment of the invention;

FIG. 6 is a simplified schematic diagram of a control system for operating an aircraft embodying the invention; and,

FIG. 7 is a detailed block diagram of the control system.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

In FIG. 1, a vertical takeoff and landing aircraft 20 embodying the invention is illustrated. The aircraft 20 derives aerodynamic lift and thrust from large paddle wheels 22, 24 respectively extending from the opposite port and starboard sides of a fuselage 26. Fuselage 26 has a nose at its forward end and a tail at its aft end, and a longitudinal axis extending therebetween. Each paddle wheel 22, 24 is mounted to the fuselage 26 for rotation about a common axis which extends perpendicular to the longitudinal axis between the nose and the tail. Each of the paddle wheels 22, 24 is provided with a plurality of airfoil-shaped blades 28 positioned about its periphery. The blades 28 of the paddle wheels 22, 24 are actuated in response to a complex mixture of control parameters which:

(a) ensure that the blades produce lift or thrust or at least operate without an adverse load;

(b) change magnitude of lift and thrust; (c) accommodate the changes in the flow relative to the blades as caused by changing flight speed and wheel rotation rate;

(d) achieve roll and yaw control;

(e) provide vehicle stability and damping of yaw and roll motions; and

(f) account for flow interference between the blades.

It will be appreciated that as an inherent safety feature, the paddle wheels are capable of autorotation. This feature can be demonstrated by operational paddle wheel type windmills which are rotatable about vertical axes.

As compared to a helicopter, the aircraft 20 has the inherent advantage of symmetry. It does not suffer from the maximum speed limitations of the helicopter arising from stall at the retreating blade since retreating blades on the aircraft 20 need not maintain lift and can be deactivated by appropriate pitch deflections so that they carry no adverse airload. Furthermore, the peripheral speed of the advancing blades need not be higher than the free stream velocity of the aircraft 20. In other words, the rotors of the aircraft 20 and, specifically, of the paddle wheels 22, 24, can be slowed down at higher flight speeds and, as a consequence, the critical blade Mach number is desirably increased. A further increase in critical blade Mach number can be achieved by sweeping the blades, i.e., by mounting them obliquely on the wheel periphery.

Additionally, the aircraft 20 fits into the high speed, high disk loading category currently represented by tilt rotor aircraft. It is therefore appropriate to compare the salient features of the two concepts. While the tilt rotor design must tilt the combined rotor and engine assembly in order to transition from hover to high speed flight and return, the aircraft of the invention achieves transition by simply changing blade pitch. For safety reasons, the outboard engines of the tilt rotor aircraft are cross shafted while the rotors of the aircraft 20 have a common drive axle. The tilt rotor aircraft cannot land safely with its rotors operating in its propulsion mode, a condition which does not apply to the aircraft 20. Additionally, while the tilt rotor aircraft requires a wing to provide aerodynamic lift at high speeds and to support the engine and rotor assemblies, the aircraft 20 does not require a wing.

It will be appreciated that design constraints limit the relative size of the paddle wheels 22, 24. Their diameters are limited to approximately twice the height the of the fuselage 26 assuming the axles 30 and 32 on which they rotate are positioned adjacent the uppermost regions of the fuselage. For structural reasons, the span of each of the paddle wheels 22, 24, would preferably be the same order as their diameters.

The main load member for each of the paddle wheels 22, 24, are the axles 30, 32, respectively, previously noted. The axles 30, 32 are suitably mounted on the fuselage for rotation about the common axis and extend, respectively, from the port and starboard sides of the fuselage. By means of a cross axle 34, the axles 30, 32 are joined for unitary rotation. The paddle wheels 22, 24 are shown as powered by a pair of engines 36, as for example gas turbine engines, mounted to fuselage 26 which drive the axles 30, 32 in rotational motion via drive shafts 38, 40 operating through suitable transmissions 42 and cross axle 34 as diagrammatically illustrated in FIG. 2. Those skilled in the art will appreciate that in other embodiments a single gas turbine engine, or more than two gas turbine engines, may be utilized.

With particular reference to FIG. 3, the construction of a paddle wheel will now be described. Although the description of a paddle wheel will be with respect to the paddle wheel 22, the description will pertain to paddle wheel 24 and any other paddle wheels which may be employed. Hence, the paddle wheel 22 is seen to include the axle 30 which extends laterally away from the fuselage 26 and is aligned with a central axis of the paddle wheel and the common axis. A pair of laterally spaced hubs 44 are fixed to the axle 30 for rotation therewith, each hub 44 having a plurality of spokes 46 integral with the hub 44, each spoke 46 extending radially away from the hub 46 to a tip end 48.

Paddle wheel 22 has a plurality of airfoil-shaped blades positioned about the periphery of the paddle wheel. Each blade 28 has a pair of laterally spaced support lugs 50 extending inwardly toward axle 30 from a underside of the blade 28 at opposing ends of each blade 28 and which are pivotably attached, respectively, by means of support pins 52, to the tip ends 48 of an associated pair of spokes 46 extending in similar radial positions from hubs 44. Each blade 28 also has a pair of laterally spaced control lugs 76 (FIG. 4) at opposing ends of the blade 28, which extend inwardly towards axle 30 and which are spaced chordwise from the support lugs 50 for pivoting the blade 28 as is discussed below.

As seen in FIG. 4, each hub 44 has associated therewith a plurality of variable stroke linear actuators 72, each actuator 72 being associated with one of the plurality of spokes 46 of the hub 44 and with the blade 28 pivotably attached to the tip end 48 of the associated spoke 46, the actuator 72 extending in similar radial position from the hub 44 as the associated spoke 46. Only three blades 28, spokes 46, and actuators 72 have been shown, but it is to be understood that all blades 28 of the paddle wheels 22, 24 are configured as those blades 28 which are shown. The actuators 72 may be of any suitable mode of operation, that is, electromagnetic, hydraulic, pneumatic, or the like. A pitch control rod 74 is associated with each actuator 72 and extends from the actuator 72 to a control lug 76 inwardly extending toward axle 30 from an underside of the blade 28, the pitch control rod 74 being pivotably attached to the control lug 76 by a control pin 77. The control lug 76 is associated with the support lug 50 of the blade 28 pivotably attached to the spoke 46 associated with the actuator 72, and is spaced chordwise from the support lug 50 such that movement of the pitch control rod 74 in the directions indicated by double arrowhead 78 results in pivotal movement of the blade 28 about the support pin 52 in the manner indicated by a double arrowhead 80.

By proper differential control of the stroke of the actuators 72 and thereby of the pivotal movement of the blades 28 of the first paddle wheel 22 of aircraft 20 of FIG. 1, relative to the strokes of the actuators 72 and the pivotal movement of the blades 28 of the second paddle wheel 24, lift, thrust, yaw, and roll control is achieved. However, for pitch control of the aircraft, that is control of the aircraft about an axis parallel to and aligned with the axles 30, 32, an aircraft pitch control rotor 54 is provided as shown in FIG. 1. In addition to providing pitch control, rotation of the rotor 54 generates moment forces to counter the torque developed by rotation of paddle wheels 22 and 24. The pitch control rotor 54 is rotatably mounted at tail 56 of the aircraft fuselage 26, longitudinally spaced along an axis of the fuselage 26 aft of the axles 30, 32. The pitch control rotor 54 has a plurality of rotor blades 58 which define a rotor disk which lies in a plane generally parallel to the plane of the common axis of rotation of the paddle wheels 22, 24 and the longitudinal, or roll, axis of aircraft 20. The pitch control rotor 54 may be driven in a suitable fashion by the engines 36 or, alternatively, may be driven by an auxiliary power plant (not shown).

Another embodiment of the invention is illustrated in FIG. 5 and represented by reference number 60. In this instance, two pairs of paddle wheels, forward paddle wheels 62, 64 and aft paddle wheels 66, 68, are provided at different longitudinally spaced locations along a fuselage 70. Forward paddle wheel 62 and aft paddle wheel 66 are pivotably mounted to and extend laterally away from the port side of the fuselage 60, and forward paddle wheel 64 and aft paddle wheel 68 are pivotably mounted to and extend laterally away from the starboard side of the fuselage 60. Forward paddle wheels 62, 64 are mounted to the fuselage 70 for rotation about a first common axis as has been described with respect to paddle wheels 22, 24. Aft paddle wheels 66, 68 are mounted to the fuselage 70 for rotation about a second common axis generally parallel to the first common axis and laterally spaced from the first common axis between the first common axis and the tail of fuselage 70. An engine or engines (not shown) drive the axles of forward paddle wheels 62, 64 as was discussed earlier with respect to axles 30,32, and also drive the axles of aft paddle wheels 66,68 through a second transmission and cross axle joining the axles of aft paddle wheels 66, 68 for unitary rotation.

Aft paddle wheels 66, 68 are mirror images of forward paddle wheels 62, 64 but may be of different diameters than forward paddle wheels 62, 64. They rotate in opposite senses to counteract each other's torque. In all other respects, the paddle wheels 62, 64, 66, and 68 are similar to the paddle wheels 22, 24. In this embodiment, however, pitch control is achieved as well as lift, thrust, yaw, and roll control, by differential adjustment of the strokes of the actuators and the pivot angles of the blades of the forward and aft paddle wheels 62, 64, 66, and 68. Yaw and roll control of the aircraft 60 is achieved by differentially adjusting the strokes of the actuators and the pivot angle of the blades of the port paddle wheels 62, 66 as compared to the strokes of the actuators and the pivot angles of the blades of the starboard paddle wheels 64, 68. Pitch control is achieved by differentially adjusting the strokes of the actuators and the pivot angle of the blades of the forward paddle wheels 62, 64 relative to the strokes of the actuators and the pivot angles of the blades of the aft paddle wheels 66, 68.

The stroke of each of the actuators 72 is controlled by a sophisticated control system 82 depicted schematically in FIG. 6. Hence, operation of a control yoke 84 by a pilot imparts inputs to a computer 86 which, in turn, operates the actuators 72 for each of the paddle wheels 22, 24 illustrated in FIG. An airspeed sensor, such as pitot tube 88 schematically depicted in FIG. 6, provides an input signal which the computer must utilize in addition to the pilot's command in order to determine the optimum blade settings. A somewhat more complicated control system would be required for the aircraft 60 depicted in FIG. 5. The stroke of the actuators 72 is controlled by the computer 86 which accounts for changes in advance ratio and in accordance with the pilot commands inputted via the control yoke 84.

The control scheme for the aircraft of the present invention is shown in detail in the block diagram of FIG. 7, depicting the processing and flow of information controlling the actuation of each rotor blade. It is a digital control system allowing the superposition of various control parameters by using a flight control computer.

Control inputs originate as pilot commands and signals from the inertial and air data systems. Similar to a helicopter, the aircraft of the present invention does not have natural flight stability. In other words, if the aircraft attitude or flight path is disturbed by a gust of air, for instance, it does not develop restoring forces or moments. In order to relieve the pilot from constantly controlling the aircraft attitude, artificial stability is provided by the control system which acts in response to signals from the inertial and air data systems.

In FIG. 7, the parameters N_x, N_y, and N_z, denote the aircraft accelerations in the directions of its longitudinal, lateral, and vertical axes, respectively. The parameter V_z, denotes the aircraft vertical rate of ascent or descent, as applicable. The term V_∞ represents aircraft speed of travel, and the term β represents the aircraft side slip angle. Other outputs from the modules of Column I are as indicated, i.e., climb/descend commands, aircraft altitude, fore/aft motion commands, roll commands, horizon position (i.e., bank angle), aircraft roll rate, yaw rate, pitch rate, and rudder commands.

For reasons of space limitations, the engines of the aircraft are depicted in Blocks V and W as "ENG1" and "ENG2," respectively, and the actuators operating on the individual blades of the rotors and the tail rotor swash plate have been depicted by those blocks marked "Act". It will be appreciated that the lines connecting the blocks of FIG. 7 in some instances represent electrical connections while in other instances, as between the engines and gear box and between the gear box and the rotors and tail rotor swash plate, they represent mechanical connections such as a power transmission drive train. It will also be appreciated that, although not shown, signal transmissions between the actuator control electronics and the rotor-mounted actuators are achieved by any conventional means known in the art such as slip rings.

The blocks in Column I (Blocks A through F) represent control input devices and aircraft and air data sensors providing information for aircraft control and stabilization. The blocks in Column II (Blocks H through M) represent computer modules for combining pilot commands and stabilization parameters to ensure smooth execution of the commands and stable flight. The functions performed by the modules of Blocks H through M include signal conversion from analog to digital, filtering, and gain scheduling. The processed control signals are then transmitted to the corresponding controller modules for the rotor blade pitch actuators, tail rotor swash plate, and engine power controllers, through the modules of Column III (Blocks N through Q) which further process the converted input commands according to their respective control algorithms to embody the steering commands in mathematical form. In the modules of Column III, the processed signals are combined and distributed to the various controller modules of Column IV (Blocks R through U). The distribution process requires additional information on rotor shaft rate and circumferential blade position, which is provided through the indicated feedback loops.

Piloting the aircraft of the present invention is unique in that independent control of vertical and horizontal motion is provided. A climb/descend lever (A), preferably for the pilot's left hand, controls the vertical component of the aircraft motion vector. Movement of the fore and aft control stick (B) controls the horizontal component of the aircraft motion vector. Therefore, either command affects not only the rotor blade position but also the power setting of the engines.

Changing the lift of the aircraft can be achieved as in ordinary aircraft by changing the angle of attack, α, of the aircraft, i.e., the angle between the aircraft longitudinal axis and the aircraft speed (V_∞) vector. However, in the aircraft of the present invention, the lift is preferably changed in a more direct way by changing the blade deflections. The fuselage attitude is controlled by the control system rather than the pilot. This is achieved by module L of Column II. There are two modes for this attitude stabilization. In regular flight, the fuselage longitudinal axis is maintained in alignment with the velocity vector, i.e., in a level orientation during horizontal flight and in a nose-up or nose-down orientation during climb and descent, respectively. The attitude stabilization is switched to a level attitude hold mode during hover and during flight at low airspeeds when the angle of attack is not accurately determinable by the air data system (F). In that case, the optical and inertial reference system (E) inputs ensure that a horizontal attitude of the aircraft is maintained. For an aircraft design having two opposed rotor assemblies on either side of the fuselage, a tail rotor provides primary attitude control and anti-torque moments.

Roll and yaw control and stabilization are also achieved through blade pitch angle changes. Pilot command inputs for such controls are made by conventional means as for fixed-wing aircraft through the use of rudder pedals (D) and a roll control stick (C).

All pilot input commands, aircraft and air data system inputs, and stabilization inputs as depicted in blocks H, I, J, and K result in the determination of an incremental blade deflection angle which is combined with the zero load blade deflection angle determined for each blade of each rotor. The zero load blade deflection angle for a blade is that deflection angle necessary to align the blade with the local flow vector. The local flow vector is the vector sum of the aircraft velocity and the tangential velocity of the rotating paddle wheel blade at the peripheral position of the particular blade. In response to a pilot input command, a flight condition as sensed by the inertial reference system and the air data system, and the stabilization inputs, the incremental and zero load blade deflection angles are continuously determined in mathematical form for each blade at each peripheral blade position as the paddle wheel rotates. The determined instantaneous incremental and zero load blade deflection angles are combined to produce an optimum net blade pitch angle for each blade at each peripheral position, and the stroke of each actuator is controlled to continuously pivot each blade to the optimum net blade pitch angle for the input command and sensed flight condition as the paddle wheel rotates. By pivoting each blade to the optimum net blade pitch angle, the paddle wheels operate at optimum efficiency in response to each pilot input command, flight condition, and stabilization input.

When a blade carries an airload, it will deflect the air flow passing it, and this air flow deflection alters the air flow directions at the other blades. The magnitude of these interferences is small, and in general only the adjacent downstream blades are affected. A larger interference exists in the four-rotor configuration of FIG. 5, where the collective flow deflection generated by the forward paddle wheels 62, 64 produces a downwash at the aft paddle wheels 66, 68. The present digital control system can easily produce compensating blade deflections to account for such phenomena and thereby achieve a performance gain. The flow interference can be calculated using computational fluid dynamics methods known in the art, or they can be determined experimentally through wind tunnel testing and mathematically modeled. In one embodiment of the present invention, such blade interference information is provided to the control system computer in the form of look-up tables or curve-fitting equations, as represented by Block G of FIG. 7. Blade interference information from Block G is utilized together with the rotor shaft rate and position feedback information in Block 0 and P to produce the appropriate blade deflection corrections for blade interference effects.

The aircraft of the present invention thus provides a vertical take-off and landing aircraft which employs a practical, simple, and flexible approach to controlling the individual blade angles of incidence of the airfoils of the paddle wheel assemblies. Because a variable stroke piston and cylinder actuator system controls the instantaneous blade pitch angle of each blade in response to blade pitch control signals processed electronically in mathematical form, blade pitch angle is controlled without recourse to the complex gear drives, cam/follower mechanisms, kinematic chains, and similar mechanical devices of prior art rotorcraft. The aircraft of the present invention thus provides an innate flexibility to adapt to changing flight conditions through changes in the blade pitch angles which are not constrained by physical and mechanical implementations of specific pitch control laws. And, through modeling of blade interference effects, the control system of the present invention enables the performance of the aircraft of the present invention to be optimized with respect to such effects, a feature not provided by the prior art.

While preferred embodiments of the invention have been disclosed in detail, it should be understood by those skilled in the art that various other modifications may be made to the illustrated embodiments without departing from the scope of the invention as described in the specification and defined in the appended claims.

What is claimed is:

1. An aircraft having vertical takeoff and landing capabilities, comprising:

a fuselage having a nose and a tail, a longitudinal axis extending therebetween, and port and starboard sides;

first and second paddle wheels rotatably coupled to the fuselage for rotation about a first common axis perpendicular to the longitudinal axis between the nose and the tail, the first paddle wheel extending laterally away from the port side, the second paddle wheel extending laterally away from the starboard side, each paddle wheel having

an axle aligned with a central axis of the paddle wheel and rotatably coupled to the fuselage,

first and second laterally spaced hubs fixed to the axle for rotation therewith,

a plurality of spokes integral with each hub for rotation therewith, each spoke extending radially away from the axle to a tip end,

a plurality of airfoil-shaped blades pivotably attached to the spoke tip ends, each blade being pivotably attached to an associated spoke integral with the first hub and to an associated spoke integral with the second hub for rotation about a lateral axis of the blade, the associated spokes having similar equi-distant radial positions in the plane of the hub, and,

a plurality of variable-stroke piston and cylinder actuators integral to each hub for rotation therewith, each actuator having a pitch control rod extending between and pivotably connecting the actuator and an associated on of the plurality of blades, a variable stroke of the actuator pivoting the associated blade in response to a cyclic steering command; and,

control means coupled to each actuator for determining an aerodynamically optimum airfoil pitch angle for each blade at each peripheral position of the blade relative to the central axis for a selected flight condition, and for providing the cyclic steering command to each variable-stroke piston and cylinder actuator to pivot the associated blade to the determined airfoil pitch angle, the control means being responsive to an input command from a pilot and to an input signal from an airspeed sensor, the pivoted blades providing a cyclic pitch of each paddle wheel required for the selected flight condition.

2. An aircraft as set forth in claim 1 wherein said control means differentially controls actuators of said first paddle wheel relative to actuators of said second paddle wheel to differentially pivot said blades of said first paddle wheel about their said lateral axes relative to said blades of said second paddle wheel to control roll of said aircraft about said longitudinal axis and to control yaw of said aircraft about a first vertical axis perpendicular to both said longitudinal axis and said first common axis; and

further comprising an aircraft pitch control rotor for controlling pitch of said aircraft about a pitch axis generally parallel to said first common axis, said pitch control rotor being rotatable about a second vertical axis parallel to said first vertical axis and distant from said paddle wheels generally along said longitudinal axis.

3. An aircraft as set forth in claim 2 wherein said pitch control rotor is rotatably mounted at said tail and has a rotor disk which lies in a plane generally perpendicular to said first vertical axis.

4. An aircraft as set forth in claim 1 further comprising drive means for rotating each of said first and second paddle wheels about its said central axis, each said central axis of said first and second paddle wheels being aligned with the first common axis.

5. An aircraft as set forth in claim 4 wherein said drive means includes at least one engine and power coupling means drivingly engaging said engine and each of said paddle wheels.

6. An aircraft as set forth in claim 1, further comprising:

third and fourth paddle wheels rotatably coupled to the fuselage for rotation about a second common axis, the second common axis being aligned with and parallel to the first common axis and spaced rearwardly thereof on the fuselage, the third paddle wheel extending laterally away from the port side, the fourth paddle wheel extending laterally away from the starboard side; wherein

the control means differentially controls actuators of the first and third paddle wheels relative to actuators of the second and fourth paddle wheels to differentially pivot the blades of the first and third paddle wheels relative to the blades of the second and fourth paddle wheels for controlling roll of the aircraft about the longitudinal axis and for controlling yaw of the aircraft about a first vertical axis perpendicular to the longitudinal axis and to the first common axis, and wherein further

the control means differentially controls actuators of the third and fourth paddle wheels relative to actuators of the first and second paddle wheels to differentially pivot the blades of the third and fourth paddle wheels relative to the blades of the first and second paddle wheels for controlling pitch of the aircraft about a pitch axis parallel to the first common axis.

7. An aircraft as set forth in claim 6, further comprising drive means for rotating each of said third and fourth paddle wheels about its said central axis, each said central axis of said third and fourth paddle wheels being aligned with the second common axis.

8. An aircraft as set forth in claim 1 wherein further said control means account for flow interference effects among said blades.

9. An aircraft as set forth in claim 6 wherein said control means account for flow interference effects among said blades and for downwash effects generated by said first and second paddle wheels at said third and fourth paddle wheels.

10. A vertical takeoff and landing aircraft comprising in combination a fuselage, a plurality of paddle wheels, engine means, and control means operatively connected and characterized as follows:

(a) said fuselage comprising a nose and a tail and having a longitudinal axis extending therebetween and port and starboard sides;

(b) said paddle wheels being mounted to said fuselage for rotation about a first common axis extending perpendicular to said longitudinal axis between said nose and said tail, a first of said paddle wheels extending from said port side of said fuselage, a second of said paddle wheels extending from said starboard side of said fuselage, each said paddle wheel comprising:

an axle suitably mounted on said fuselage for rotation of said axle and said paddle wheel about said first common axis, said axle extending laterally away from said fuselage and being aligned with a central axis of said paddle wheel and with said first common axis,

a pair of laterally spaced hubs fixed to said axle for rotation therewith,

a plurality of spokes integral to each said hub, each spoke of said plurality of spokes extending radially away from each said hub to a tip end,

a plurality of airfoil-shaped blades positioned about a periphery of said paddle wheel, each blade of said plurality of blades having a pair of laterally spaced support lugs extending inwardly toward said axle from an underside of said blade at opposing ends of said blade, each of said support lugs being pivotably attached by a support pin to an associated tip end of each spoke of an associated pair of spokes, said associated pair of spokes extending in similar radial position from said hubs, each said blade further having a pair of control lugs extending inwardly toward said axle from said underside of said blade at opposing ends of said blade, each of said control lugs being spaced chordwise from an associated support lug of said blade,

a plurality of variable stroke linear actuators associated with each said hub, each actuator of said plurality of actuators being associated with one spoke of the plurality of spokes of said hubs and with said blade pivotably attached to said tip end of said associated spoke, said actuator extending in similar radial position from said hub as said associated spoke, and,

a pitch control rod and extending between each said actuator and an associated control lug, said pitch control rod being pivotably attached to said associated control lug by a control pin, said associated control lug being further associated with said support hub of said blade pivotably attached to said tip end of said associated spoke, whereby movement of said pitch control rod by actuation of said actuator results in pivotal movement of said blade about said support pin;

(c) said engine means comprising at least one gas turbine engine mounted to said fuselage, said engine driving said axles of said first and second paddle wheels in rotational motion about said first common axis by rotational actuation of a drive shaft, said drive shaft engaging a first transmission and a first cross axle, said first cross axle joining said axles of said first and second paddle wheels for unitary rotation; and,

(d) said control means being operatively connected with each said actuator for adjusting a stroke of each said actuator to pivot each said blade about said control pin in response to a pilot input command, a flight condition as sensed by an inertial reference system and an air data system, and a stabilization input, wherein an incremental blade deflection angle and zero load blade deflection angle are continuously determined in mathematical form for each said blade at each peripheral position of each said blade for each said pilot input command, flight condition, and stabilization input as said paddle wheels rotate, said incremental blade deflection angle and zero load blade deflection angle being combined to produce an optimum net blade pitch angle for each said blade at each said peripheral position, said stroke of each actuator being controlled to pivotably move each said blade to said optimum net blade pitch angle, whereby an optimum cyclic pitch for said paddle wheels is produced for said pilot input command, flight condition, and stabilization input.

11. A vertical takeoff and landing aircraft as set forth in claim **9**, wherein said control means differentially adjusts said strokes of said actuators to differentially pivot said blades of said first paddle wheel relative to said blades of said second paddle wheel, whereby yaw and roll control of said aircraft is achieved.

12. A vertical takeoff and landing aircraft as set forth in claim **11**, wherein said aircraft further comprises a pitch control rotor rotatably mounted at said tail of said fuselage aft of said axles of said paddle wheels, said pitch control rotor having a plurality of rotor blades defining a rotor disk lying in a plane generally parallel to said first common axis and to said longitudinal axis, a rotation of said pitch control rotor generating moment forces for pitch control of said aircraft and compensation for torques produced by rotation of said first and second paddle wheels.

13. A vertical takeoff and landing aircraft as set forth in claim **11**, wherein:

said plurality of paddle wheels further comprises third and fourth paddle wheels mounted to said fuselage for rotation about a second common axis generally parallel to said first common axis and laterally spaced from said first common axis between said first common axis and said tail, said third paddle wheel extending laterally away from said port side of said fuselage, said fourth paddle wheel extending laterally away from said starboard side of said fuselage,

said third and fourth paddle wheel being mirror images respectively of said first and second wheels, and being rotated in a direction opposite to a rotation direction of said first and second paddle wheels, whereby rotational torques of said paddle wheels are counteracted,

said engine means further driving said axles of said third and fourth paddle wheels in rotational motion about said second common axis, said drive shaft of said engine means further engaging a second transmission and a second cross axle, said second cross axle joining said axles of said third and fourth paddle wheels for unitary rotation,

said control means differentially adjusting said strokes of said actuators to differentially pivot said blades of said first and third paddle wheels relative to said blades of said second and fourth paddle wheels, whereby yaw and roll control of said aircraft is achieved, and

said control means differentially adjusting said strokes of said actuators to differentially pivot said blades of said first and second paddle wheels relative to said blades of said third and fourth paddle wheels, whereby pitch control of said aircraft is achieved.

14. A vertical takeoff and landing aircraft as set forth in claim **10**, wherein said control means further adjusts said stroke of each said actuator and pivot angle of each said blade in response to blade interference effect information in the form of look-up tables of data stored in said control means.

15. A vertical takeoff and landing aircraft as set forth in claim **10**, wherein said control means further adjusts said stroke of each said actuator and pivot angle of each said blade in response to blade interference effect data in the form of an equation stored in said control means.

16. A vertical takeoff and landing aircraft as set forth in claim **13**, wherein said control means further adjusts said stroke of each said actuator and pivot angle of each said blade in response to blade interference effect and downwash effect information in the form of look-up tables of data stored in said control means.

17. A vertical takeoff and landing aircraft as set forth in claim **13**, wherein said control means further adjusts said stroke of each said actuator and pivot angle of each said blade in response to blade interference effect and downwash effect information in the form of an equation stored in said control means.

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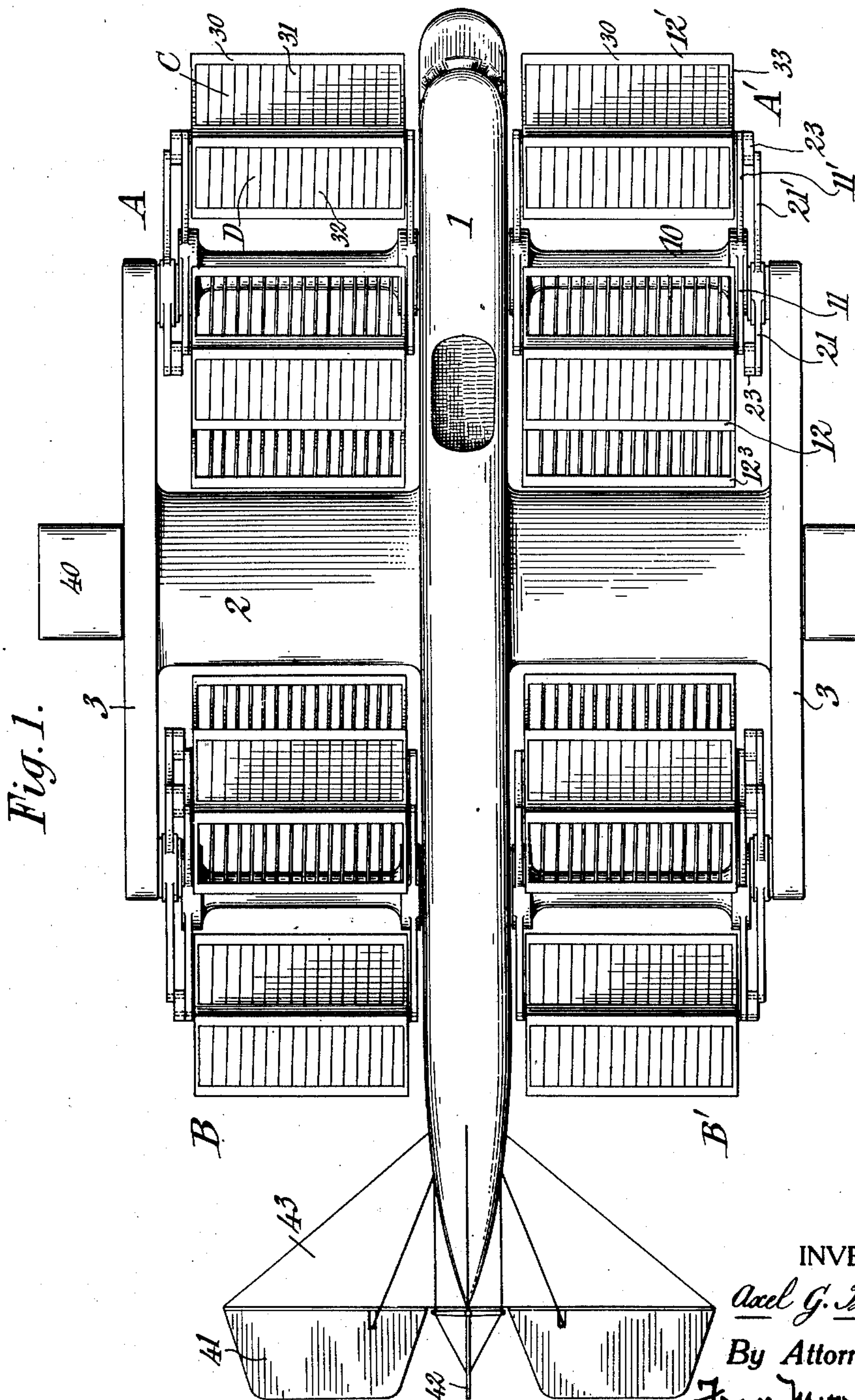
VERTICAL RISING AIRPLANE

Filed July 13, 1925 2 Sheets-Sheet 1



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April 15, 1930. A. G. BERGMAN 1,754,977

VERTICAL RISING AIRPLANE

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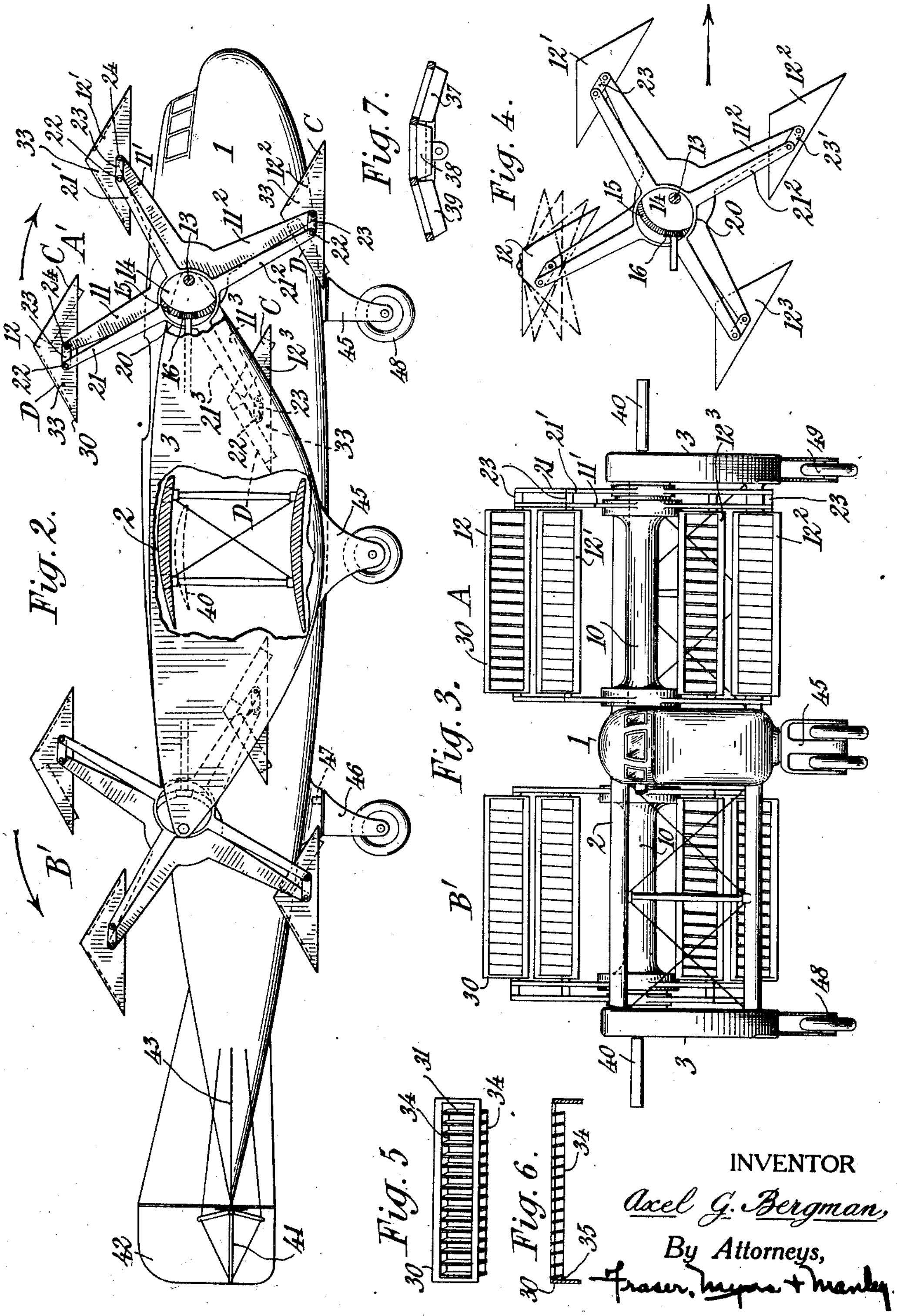

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Patented Apr. 15, 1930 1,754,977

UNITED STATES PATENT OFFICE

AXEL G. BERGMAN, OF NEW YORK, N. Y.

VERTICAL-RISING AIRPLANE

Application filed July 13, 1925. Serial No. 43,294.

This invention relates to an airplane having the capacity to rise vertically and to traverse through the air horizontally at will. The primary object of this invention is to provide an aircraft combining the advantages of the helicopter with those of the airplane.

The invention provides an improved application of the feathering blade paddle wheel type of propeller to vertical rising aircraft whereby the torques of such wheels are balanced one against another, so that there is no resultant tendency whatever to rotate the machine about the axes of such wheels, and at the same time having the wheels disposed with their rotational axes transverse to the line of flight of the machine whereby the horizontal components of thrust may be utilized to propel the machine horizontally.

A further object of the invention is to provide an improved propelling means for driving aircraft and the like in any desired direction. The invention further provides improved means for stabilizing vertical rising airplanes at times when the forward speed of the machine would be insufficient to render the ordinary controls, such as are applied to the standard heavier-than-air machine today effective for the purpose of obtaining longitudinal and lateral stability.

According to the present invention there is provided an aircraft of the heavier-than-air type, having the capacity to rise vertically from the ground without any running take-off whatever and to descend vertically in still air upon a given ground space and without detrimental shock to the machine. The machine is capable of horizontal flight at a chosen elevation at speeds considerably in excess of the velocity of any of the impeller parts, and its course, and lateral and longitudinal stability are at all times under the control of the pilot, regardless of whether the motors are running or at a standstill. A vertical rising airplane according to this invention is provided, by virtue of the design and arrangement of the propelling surface and certain auxiliary sustaining areas, with sufficient lifting surface to permit it to glide or volplane safely to the ground without the application of any power whatsoever to the propelling means. According to one design for a man-carrying machine of the type now being described, the total load on the sustaining surface which would be active in gliding flight is less than six pounds per square foot. This is well within the safe loading for gliding at ordinary landing speeds. When the machine is in full horizontal flight the ordinary aileron, rudder, and stabilizer surfaces may be employed to control its course. Until normal horizontal flying speed has been attained means are provided for independently controlling the efficiency of the several impeller devices, whereby through increasing the lifting efficiency of one or more or decreasing the efficiency of others the machine may be kept on an even keel.

Referring to the drawings,—

Figure 1 shows a plan view of one form of heavier-than-air machine according to the present invention.

Fig. 2 is a side elevation partly in section of the same machine.

Fig. 3 is a front elevation of the assembled machine according to Figs. 1 and 2, the forward left-hand rotary impeller being removed to show the rear left-hand impeller.

Fig. 4 shows in side elevation one of the wheel propelling devices and illustrates various adjustments of the blade feathering device.

Fig. 5 shows in detail a plan view of a modified form of surface element of an impeller blade.

Fig. 6 is a cross section of the impeller blade shown in Fig. 5.

Fig. 7 shows a further modification of one of the propelling surfaces divided into three shutter sections.

The invention according to the preferred embodiment illustrated in the drawings comprises a body portion or fuselage 1 upon which are mounted a plurality of feathering blade impellers preferably four in number, and arranged in fore and aft pairs, the right and left-hand forward impellers as viewed from the front of the machine being designated as A A′ and the corresponding impellers in the rear being B B′ respectively. The transverse supporting frame 2 is rigidly attached to the central body 1 and at its outward extremities carries longitudinal truss members 3 at the forward and rear ends of which are provided suitable mountings for the outward bearings of the several rotary impellers, as shown. The transverse frame 2 is preferably of the wire braced truss construction similar to that employed in the usual biplane, and its upper and lower portions may be formed externally in accordance with standard wing construction, the top and bottom surfaces of each wing being cambered in accordance with proper wing design for the speed at which the machine is intended to fly. The machine is provided with suitable landing gear as shown, which will be hereinafter more fully described.

The principal sustaining means and preferably the sole propelling surfaces are comprised by the blades or active pressure surfaces of the rotary impellers A A′ and B B′. One of these impellers will now be described in detail, it being understood that each of the others is preferably of the same identical construction with the exception that the impeller on the opposite side of the machine from the one now to be described will be a right hand duplicate, since the present one will be the left-hand forward impeller A.

According to the preferred embodiment illustrated in the drawings, the impeller is constructed as follows:

Power is applied to the impeller A at its central axis and at a point adjacent the fuselage, said axis comprising a relatively large tubular shaft 10, as this shaft is required to transmit quite heavy torque. It is made preferably in hollow cylindrical form, as this affords a greater rigidity against deformation through twisting stresses than a solid shaft of the same weight. At either end of the driving tube 10 are blade-supporting arms 11, 11′, 11^2, 11^3, preferably 90° apart, the corresponding arms at either end of the tube being parallel. At their inner portions these arms are rigidly attached to the torque tube 10 and at their outer ends are provided with bearings suitable for the pivotal support of the impeller blades 12, 12′, 12^2, 12^3. A bearing shaft 13 extends from the outer portion of the impeller A and is suitably journaled in a bearing supported by the longitudinal truss member 3. Pivotally mounted on said shaft and inwards of the longitudinal truss member is an eccentric 14 on the face of which may be cut an arc of gear teeth 15, having the axis 13 as a center. A control shaft and pinion 16 is rotatably mounted on the truss member 3, the pinion meshing with teeth 15, whereby the position of the eccentric 14 may be regulated and fixed in any desired relationship with the shaft 13. Surrounding the eccentric 14 is an eccentric band 20 at the four quadrants of which are blade feathering arms 21, 21′, 21^2, 21^3. These arms are rigidly attached to the eccentric band and at their outer extremities are provided with studs or bosses 22. The bosses 22 form a pivotal connection with crank arms 23, which arms are rigidly attached to shafts 24 passing through the bearing in the outer ends of arms 11, 11′, 11^2 and 11^3. To each shaft is fixed respectively the impeller blades 12, 12′, 12^2 and 12^3.

By virtue of the arrangement of the impeller arms 11, 11′, 11^2 and 11^3 and the feathering control arms 21, 21^1, 21^2 and 21^3, the effective center of the feathering control eccentric 14 being disposed at a distance from the center 13 equivalent to the length of the crank arm 23 and the line of said centers being parallel to said crank arm, there is provided a parallel motion device, whereby the crank arms 23 and consequently the impeller blades rigidly connected therewith, will be maintained parallel to a predetermined plane throughout their entire revolution about the axis 13. The plane with respect to which all the blades will be parallel may be varied at will by shifting the eccentric 14 under the control of pinion 16, as will be more fully described hereafter.

The impeller blades will now be described in detail, reference being had to the blade 12, which, however, is typical and similar in every respect to each of the other blades on the four impellers A A′ and B B′. Because of the preferred method of feathering the blades, namely, causing them to maintain positions parallel to a given plane throughout their entire rotation about the central shaft of the impeller, it is necessary to provide means for rendering the blades effective in their action against the air in directions that render them useful in producing lift or horizontal thrust and at the same time to reduce the efficiency of these surfaces to a minimum when they are traveling in directions not suited to the production of such lift or thrust. Other types of feathering may be employed whereby the blades are caused to automatically assume as a whole, varying angles of incidence suitable to the production of the desired air reactions and at times when their motions are such as to render them incapable of producing such reactions, to assume angles of approximately zero incidence, whereby the rotation of such blades through their inactive arcs of travel will absorb in such useless rotation as little power as possible. Because of the complication and various structural difficulties of obtaining such latter feathering motion as described above, the comparatively simple parallel motion type of feathering has been chosen and the blades themselves provided with automatic shutter devices which perform the function of feathering the blades at the appropriate times for the purpose of minimizing the air resistance during the inactive rotation of the blades without any mechanical control whatsoever other than the air pressure. Accordingly, in the preferred embodiment of the invention, the impeller blades, active pressure surfaces or aerofoils, as they may be termed, are constructed as follows:

As will be seen in Figure 1, the blades comprise a plurality of shutter vanes, thirty-two in number in the particular form illustrated, although the number of vanes are not material and structural considerations may dictate the use of many small vanes or a comparatively few larger ones. The blade is preferably formed as an inverted trough (see Figs. 1, 2, 3 and 5), the upper, forward and rearward surfaces C and D of which form an angle of approximately 120° between each other. The valley or long axis of the trough is furthermore, in the preferred form, at right angles to the longitudinal axis of the machine. Pivotally hung in a suitable frame 30 and forming when closed the aforesaid surfaces C, D, are rows of shutter-vanes or flaps 31 and 32 respectively, the same being adapted to swing down into a substantially vertical plane whenever there is a resulting pressure on the upper faces thereof, and to be swung into the planes of the blade surfaces C, D respectively when the resultant pressure is from the underside of the blade. As has been previously described, the crank arm 23 actuating the shaft 24, positively controls the angle of incidence of the blade 12 at all times, the shaft being rigidly secured to the frame of the blade.

One of the objects in constructing the impeller blade 12 in the form of an inverted trough is to provide a blade for striking a downward blow on the air more effectively than is possible with a flat blade; also to provide members, which, while traveling upwardly over a necessary idle arc of rotation and while the vanes 31 are open, will present inclined surfaces to the air which will offer less resistance than if they were disposed normally to their path of motion through the air. A further advantage of constructing the blade as a trough is that the rear surfaces of blades rotating in a clockwise direction, such as are the blades of impeller A′, will close and become effective as lifting surfaces earlier than if they were disposed in a horizontal plane, and this will produce a condensation of air within the trough which causes the earlier closing of vanes 31 in the forward surface C of the impeller blade 12.

It will be seen in Figure 2 that the forward row of vanes comprising the surface C of impeller blade 12, are still open, while the rear blades 32 are closed. When blade 12 has reached the position now occupied by blade 12^1, both the forward and rear shutter vanes will be closed, as shown. Continuing further in the course of a revolution, to the position now occupied by the blade 12^2, it is seen, the rear vanes 32 will have opened under the air pressure acting downwardly through the surface D while the forward vanes 31 still remain closed by virtue of their angle of incidence and a certain condition of pressure still obtaining within the trough. When the blade reaches the position now occupied by blade 12^3, both the forward and rear surface elements or vanes 31 and 32 respectively will have opened to the vertical position rendering the impeller surfaces C and D from that point upward to the position first described in the orbit of the blades, practically free from resistance. It will thus be seen that the impeller blades in traveling from the position illustrated for blade 12^1 to the position of blade 12^2 will be acting downwardly against the air with maximum efficiency, the blade throughout this arc of travel forming a perfect inverted trough, the upper surfaces of which are tightly closed and spillage from the ends may also be reduced by vertical triangular end surfaces 33. From the position represented by blade 12 to that of blade 12^1, the efficiency averages considerably above fifty per cent. of the maximum possible efficiency of the blade, as is also true of the travel from the position represented by blade 12^2 to that of blade 12^3. From the position of 12^3 to that of 12 the vanes in the 90° arc therebetween are necessarily idle.

In Figure 1 it will be observed that the vanes 31 and 32 of the impeller blades are set at a slight angle to the axis of the machine. The purpose of this is to give the vanes an inherent tendency to close after they have swung into the vertical position, by virtue of their being carried through the air, their position being such that with respect to the plane of rotation of the impeller there is present an angle of incidence or attack, to the air through which they are being carried horizontally and which causes them to be swung transversely and caused to approach towards the plane of the blade surfaces C and D. By this means the danger of the vanes falling into a state of neutral equilibrium and not being caused to return to their working positions in which they act on the air to produce useful lift and thrust, is practically avoided. However, it is preferable to provide, as shown in Figures 5 and 6, spacing rods 34 tying all the vanes of a common surface together and which rod engages a portion of the blade frame 30 at a point 35 to prevent the vanes from swinging quite into the vertical positions thereby avoiding a tendency for them to fall into a state of neutral equilibrium with respect to the air pressures acting on them, and which, as above mentioned, might interfere with their proper closing.

In Figure 7 there is illustrated in cross section a modified form of impeller blade in which the inverted trough frame has three vane-carrying surfaces instead of two as in the form previously described, the three rows of vanes being shown as 37, 38 and 39. Such a modified blade construction is probably slightly more efficient than the two-sided trough form but has 50% more parts and is correspondingly more expensive to build. Obviously for the sake of efficiency the number of rows of surface elements comprising the trough-like impeller blades may be increased until the surface of the trough closely approximates the cambered surface of the usual airplane wing, although this construction is not preferred because of its costliness.

In Figure 4 the impeller blades 12, 12^1, 12^2 and 12^3 are shown adjusted to a position in which they form a very considerable angle with the horizontal. With the blades adjusted to the position shown, the effect of their rotation in their substantially circular orbit about the center 13 is to produce, in addition to a vertical lift, a horizontal component of force which tends to propel the machine forwardly in the direction of the arrow. When the four impellers of the machine are caused to rotate by the engine, the machine is being lifted by the vertical force due to the downward travel of the blades through the course of their effective rotation, and at the same time it may be said to be gliding forward on the said surfaces. As adjusted in Figure 4, these surfaces provide lifting areas inclined to the horizontal, which, if the impellers were stationary, would provide sufficient surface to permit the machine to glide at high speed in the course of a gliding descent.

In the case where power is applied to the impellers, the necessary loss of altitude through such pure gliding action is overcome and the body of the machine is caused to maintain a constant altitude or even to ascend, while at the same time the machine may be said to be gliding forward and at a rate of speed greatly in excess of the rotational speed of the impeller blades. This may be better understood if the gliding flight of an ordinary airplane is considered. The motor of an airplane may be stopped, and by suitably inclining the axis of the machine to the horizontal, the airplane, if it has sufficient altitude, may be caused to fly at a high rate of speed and for long distances without any propulsive force whatever other than the action of gravity in producing what is recognized as gliding flight. It is this principle which is availed of to produce the horizontal travel of the present machine, and as already pointed out, permits it to travel forward at relatively high speeds and at a constant altitude when the motor is running, and which also, when the motor is shut off, permits the machine to continue its flight by gliding downwardly and gradually losing altitude. Furthermore, while so gliding, the machine can be maneuvered and landed in the same way as the usual type of airplane does at present.

The blade 12 in Figure 4 is shown in dotted lines in various positions which it may be caused to assume by the action of the feathering control eccentric 14. In these various positions the machine may be caused to rise vertically or to perform any desired combination of vertical and horizontal motion within its speed limits. When adjusted to the extreme counter-clockwise position illustrated, the blades will exert a considerable thrust in a direction opposite to that indicated by the arrow in Figure 4. A capacity to produce thrust in this direction may be useful in retarding the forward flight of the machine or causing it to hover over a given point on the ground when the wind is blowing from the rear of the machine, with the consequent tendency to cause it to drift forward. By inclining the impeller blades of both the forward and rear impellers parallel to a common plane, the thrust produced by forward impellers A, A′ and rear impellers B, B′ will both be in the same direction in spite of the fact that these two pairs of impellers are rotated in opposite directions. This fact permits of the use of rotary impellers of the present type to produce useful horizontal and vertical forces, but without any resultant torque whatsoever due to the rotation of the said impellers because of the fact that any number may be arranged in symmetrical oppositely rotated pairs whereby their resultant torques are neutralized. Each is rotated about an axis transverse to the line of flight of the machine whereby their horizontal components may be added together to produce useful flying thrusts without resultant torque, and thus dispensing with auxiliary horizontal propelling means heretofore resorted to for the purpose of maintaining horizontal flight in a machine capable also of rising vertically.

According to the present invention there is provided means for individually controlling the inclinations of the vanes of the four impellers each independently of the others so that the vertical and horizontal components of force of each impeller may be varied at will, whereby the machine may be stabilized both laterally and longitudinally and also turned in a horizontal plane to the right or left by the appropriate relative adjustment of the several impellers. For example, if the nose of the machine is lower than the tail, and the pilot desires to right it, the lifting efficiency of the forward impellers A, A′ may be increased or the lift of the rear impellers B, B′ diminished. If the machine is tipped to the left, the lifting efficiency of the impellers A′, B′ may be increased or the efficiency of impellers A, B diminished, and the machine will be laterally stabilized to the desired horizontal position. If it is desired to cause the machine to travel in a circle or even to practically pivot about its own center without any horizontal flight whatever, the lifting efficiencies of the impellers A, B may be maintained equal to that of the rotors A′, B′, but the horizontal components of the right and left hand impellers may be oppositely directed, A and B producing a forward thrust and A′, B′ producing a rearward thrust. This will create a force couple tending to revolve the machine in a clockwise direction. Obviously the reverse adjustment of the right and left hand impellers will cause the machine to turn in a counter-clockwise direction.

The same adjustments above described may be made use of to control the free gliding flight of the machine when the motor is not running, the impellers in fact constituting four lifting surfaces of an airplane, the incidence of each of which may be varied independently of the others. However, when a horizontally flying speed of over forty miles per hour is attained, the control of the stability and direction of flight may be accomplished without interfering with the lifting or propelling efficiency of the impellers by the use of the usual control surfaces, namely, ailerons, elevator and rudder. Ailerons 40 may be carried, as shown, extending outwardly from the transverse supporting frame 2. The elevator and rudder 41 and 42 respectively are mounted at the rear of the machine in accordance with standard airplane practice, a stabilizing plane 43 completing the surface formed by the elevator 41 into a tail plane contiguous with the fuselage of the machine.

Through the individual control of the impellers as above set forth, an adjustment may be obtained by which practically automatic longitudinal stability may be achieved when the machine is rising vertically. This is accomplished by setting the blades of the forward impellers to form a slightly positive angle of incidence with respect to the longitudinal axis of the machine, and the blades of the rear impellers with a slightly negative angle of incidence thereto. Because of the dihedral angle between the forward and rear surfaces, automatic longitudinal stability is obtained in the same way as it is achieved in airplane design by making the incidence of the rear stabilizer plane slightly less than that of the main lifting surfaces. With such an arrangement, when the machine tilts forward the front surfaces become more efficient than the rear surface, and consequently, the machine tends to right itself.

The machine may be driven by any suitable source of power, the power unit or units being preferably situated within the fuselage of the machine and so disposed with respect to the center of lift of the combined blade surfaces of the several impellers that the center of gravity of the machine will substantially coincide therewith.

The running gear of the machine may comprise forward and rear main wheels mounted, as shown, in suitable frames 45 and 46 respectively, the forward wheel frame being rotatable about a vertical axis and susceptible of directional control by any suitable steering mechanism. The rear wheel frame 46 is preferably swivel hung, the pivotal point being somewhat ahead of the wheel axle, as shown at 47. Balancing wheels 48 and 49 may be conveniently mounted in forks rigidly connected to the longitudinal truss members 3 and at an elevation somewhat above the plane of the main wheels so that the major landing stress will be normally received by said wheels. The wheels are preferably each provided with suitable shock-absorbing mountings in accordance with usual airplane practice.

While only a single embodiment of the invention has been illustrated and described, it is to be understood that the scope of the invention is not limited thereto and that it may be variously modified without departing from the spirit of the invention. The number and arrangement of the several rotary impellers is not material, the important aspect of the impeller arrangement being only that whatever the number employed they are to be arranged in oppositely rotated pairs with the axes of rotation substantially at right angles to the horizontal line of flight of the machine. The system of impellers hereinabove described is furthermore applicable to the propulsion of lighter than air machines and also as a means of marine propulsion. By suitable adaptation, the impellers may be used in any fluid medium whatsoever.

In the specification and claims it is to be understood that the expression "trough-like surfaces" applied to the impeller blades is intended to convey merely the idea of the surface being concave in the same sense that the airplane wing is said to be concave on its under side, it being not in any way essential that vertical end surfaces be provided to close the ends of the trough-like surfaces.

What I claim is:

1. A vertically rising airplane including oppositely rotating frames revolving about axes substantially transverse to the horizontal line of flight of the machine, and aerofoils carried thereby through substantially circular orbits, said aerofoils comprising in-

verted, trough-like surfaces, said trough-like surfaces being disposed with their valleys substantially parallel to the axes of rotation of the frames, and each of said surfaces being formed of a plurality of feathering shutter vanes.

2. A vertically rising airplane including a rotating frame revolving about an axis transverse to the horizontal line of flight of the machine, aerofoils carried thereby through substantially circular orbits, said aerofoils comprising dihedral surfaces, the line of intersection of the two planes of said surfaces being substantially parallel to the axis of rotation of the frame, and each of said surfaces comprising a plurality of feathering shutter vanes, the vanes of one surface being operable independently of those of the other.

3. A vertically rising airplane including a rotating frame, aerofoil surfaces carried thereby through substantially circular orbits about an axis which is transverse to the horizontal line of flight of the airplane, said aerofoil surfaces being formed by a plurality of feathering vanes, the individual pivotal axes of said vanes being substantially parallel to the line of flight of said airplane.

4. A vertically rising airplane including substantially axially transverse, oppositely rotated fore and aft rotary frames, each frame carrying a plurality of aerofoil surfaces pivotally mounted thereon, mechanical feathering means for automatically regulating the fore and aft or longitudinal incidence of said surfaces while they are rotated with the frames, said surfaces comprising sets of longitudinally pivoted vanes adapted to be feathered by the variation in air reaction whereby their transverse inclination is automatically varied to effect an opening and closing shutter action.

5. A vertically rising airplane including substantially axially transverse, oppositely rotated, fore and aft rotary frames, aerofoil surfaces pivotally mounted thereon and feathering means adapted to maintain the operative surfaces of said fore and aft frames substantially parallel to a chosen plane oblique to the horizontal throughout the rotation of said frames, whereby the airplane will be propelled in the same direction by the surfaces of both fore and aft rotary frames.

6. A rotary propelling device adapted for use in a fluid medium, said device including a rotary frame, propelling surfaces pivotally mounted thereon, said surfaces including a plurality of shutter vanes the pivotal axes of which are substantially at right angles to the axis of said rotary frame, and eccentric means adapted to maintain said surfaces parallel to a chosen plane throughout the rotation of said frame.

7. A rotary propelling device according to claim 6, further characterized in that stop means are provided to prevent at any time the said shutters from opening quite to dead center with respect to fluid pressures normally tending to close them.

8. A vertically rising airplane comprising a fuselage, fore and aft pairs of coaxial, transverse rotary frames, each pair being medially supported by said fuselage, each frame carrying a plurality of aerofoil surfaces, feathering means for said surfaces, a transverse supporting structure extending outwardly on either side of the fuselage and between said fore and aft rotary frames, at least one horizontal surface of said structure being covered to form a stationary lift area, each outer portion of said transverse supporting structure carrying longitudinal truss members which support the outer bearings of said fore and aft rotary frames.

9. A vertically rising airplane, said airplane including inverted trough-like aerofoils the active surfaces of which consist of shutter vanes, said aerofoils being disposed with their long axes substantially at right angles to the longitudinal axis of the machine, aerofoil actuating means adapted to continuously move certain of said aerofoils in opposite directions over closed orbits, the planes of which orbits are substantially parallel to the longitudinal axis of the machine, and mechanical feathering means adapted to maintain said aerofoils parallel to a common plane throughout their orbital movements.

10. A vertically rising airplane including a plurality of rotating frames, and aerofoils the active surfaces of which consist of shutter vanes, said aerofoils being moved by said frames through closed orbits, the planes of said orbits being substantially parallel to the longitudinal axis of the airplane, one half of said aerofoils being moved in one direction through said orbits, the other half of said aerofoils being moved in the opposite direction through said orbits, and feathering means adapted to incline the aerofoils moving in both directions through said orbits, to substantial parallelism with a common plane which is oblique to the horizontal, whereby a common propulsive thrust is obtained from the aerofoils of said frames.

11. A propelling device including a frame, means for moving said frame about a closed orbit, said frame carrying two series of feathering vanes, the vanes of one series forming with relation to the vanes of the other series a dihedral angle such that the angle of incidence of one series relative to the orbital movement differs from that of the other, the vanes forming when closed a trough-like aerofoil the valley of which is transverse to the plane of orbital movement.

12. A propelling device for use in air, said device including a rotatable frame, vane-supporting frames pivotally mounted on said rotatable frame, mechanical feathering means adapted to maintain said vane-supporting

frames substantially parallel to a common fixed plane, and at least two series of pivoted vanes carried by each of said supporting frames and adapted to be automatically feathered by air reaction, the vanes of one series being disposed so as to form a dihedral angle in the plane of rotation of said frames, with respect to the vanes of the other series, whereby the vanes of one series will have a different angle of air attack from the vanes of the other series and will therefore open and close at different times.

In witness whereof, I have hereunto signed my name.

AXEL G. BERGMAN.

US005100080A

United States Patent [19]

Servanty

[11] **Patent Number: 5,100,080**

[45] **Date of Patent: Mar. 31, 1992**

[54] **ROTOR FOR DEVELOPING SUSTAINING AND PROPELLING FORCES IN A FLUID, STEERING PROCESS, AND AIRCRAFT EQUIPPED WITH SUCH ROTOR**

[76] Inventor: **Pierre Servanty,** 14 Avenue Jean-Jacques Rousseau, 93600 Aulnay Sous Bois, France

[21] Appl. No.: **508,986**

[22] Filed: **Apr. 12, 1990**

[30] **Foreign Application Priority Data**

Apr. 17, 1989 [FR] France 89 05185

[51] **Int. Cl.**[5] **B64C 39/08;** B64C 11/30

[52] **U.S. Cl.** **244/9;** 244/70; 440/93; 416/147

[58] **Field of Search** 416/147, 166, 162, 155; 440/92, 93; 244/9, 19, 20, 70

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Primary Examiner—Sherman Basinger
Assistant Examiner—Virna Lissi Mojica
Attorney, Agent, or Firm—Harold H. Dutton, Jr.

[57] **ABSTRACT**

The invention relates to a rotor able to develop in a fluid lifting and/or propelling forces and its process for control. Said rotor comprises several profiled blades (9) with axes parallel to the drive axis (3); the incidence of each profiled blade is controlled in real time as a function of its angular azimuth and the flight conditions, for obtaining the desired lift and propulsion forces.

19 Claims, 15 Drawing Sheets

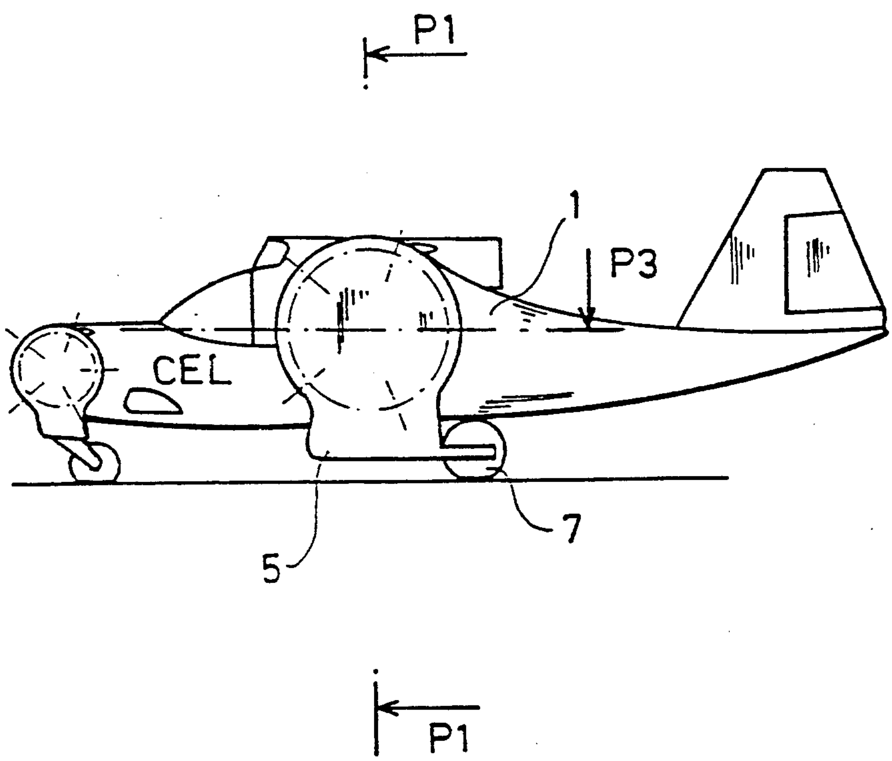


Fig. 1

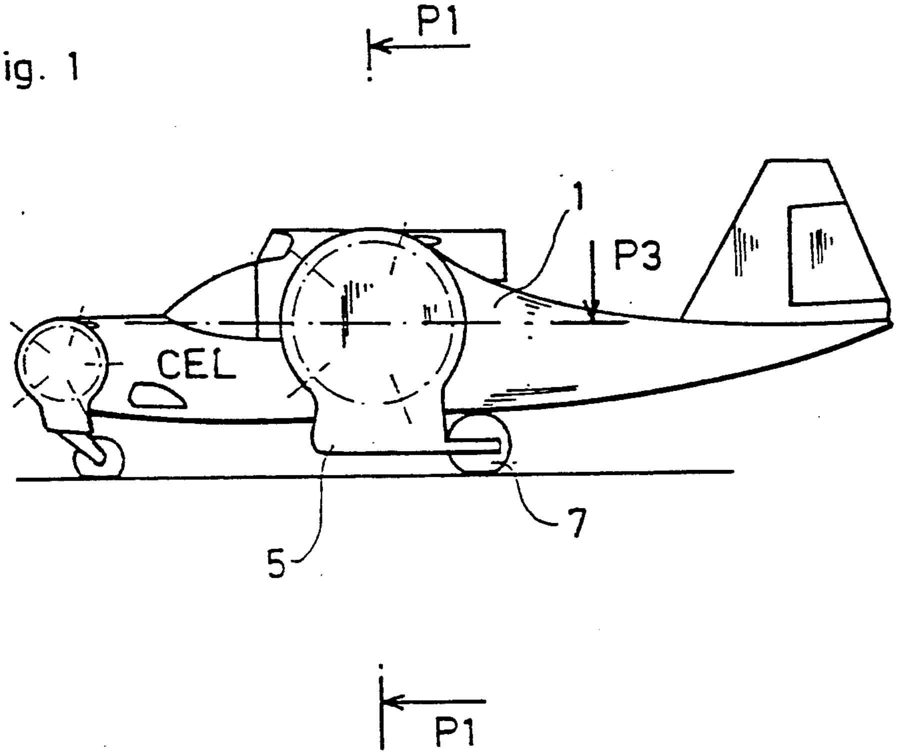


Fig. 2

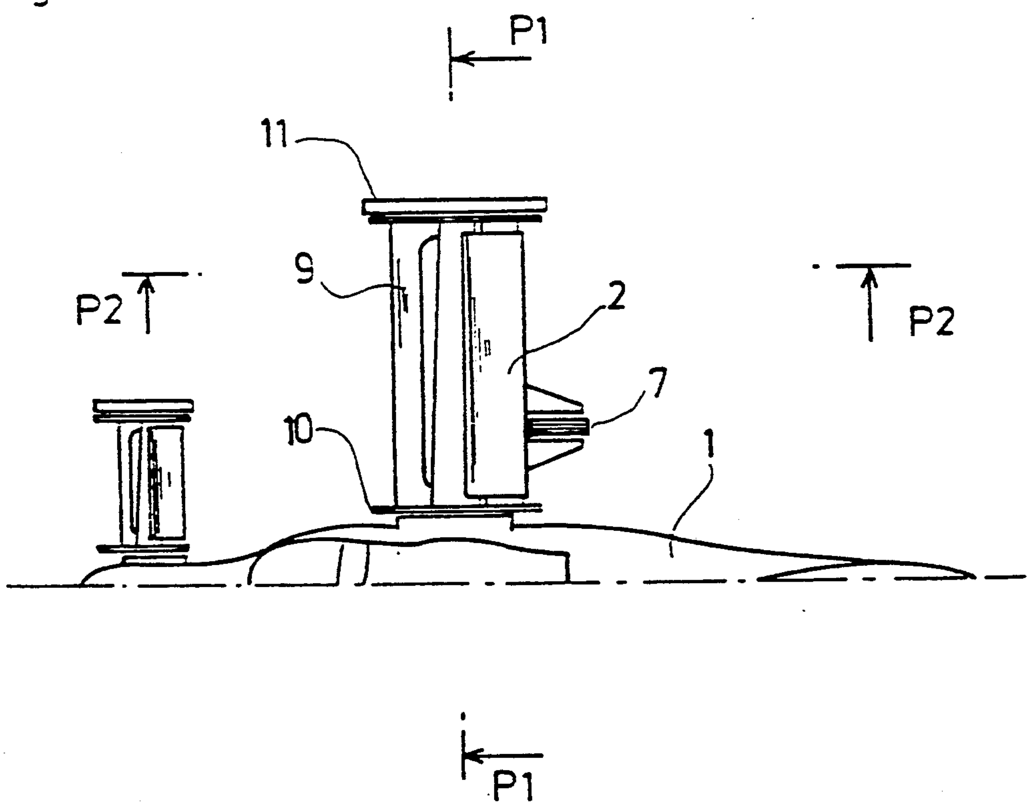
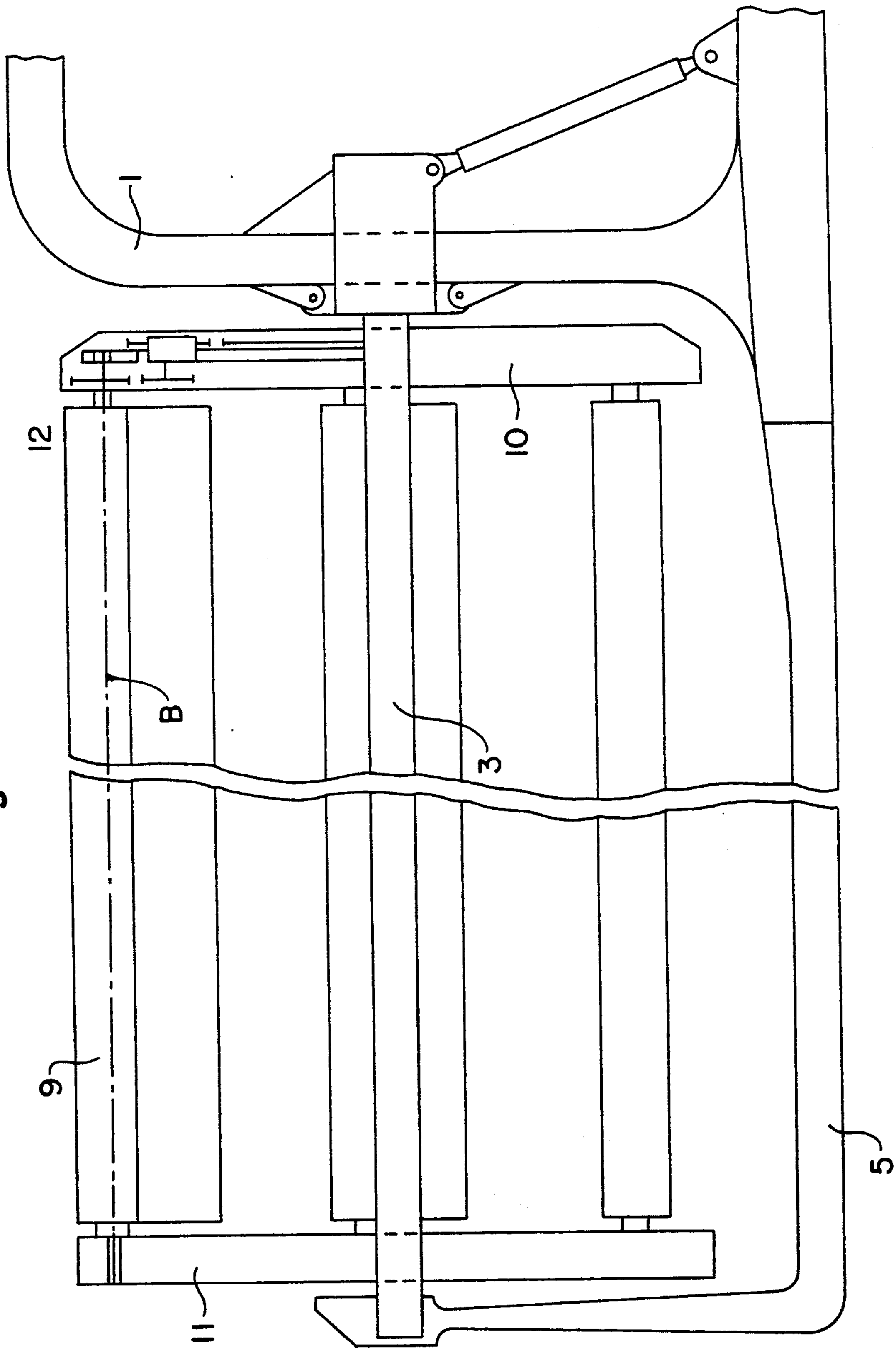


Fig. 3



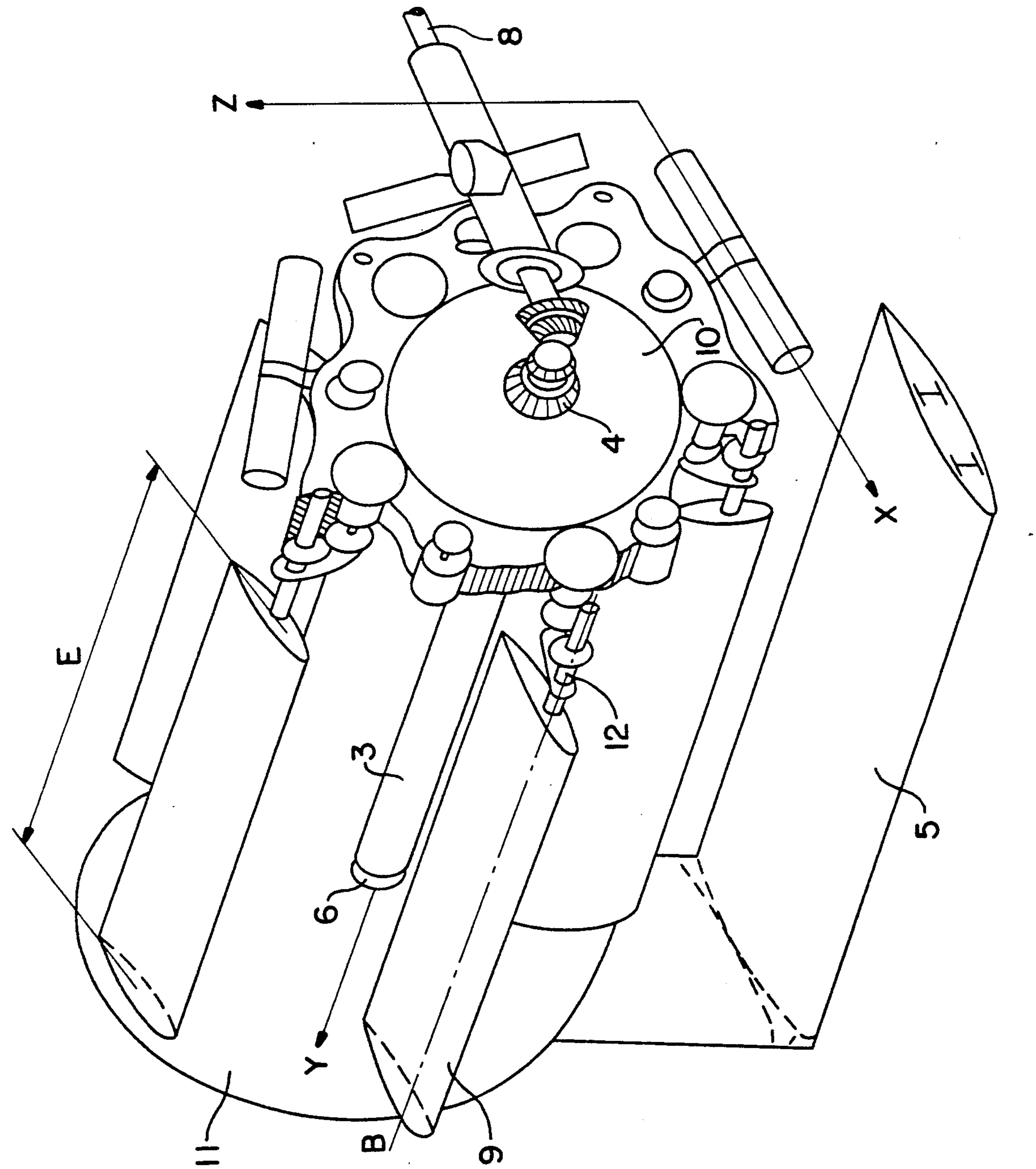


Fig. 4

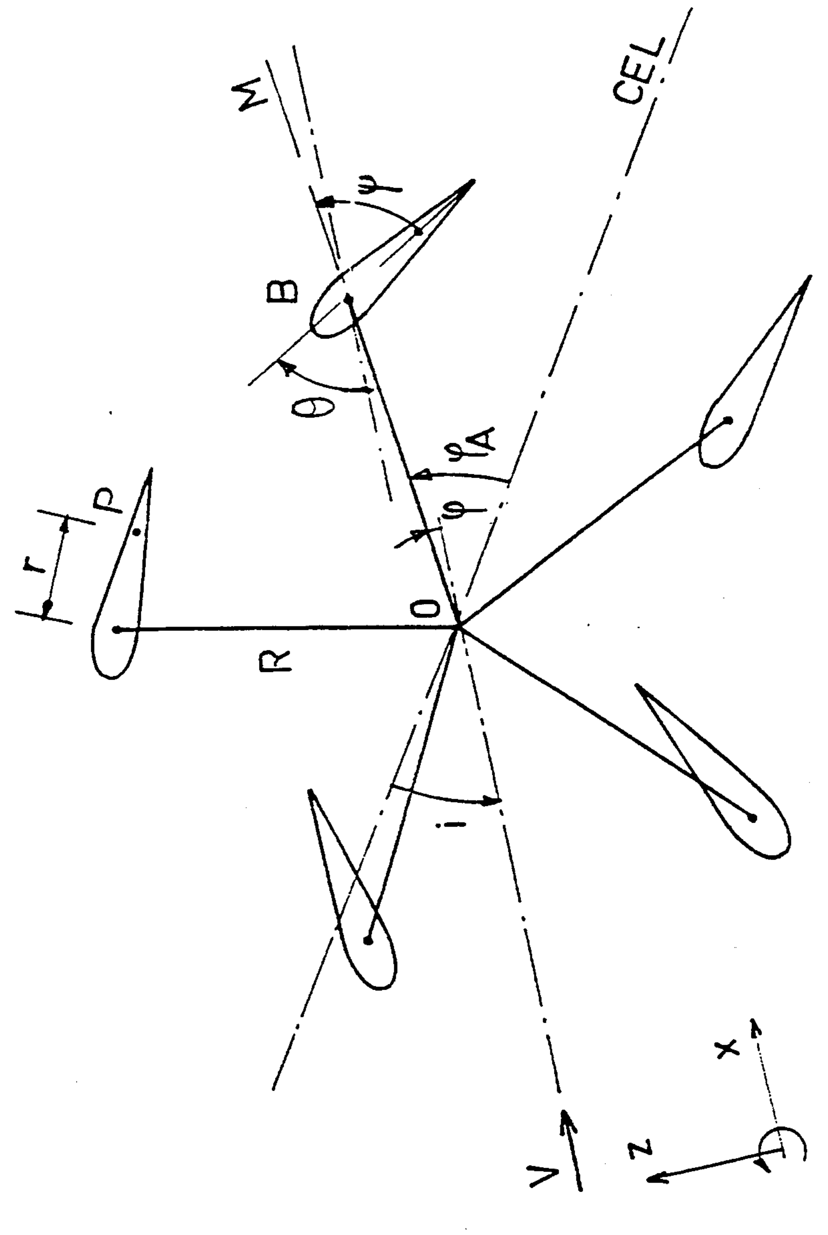


Fig. 5

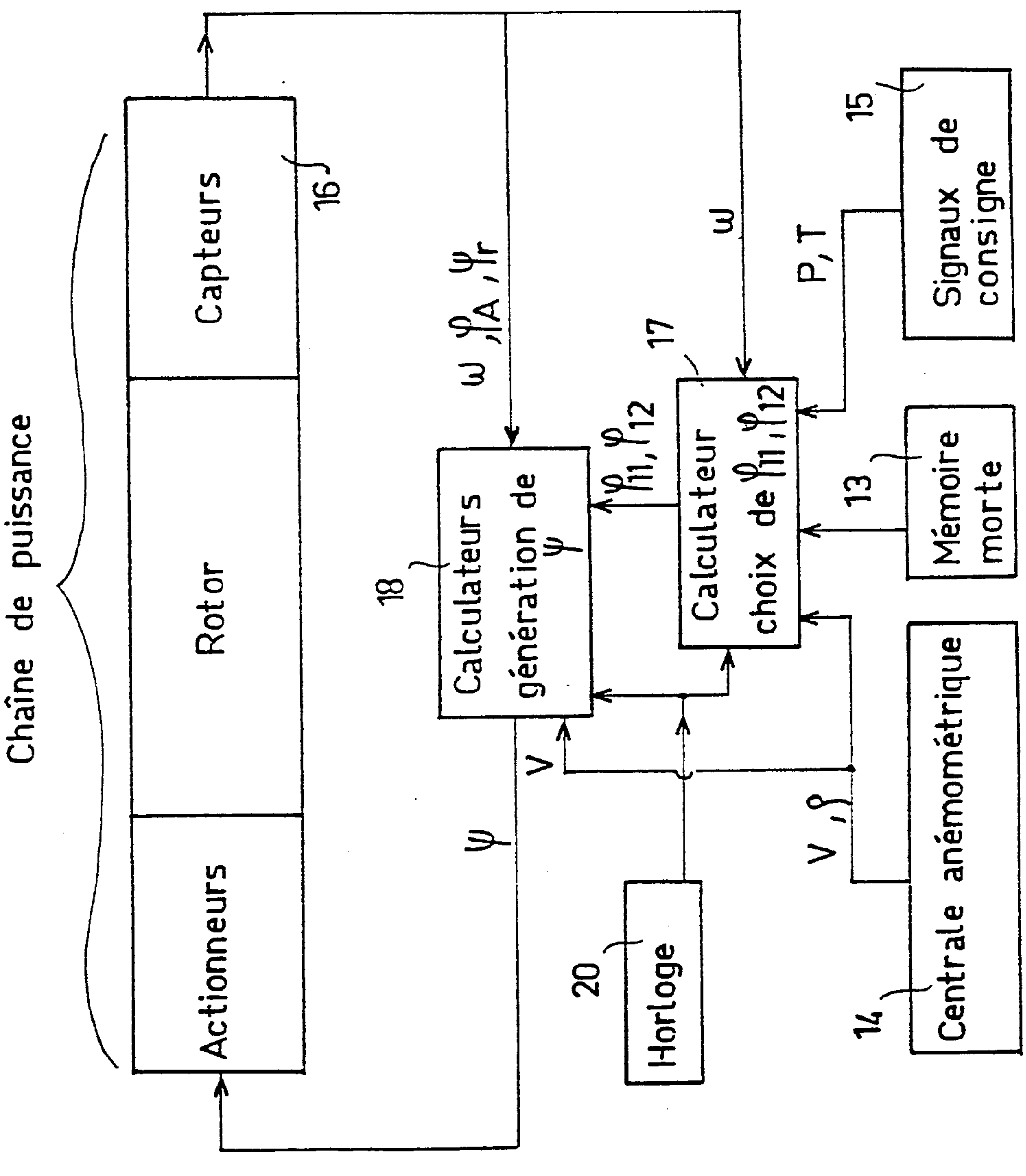
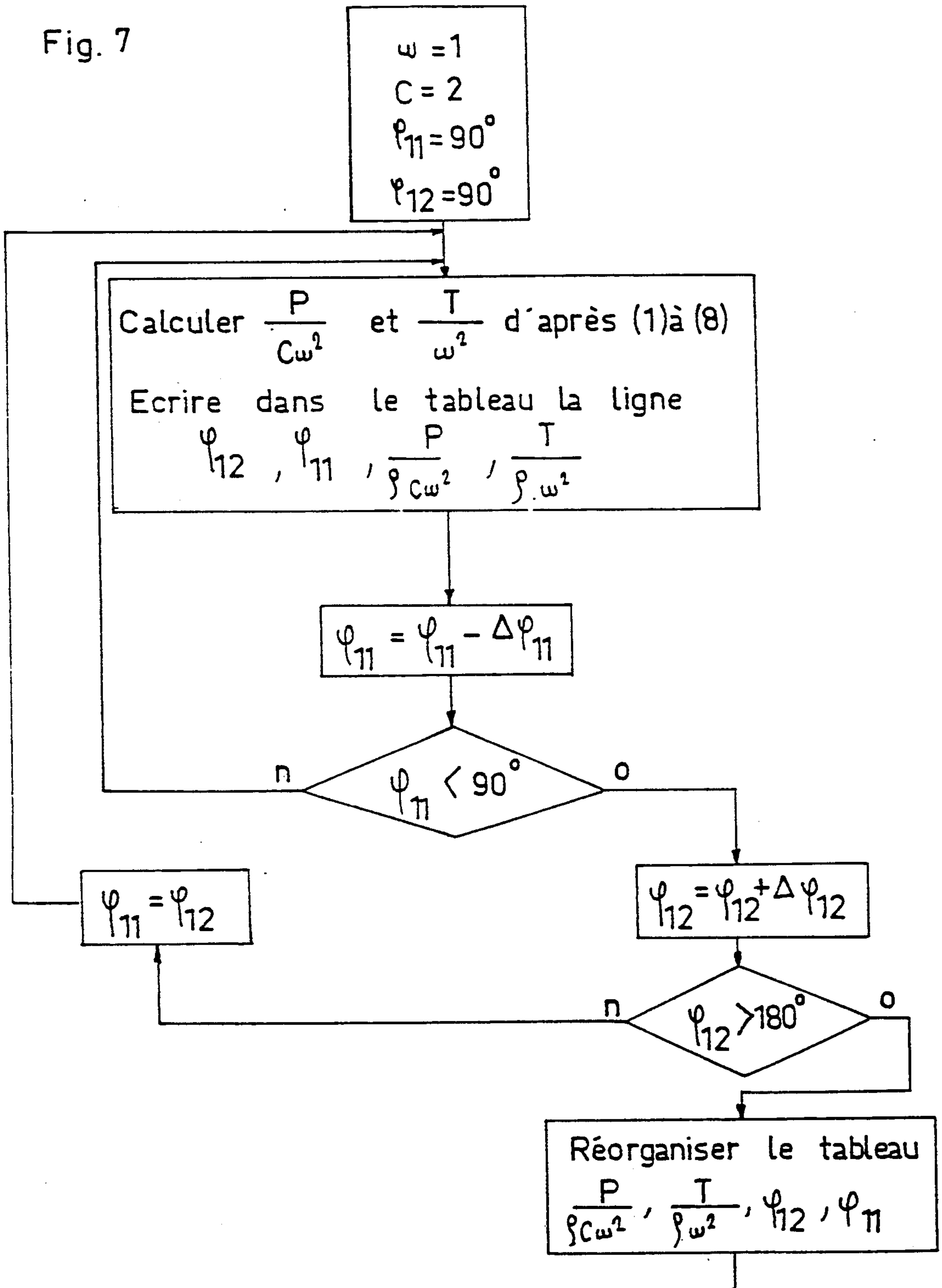

Chaîne de puissance
Actionneurs
Rotor
Capteurs
16
Calculateurs génération de ψ
18
Calculateur choix de φ11, φ12
17
Horloge
20
Centrale anémométrique
14
Mémoire morte
13
Signaux de consigne
15
ω, φA, φr
ω
P, T
V, ρ
V
ψ
φ11, φ12

Fig. 6

Fig. 7



$\Delta\varphi_{11}$ incrément sur φ_{11}
$\Delta\varphi_{12}$ incrément sur φ_{12}

Fig. 8

$\frac{P}{\rho C W^2}$ (m^4)	$\frac{T}{\rho W^2}$ (m^4)	Phi12 (°)	Phi11 (°)
0.0	0.0	90	90
0.0	-2.5	94	86
0.0	-5.0	97	83
0.0	-7.5	101	79
0.0	-10.0	106	74
0.0	-12.5	109	71
0.0	-15.0	114	66
0.0	-17.5	118	62
0.0	-20.0	123	57
0.0	-22.5	129	51
0.0	-25.0	136	44
0.0	-27.5	144	36
0.0	-30.0	165	15
5.0	0.0	95	95
5.0	-2.5	99	91
5.0	-5.0	103	88
5.0	-7.5	108	84
5.0	-10.0	111	80
5.0	-12.5	116	77
5.0	-15.0	121	73
5.0	-20.0	134	65
5.0	-22.5	142	61
5.0	-25.0	158	56
10.0	0.0	100	100
10.0	-2.5	104	96
10.0	-5.0	108	93
10.0	-7.5	113	90
10.0	-10.0	118	86
10.0	-12.5	124	83
10.0	-15.0	130	79
10.0	-17.5	138	76
10.0	-20.0	150	72
15.0	0.0	104	104
15.0	-2.5	109	101
15.0	-5.0	114	98
15.0	-7.5	119	95
15.0	-10.0	125	91
15.0	-12.5	133	88
15.0	-15.0	142	85
20.0	0.0	109	109
20.0	-2.5	115	106
20.0	-5.0	120	103
20.0	-7.5	127	100
20.0	-10.0	135	97
20.0	-12.5	146	94
25.0	0.0	114	114
25.0	-2.5	121	111
25.0	-5.0	127	108
25.0	-7.5	136	105
25.0	-10.0	149	102
30.0	0.0	120	120
30.0	-2.5	127	117
30.0	-5.0	136	114
30.0	-7.5	149	111
35.0	0.0	125	125
35.0	-2.5	134	122
35.0	-5.0	147	119
40.0	0.0	131	131
40.0	-2.5	143	128
45.0	0.0	138	138
50.0	0.0	146	146
55.0	0.0	155	155
60.0	0.0	174	174

R = 1,1 m

r = 0,4 m

E = 3,5 m

n = 5

w = 3,15 tr s

a = 0,2269

$A = -1{,}258\ 10^{-2}\ m^2$

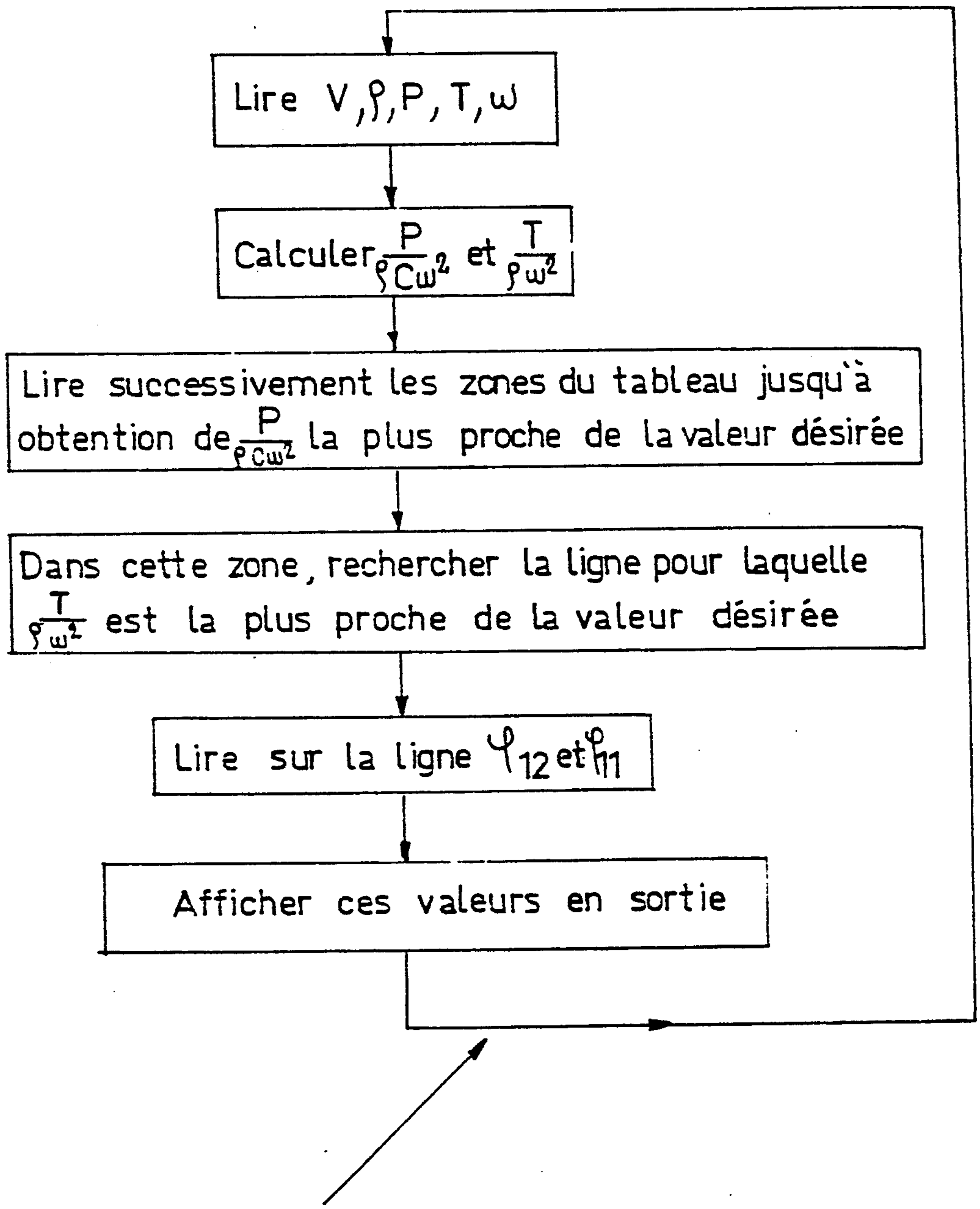
$B = 4{,}891\ 10^{-1}\ m^2$

$C_1 = 6{,}233\ 10^{-3}\ m^3$

Précision sur

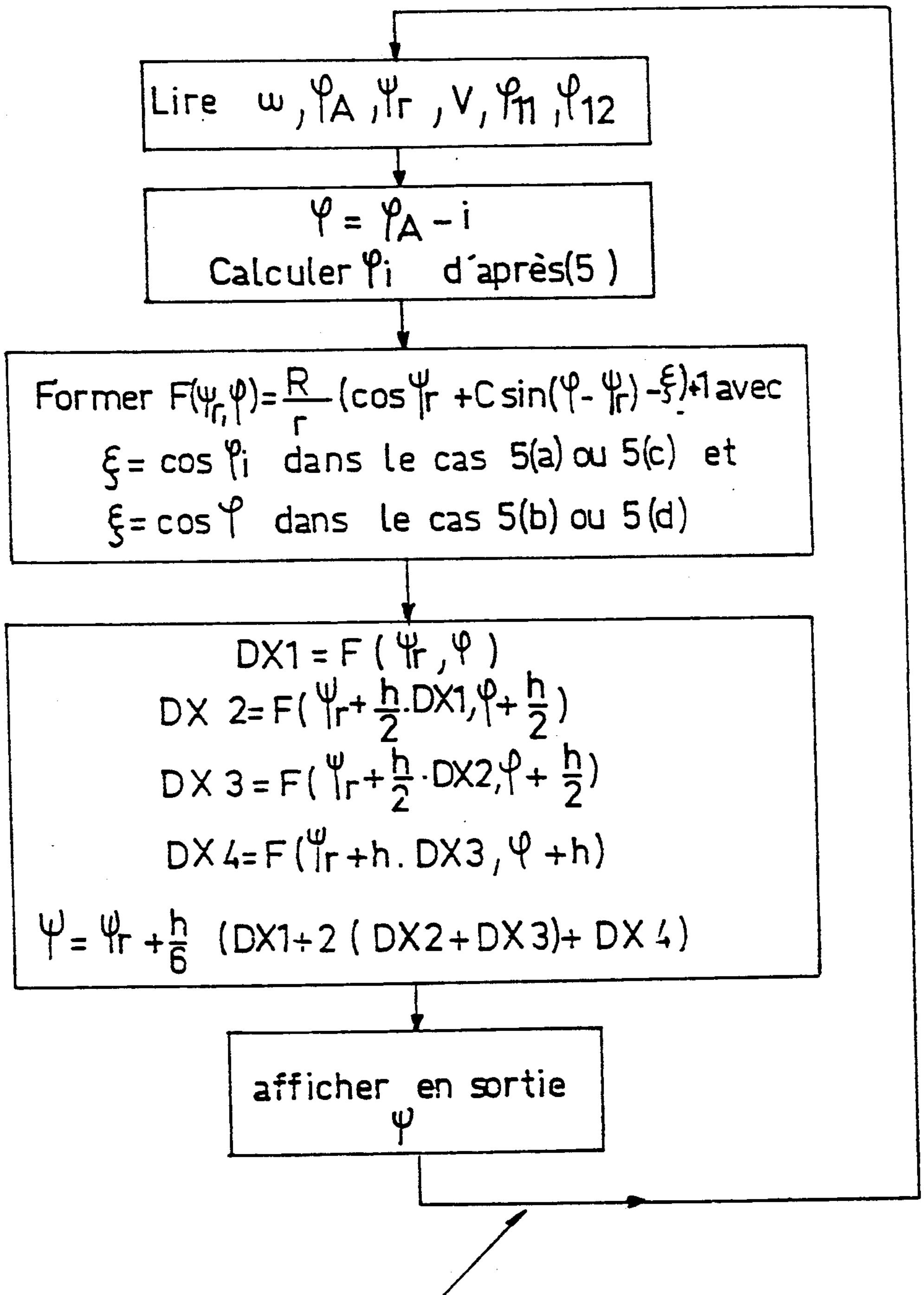
φ_{11} et φ_{12} : ±1°

Fig. 9



Boucle synchronisée par l'horloge 20

Fig. 10



Boucle synchronisée par l'horloge 20 de période t

$h = t\omega$

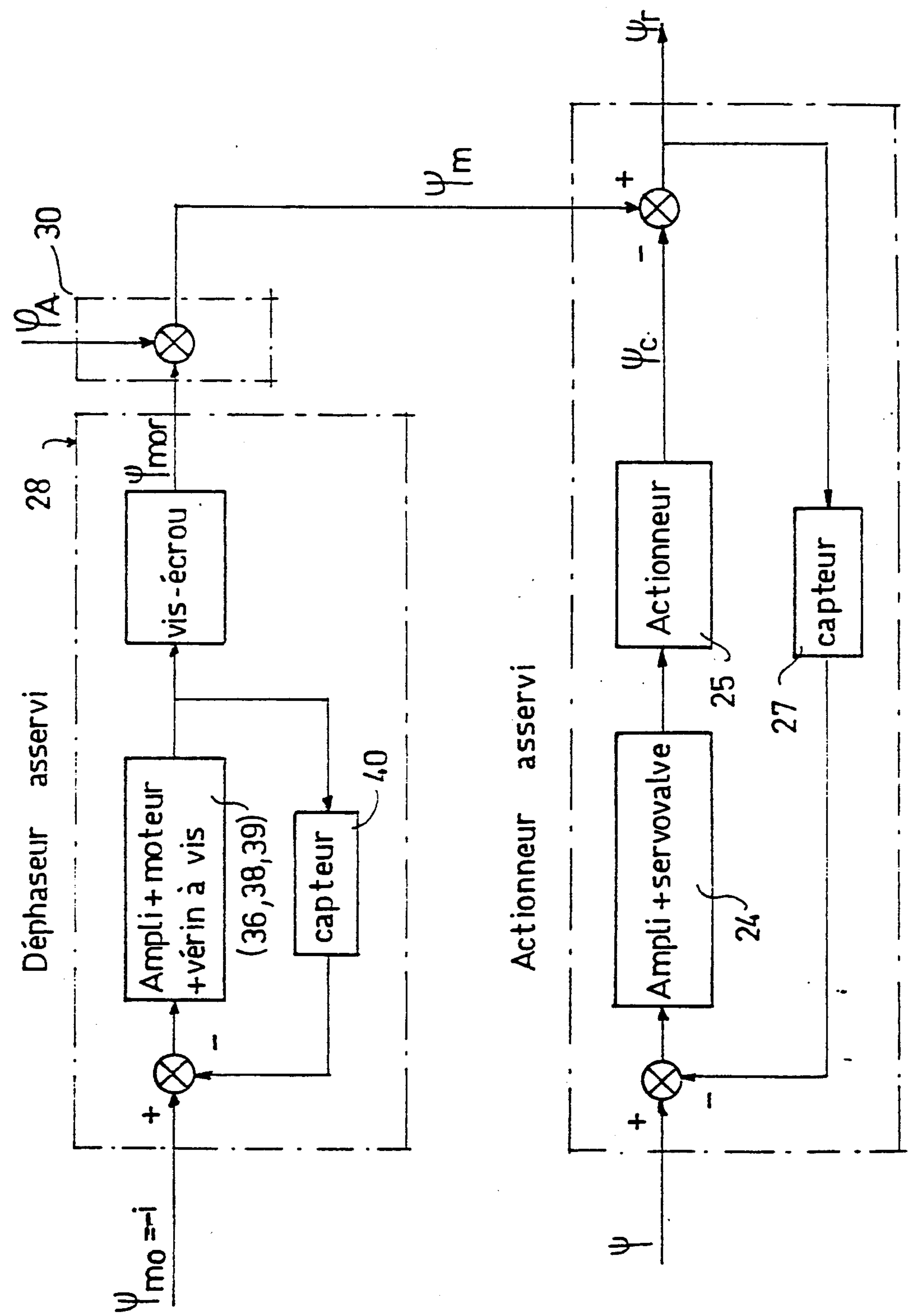
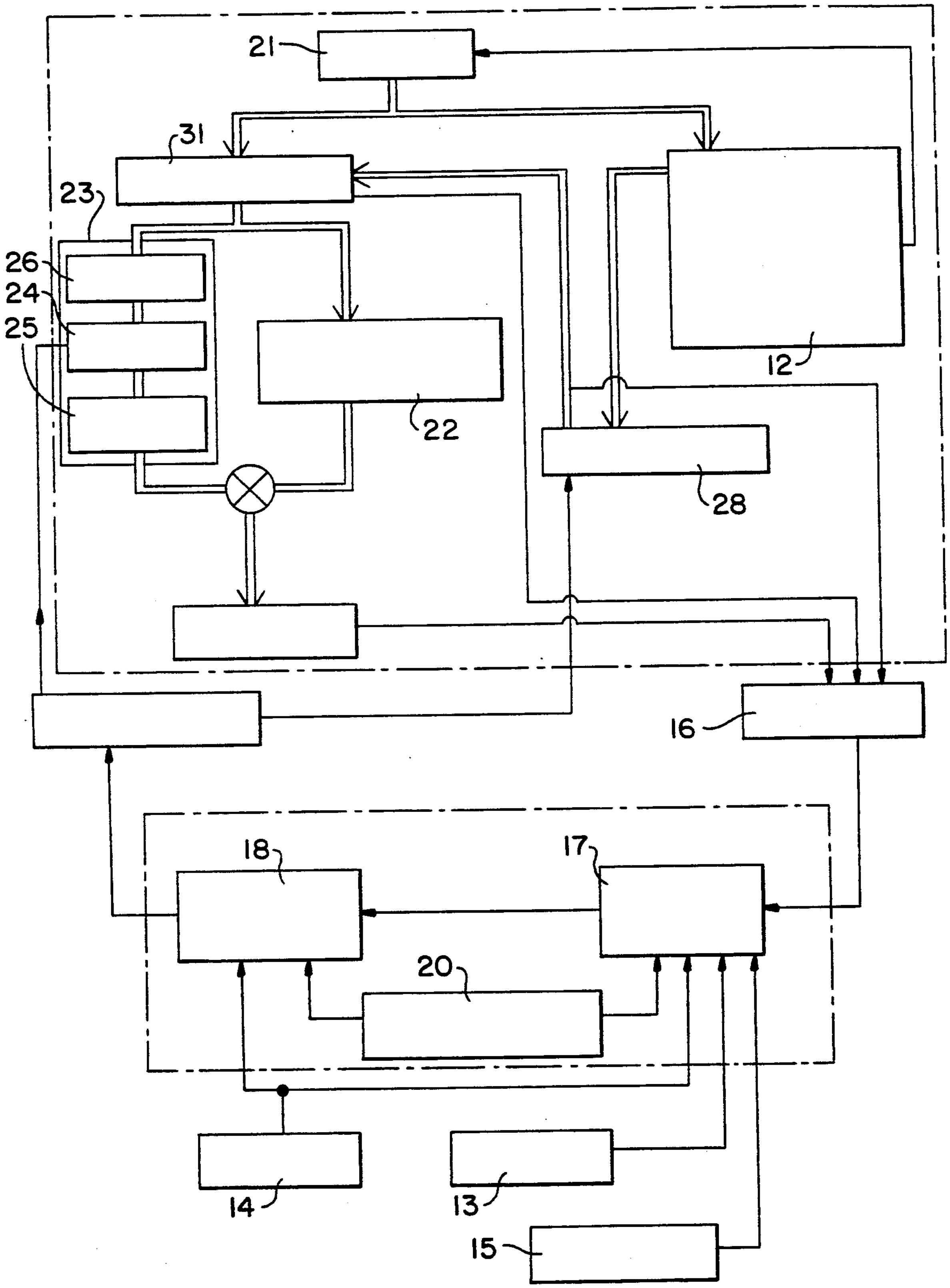

Déphaseur asservi
28
Ampli + moteur +vérin à vis
(36,38,39)
capteur
40
vis-écrou
ψ_{mor}
$\psi_{mo} = -i$
φ_A
30
ψ_m
Actionneur asservi
Ampli +servovalve
24
Actionneur
25
capteur
27
ψ_c
ψ_r
ψ
+
-

Fig.11

Fig. 12



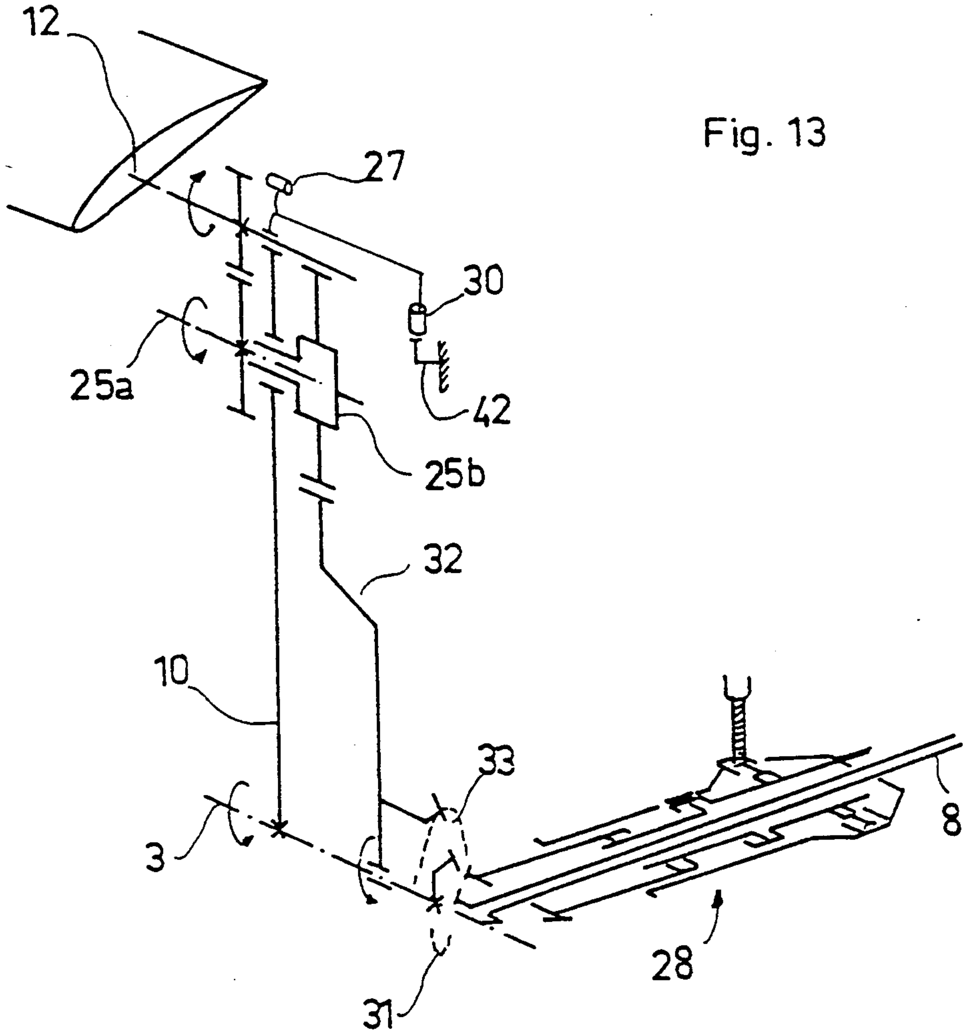


Fig. 13

Fig. 14

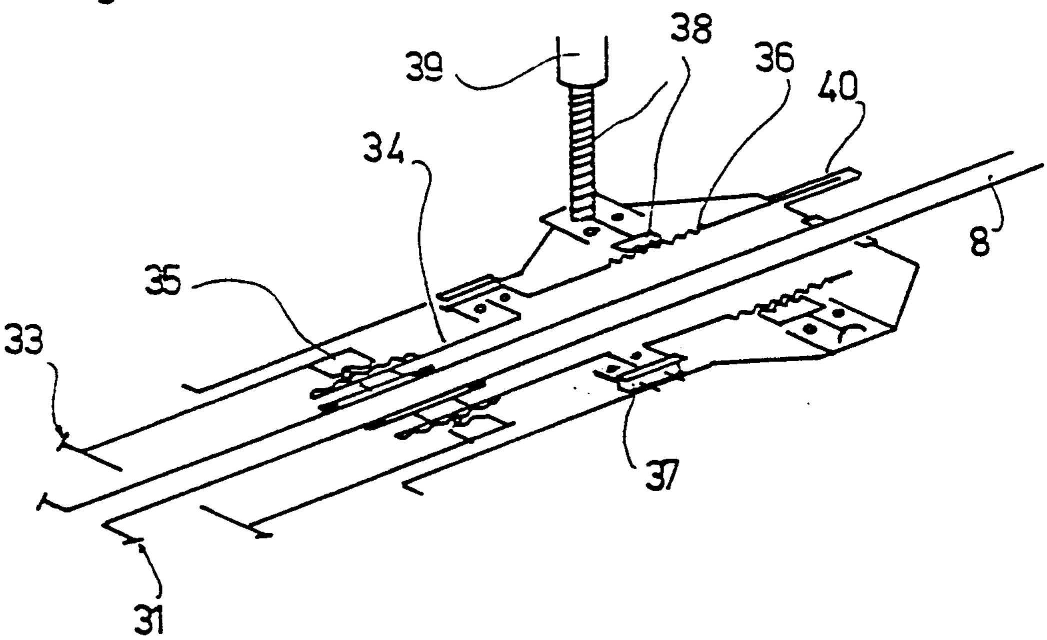
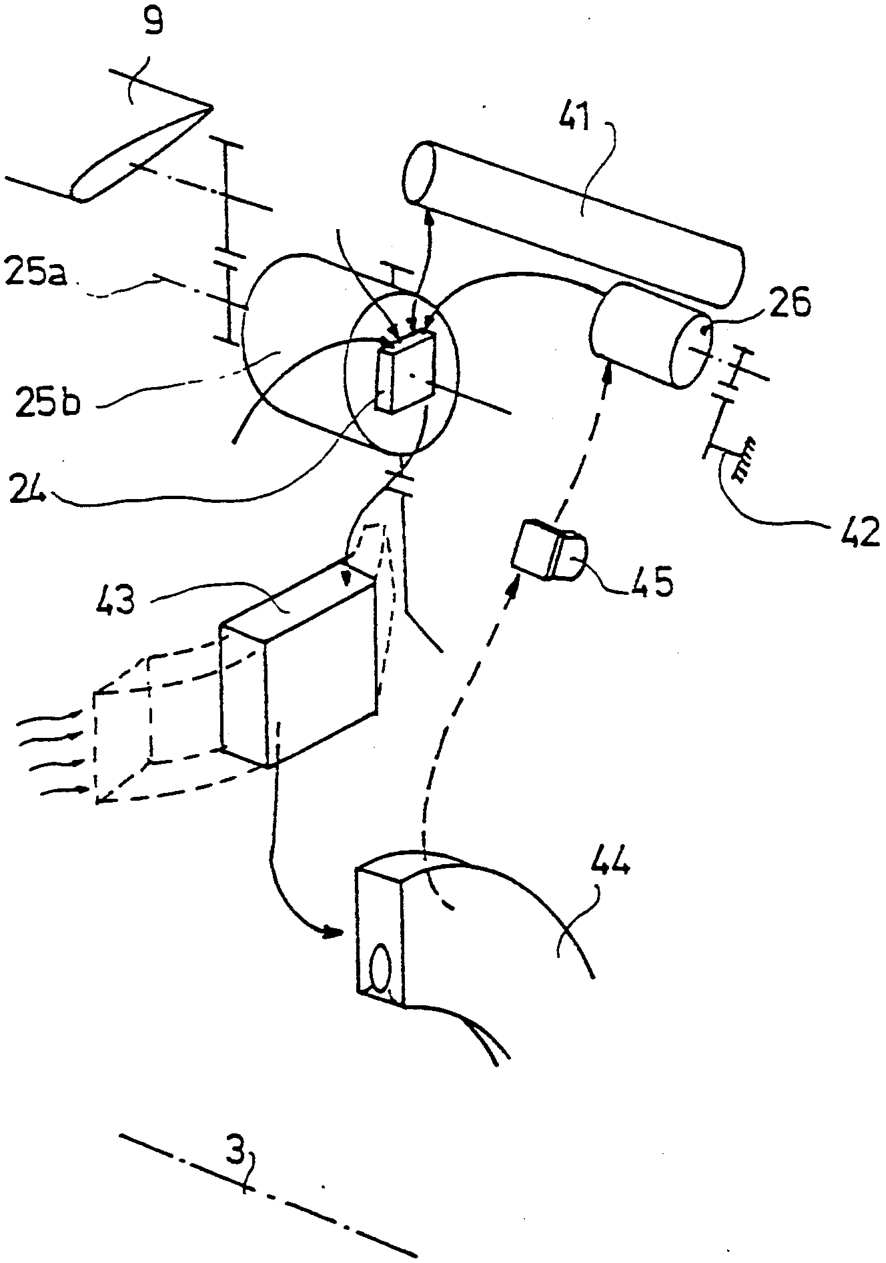


Fig. 15



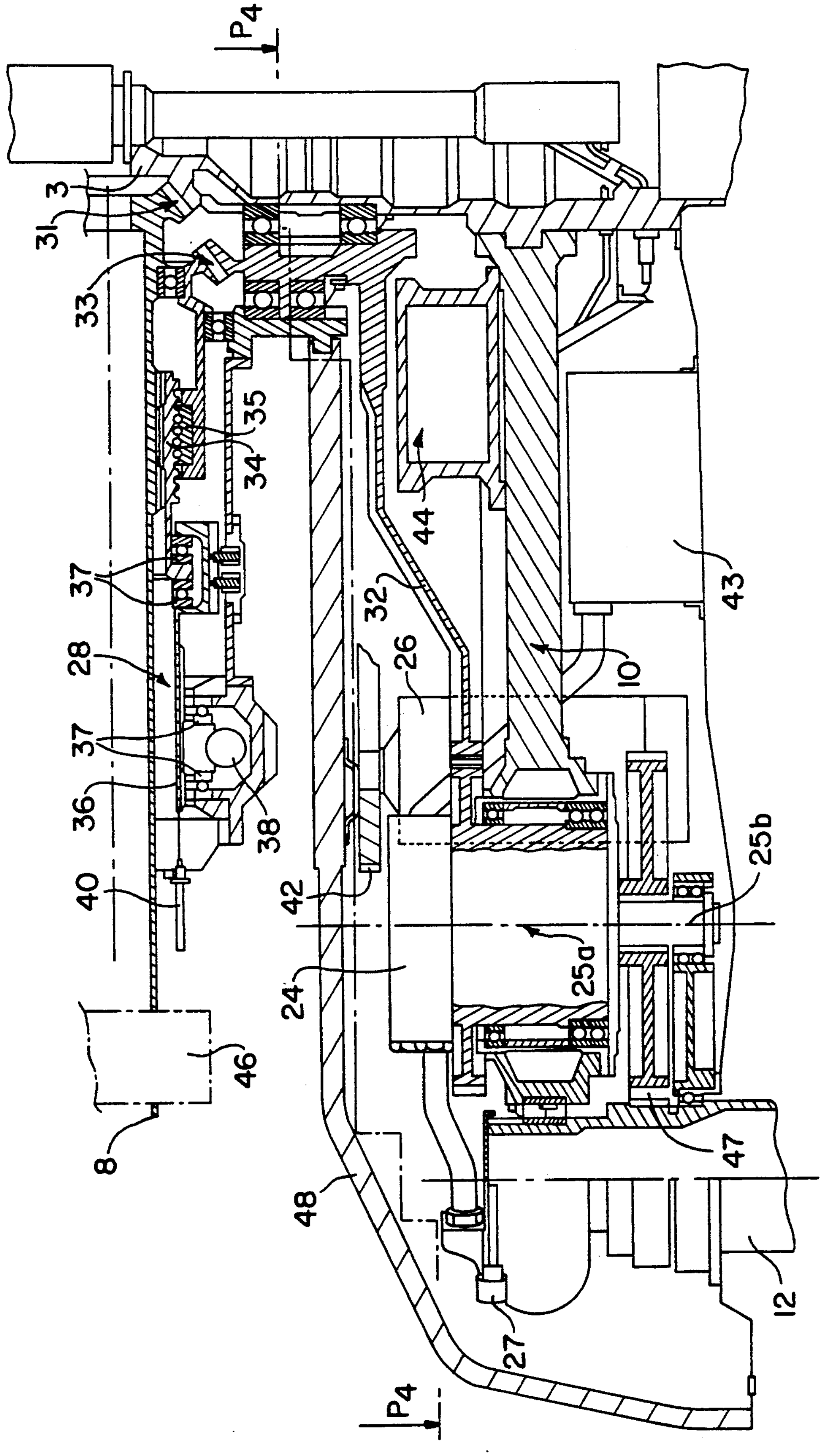

P4
3
31
33
35
34
44
37
32
28
37
36
38
40
42
26
10
43
24
25a
25b
46
8
47
48
27
12
P4

Fig. 16

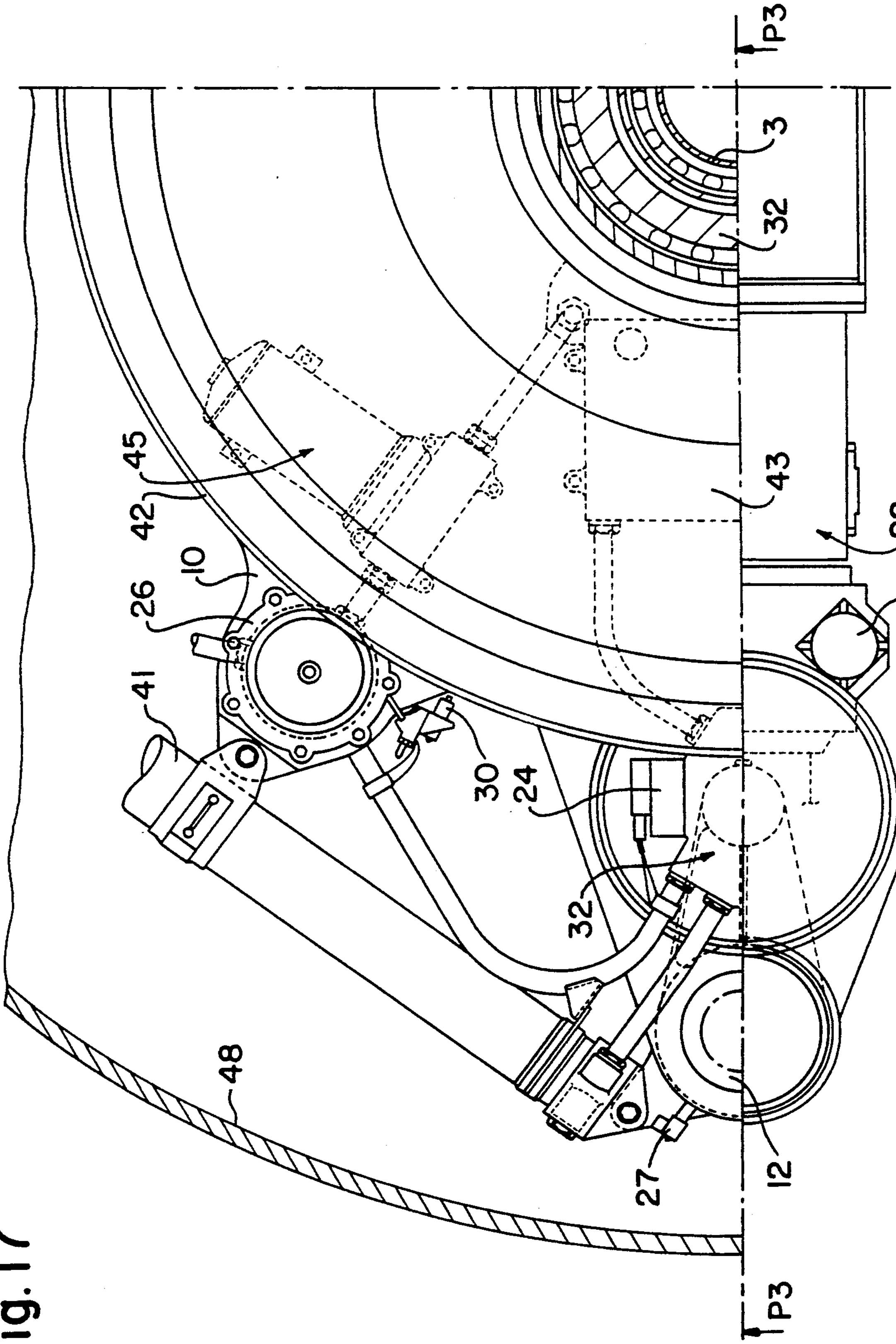


Fig. 17

ROTOR FOR DEVELOPING SUSTAINING AND PROPELLING FORCES IN A FLUID, STEERING PROCESS, AND AIRCRAFT EQUIPPED WITH SUCH ROTOR

This invention relates to an improved rotor assembly, hereinafter referred to as a "rotor", comprising at least one profiled wing and intended to be caused to rotate in a fluid in order to develop sustaining and/or propelling forces. The invention also relates to a steering process for said rotor permitting controlling at each instant the movement of the profiled wings in order to obtain desired aerodynamic (or hydrodynamic) forces. The invention applies in particular in the aeronautical field for the production of aircraft.

BACKGROUND AND OBJECTS OF THE INVENTION

Helicopters are known which have a rotor comprising vanes caused to rotate about an axis perpendicular to their longitudinal direction; each section of the vane is thus driven with a linear speed relatively proportional to its distance from the axis of rotation. Under these conditions, the sustaining and/or propelling forces produced, relative to the swept surface, remain limited by aerodynamic phenomena (maximum speed at the tip of the vane, very low efficiency near the hub, . . .) and it therefor follows that the energy efficiency of this type of rotor is limited (specific lift on the order of 40 to 50 Newtons per horsepower.)

Another type of rotor has been the object of study, and one can refer for example to the following patents which describe examples thereof: French patents 2,375,090, 2,309,401, 2,181,486 and 2,080,452. These rotors comprise profiled vanes or wings (hereinafter referred to as "profiled wings" by reason of their arrangement with respect to the flow of fluid which is similar to that of the wings of airplanes) which are caused to rotate about an axis parallel to their longitudinal direction. Under these conditions, each profiled wing section works under the same aerodynamic conditions (identical speed, incidence, circulation). One would therefor expect that this type of rotor would benefit from an aerodynamic efficiency which is much superior to that of helicopter rotors. However, in this type of rotor, each profiled wing is brought during its rotation to follow a rule or law of incidence which determines the performances of the rotor and the theory behind known rotors of this type directs a fixed rule of incidence, that is, one which repeats indefinitely, identically to itself: the relatively arbitrary choice of this rule (in particular imposed by technological constraints) cannot in any case in known rotors of this type, permit optimizing the efficiency when the operating conditions vary (speed of rotation of the rotor, speed of advance, relative incidence of the air . . .). Further, these rotors of fixed kinetics are unusable in practice since, in the given operating conditions, they impose the intensity and/or the direction of the aerodynamic force produced and do not permit producing the necessary modulations for an effective steering of the aircraft. Further, even in the theoretical scheme, the prior documents which describe this type of rotor do not provide any suggestions which would permit adjusting the law of incidence to the desired forces.

The present invention seeks to overcome the deficiencies of known rotors of the aforementioned type having profiled blades or wings rotating about an axis parallel to the longitudinal direction of the profiled wings. The invention seeks to benefit fully from the advantages that may be expected from this type of rotor, in particular improved aerodynamic efficiency with respect to that of helicopter rotors.

One of the objects of the invention is in particular to provide an improved rotor having profiled wings or blades, the incidence of which is adjustable in real time according to a non-fixed rule.

Another object is to provide a process for steering said rotor, permitting at each instant controlling the rule of incidence of each profiled wing for obtaining sustaining and/or propelling forces desired at the moment considered, with an optimum energy efficiency.

DESCRIPTION OF THE INVENTION

The rotor provided by the invention, which is intended to be attached to an airframe movable in a fluid for exerting thereon sustaining and/or propelling forces, is of the type comprising a supporting structure mounted on the airframe in such a manner as to be able to be rotatingly driven about an axis of rotation (O) and at least one profiled wing extending parallel to the axis of rotation (O) and articulated about its supporting structure by a pivot connection of the axis (B) essentially parallel to said axis of rotation (O) at a speed of rotation: the controlling process according to the invention comprises:

storing preliminarily data representative of the following structural parameters of the rotor: n (number of profiled wings of the rotor); E (the span of each profiled wing); R (the distance between the axis of rotation O and the axis B of the pivot connection); r (the distance on the chord of the profiled wing between the axis B and a point P situated essentially at the rear quarter of the profile); a (coefficient of transformation conforming to the profiled wing);

$$A = 2\pi(a_1 - a^2) + S$$
$$B = 2\pi(a_1 + a^2 - S)$$

$$C_1 = 2\pi\left(\frac{a_1a_2}{a^2} + \frac{a_2a_3}{a^4}\right) - \pi(A_{-1} - a_1A_1 - 2a_2A_2 - 3a_3A_3 \ldots)$$

where $a_1, a_2 \ldots a_i$ are the terms of the congruent transformation developed in the Laurent series, $A_{-1}, A_1, \ldots A_i$ are the terms of the product of the congruent transformation and its conjugate developed in the Laurentian series and S the surface normal to the profile,

measuring and determining at each instant the relative speed V of displacement of the airframe with respect to the fluid, the speed of rotation ω of the rotor and the volumic mass ρ of the fluid from measurements of the dynamic pressure, the static pressure and the temperature of the fluid,

measuring and permanently determining during rotation, the aerodynamic azimuth ϕ of each profiled wing for generating a corresponding measurement signal, said aerodynamic azimuth being the angle formed by the direction of the relative wind and the plane M containing the axis of rotation O and the axis B of the pivot connection of the profiled wing considered,

generating reference signals representative of the desired forces on the airframe (forces translated by their projections P and T respectively according to a direction perpendicular to the relative wind and according to the direction of the relative wind, said forces P and T being designated by the sequence of lift and drag),

determining permanently, for each profiled wing, from the stored parameters, the measured values and the reference signals, the instantaneous geometric angle Ψ defined by the chord of the profiled wing and by the plane M corresponding to ±0.2 radians close to the following relationships (all angles being defined in the trigonometric sense):

$$\mathrm{Cos}\phi_i = C\sin(\phi - \Psi) + \cos\Psi + \frac{r}{R\omega}\left(\omega - \frac{\delta\Psi}{\delta t}\right) \tag{1}$$

$$P = \frac{\eta E}{2}\pi\int_0^{2n} - f\left\{\left[\Gamma - B\left(\omega - \frac{\delta\Psi}{\delta t}\right)\right]m - C_i\left(\omega - \frac{\delta\Psi}{\delta t}\right)^2 - A\frac{\delta l}{\delta t}\right\}\sin(\phi - \Psi)\cdot\delta + \frac{\eta E}{2\pi}\int_0^{2n} f\left\{\left[\Gamma + A\left(\omega - \frac{\delta\Psi}{\delta t}\right)\right]l + C_1\frac{\delta^2\Psi}{\delta t^2} - B\frac{\delta m}{\delta t}\right\}\cos(\phi - \Psi)\cdot\delta\phi \tag{2}$$

$$T = \frac{\eta E}{2\pi}\int_0^{2n} - f\left\{\left[\Gamma - B\left(\omega - \frac{\delta\Psi}{\delta t}\right)\right]m - C_1\left(\omega - \frac{\delta\Psi}{\delta t}\right)^2 - A\frac{\delta l}{\delta t}\right\}\cos(\phi - \Psi)\cdot\delta\phi + \frac{\eta E}{2\pi}\int_0^{2n} - f\left\{\left[\Gamma + A\left(\omega - \frac{\delta\Psi}{\delta t}\right)\right]l + C_1\frac{\delta^2\Psi}{\delta t^2} - B\frac{\delta m}{\delta t}\right\}\sin(\phi - \Psi)\cdot\delta\phi \tag{3}$$

$$0 \leqq \phi_{11} \leqq \phi_{12} \leqq \pi \tag{4}$$

$$\phi_i = \phi_{11} \text{ and } \Gamma = 4\pi aR\omega(\cos\phi_{11}) \text{ if } -\phi_{11} < \phi < \phi_{11} \tag{5)(a}$$

$$\phi_i = \phi \text{ and } \Gamma = 4\pi aR\omega(\cos\phi) \text{ if } \phi_{11} \leqq \phi < \phi_{12} \tag{5)(b}$$

$$\phi_i = \phi_{12} \text{ and } \Gamma = 4\pi aR\omega(\cos\phi_{12}) \text{ if } \phi_{12} < \phi < 2\pi - \phi_{12} \tag{5)(c}$$

$$\phi_i = \phi \text{ and } \Gamma = 4\pi aR\omega(\cos\phi) \text{ if } 2\pi - \phi_{12} \leqq \phi \leqq 2\pi - \phi_{11} \tag{5)(d}$$

$$l = -R\omega[\sin\Psi + C\cos(\phi - \Psi)] \tag{6}$$

$$m = R\omega[\cos\Psi + C\sin(\phi - \Psi)] - \frac{\eta}{2}\left(\omega - \frac{\delta\Psi}{\delta t}\right) \tag{7}$$

and

$$C = \frac{V}{\omega R} \tag{8}$$

and controlling the instantaneous geometric angle of each profiled wing at the value of the angle Ψ obtained for said wing.

A model of the non-stationary aerodynamic phenomena has permitted determining a family of rules of incidence corresponding to a maximum energy efficiency, defined by equations (1), (4) and (5). In the process of the invention, the rotational cycle (one turn of the rotor) is divided into four sectors limited by the angles Ψ_{11}, Ψ_{12}, $2\pi-\Psi_{12}$, $2\pi-\Psi_{11}$, called commutation an-

gles. The two sectors which correspond to the aerodynamic azimuth Ψ comprise between $2\pi-\Psi_{11}$ and Ψ_{11} on the one hand and Ψ_{12} and $2\pi-\Psi_{12}$, are governed with a law of incidence which assures a discharge at constant circulation (which may be different for each of the sectors). These laws are characterized by the constance of the circulation and are translated by differential equation (1) under the corresponding conditions (5 a, c): no energy loss is generated over these sectors by reason of the constance of the circulation. The two other sectors assure the continuity of the circulation between the two sectors with the aforesaid constant circulation. This continuity is assured by differential equation (1) under the corresponding conditions (5 b, d) and authorize the effective passage from one law of incidence to the other. The direction and the intensity of the forces produced are adjusted at each moment by the value which is given to each cycle at each of the commutation angles, according to equations (2), (3), (6) and (7). The integration at each instant of the differential equation (1) under the condition (5) (corresponding to the sector in progress) provides the record of control of the instantaneous geometric angle Ψ of each profiled blade. It is suitable to note that the the assembly of the aforesaid relationships (1) through (8) define the kinematics of a profiled blade, the aerodynamic azimuth Ψ being relative to this profiled blade.

According to a preferred embodiment, the instantaneous geometric angle Ψ is determined by the following operations:

for the assembly of profiled blades:

determining preliminarily from a table of correspondance of values between the parameters Ψ_{11}, Ψ_{12},

$$\frac{P}{C\omega^2\rho} \text{ and } \frac{T}{\omega^2\rho},$$

this table being determined by carrying out on the parameters Ψ_{11}, Ψ_{12} (called commutation angles), the discrete values arranged in a series over the range of variation (4) and calculating for each pair of values (Ψ_{11}, Ψ_{12}) the values of the solutions

$$\frac{P}{C\omega^2\rho} \text{ and } \frac{T}{\omega^2\rho},$$

of the relations (2), (3),

storing said table of correspondance,

calculating permanently the magnitudes

$$C = \frac{V}{\omega\rho}, \frac{P}{C\omega^2\rho}, \text{ and } \frac{T}{\omega^2\rho}$$

as a function of the desired forces P and T and the parameters V, ω and ρ determined,

searching the correspondence table for retrieving the couple

$$\frac{P}{C\omega^2\rho}, \frac{T}{\omega^2\rho}$$

closest to the corresponding calculated magnitudes and extracting the values of the corresponding parameters Ψ_{11}, Ψ_{12},

for each profiled blade:

resolving the differential equation (1), while giving to the parameters Ψ_{11}, Ψ_{12} the values extracted from the table, for obtaining the searched for value of the instantaneous geometric angle Ψ concerning the profiled blade considered.

The determination of the commutation angles from the aerodynamic forces to be generated (P, T) leads to calculations which are very burdensome by reason of the inverse character of the equations (permitting an easy calculation of the forces P and T from a law of incidence of the family, but much more complex in the reverse direction). The correspondence tables mentioned above are established preliminarily by means of a calculator arranging a memory in which are stored the structural parameters of the rotor, while resolving the equations in the direct direction; this permits subsequently, during flight, a rapid determination by quick, conventional calculating means, of the commutation angles ϕ_{11}, ϕ_{12} from the forces P and T (a determination compatible with control in real time). Then, integration of the differential equation over each sector of the cycle is a calculating operation running in real time, which provides the desired geometric angle ϕ for controlling the operating mechanism.

To assure the continuity of the real movement of each profiled blade, the real value Ψ_r of the instantaneous geometric angle of each profiled blade comprises:

providing an operating means for the assembly of profiled blades according to a cyclic average law of incidence $\Psi_m=f(\phi)$ by a reversible kinematic able to provide or recover energy according to the load characteristics of the profiled blades,

providing a complementary operating mechanism for each profiled blade, from the calculated value of the instantaneous geometric angle Ψ, while adjusting at each instant an additional incidence $\Psi_c=\Psi-\Psi_m$ by means of an actuator.

This operating mechanism by totalizing permits minimizing the power to be installed for driving the rotor and the adjusting the incidence of the profiled blades. In effect, at certain moments of the cycle, the profiled blades are generators of power, while at other moments, they require significant power. The reversible kinematic chain common to profiled blades operates a transfer of energy between the different profiled blades, while the actuator of the complementary operating mechanism associated with each profiled blade provides a fine adjustment of the geometric angle Ψ of the blade considered: because of the presence of the reversible kinematic chain, these actuators have less energy to be furnished (lesser dimensions, lesser response time . . .).

The invention relates to an improved rotor comprising a carrier member adapted to be mounted on the airframe in such a manner as to be able to be driven in rotation about an axis of rotation (O) and at least one profiled blade extending parallel to the axis of rotation (O) and articulated on the carrier member by a pivot connection about axis (B) essentially parallel to the axis of rotation (O); according to the present invention, this rotor comprises, combined with the preceding means:

means for storing specific data of the rotor,

means for measuring and determining the relative speed V of the displacement of the cell, of the speed of rotation ω of the rotor and of the volumic mass of the fluid ρ,

means for measuring and determining the aerodynamic azimuth ϕ of each profiled wing during rotation,

means for generating a control signal representative of the desired forces P, T,

means for calculating the instantaneous geometric angle Ψ for each profiled blade as a function of the stored parameters, the values determined and the control signals,

control means for each profiled blade, adapted to control at each instant the angular position of the blade at the value Ψ calculated and emitted from the calculating means.

According to a preferred embodiment, the control means comprises:

a kinematic chain, common to the assembly of profiled blades and mechanical structure adapted to cause at its output a rotation according to a cyclic law of incidence Ψ_m,

a hydraulic distributor with a servo-valve, associated with each profiled wing, said distributor receiving a signal representative of the angular variation $\Psi-\Psi_r$, for the profiled blade considered and being adapted to generate a hydraulic power directly related to said angular variation,

and a rotary hydraulic actuator associated with each profiled blade and receiving the hydraulic power from the corresponding distributor, said actuator comprising a rotatably movable body driven by the kinematic chain according to the average law Ψ_m, an output shaft connected to the profiled blade for achieving the angular position thereof.

Thus, the kinematic chain may for example provide a circular translation of the assembly of profiled blades, in such a manner that the actuator body associated with each profiled blade produces an adjustment with respect to the relative wind, imposed by the cyclic law of incidence. This law is once and for all fixed by the structure of the kinematic chain. The controlling and optimizing of the law of incidence (such as previously defined) are obtained by the intervention of the hydraulic distributor and actuator attached to each blade, which imposes thereon its effective angle of incidence at each instant. The additional angle caused by this hydraulic actuator is adjustable at each instant through the hydraulic distributor. This hydraulic solution permits very high [massique] forces and limits the inertia of the moving parts, thus permitting the rapid accelerations necessary for obtaining the optimum law of steering of the rotor defined above.

Preferably the aforementioned kinematic chain comprises a phase shifter adapted to permit a predetermined adjustment of the origin Ψ_{mo} of the cyclic law of incidence Ψ_m while limiting the maximum amplitude that each actuator must provide. At each cycle, it is, in effect, possible to minimize the peak amplitude of the additional angle Ψ_c which must be provided to each actuator by a controllable [recalage] and appropriate to the angular position of the actuator bodies with respect to the relative wind (the origin of the law Ψ_m).

The hydraulic distributor and servo-valve associated with each profiled blade is advantageously connected to at least one hydraulic supply pump and to at least one hydraulic reservoir, arranged in such a manner that said hydraulic reservoir will be filled in case of excess power available on the pump and drained in the opposite case. The power to be provided is reduced considerably, since, for the pumps, only the average maximum power is to be provided (and not the instantaneous maximum power).

The invention also relates to an aircraft comprising at least one rotor such as described above and an integrated motor group at its airframe and coupled with the motor shaft of each rotor.

DESCRIPTION OF THE DRAWINGS

The invention having been described in its general form, the description which follows in reference to the accompanying drawings showing one embodiment and illustrating the steering process. In these drawings which form an integral part of the present description:

FIG. 1 is a schematic side view of an aircraft according to the invention;

FIG. 2 is a half-section from above;

FIG. 3 is a partial and simplified cross-sectional view of a rotor through plane P_1;

FIG. 4 is a perspective schematic view with parts broken away;

FIG. 5 is a transverse schematic cross-sectional view of the rotor through a plane P_2;

FIG. 6 is an block diagram showing the steering process;

FIGS. 7, 9 and 10 are block diagrams illustrating the calculating procedures, while FIG. 8 is a simplified example of the correspondence table initially prepared and stored;

FIG. 11 is an operating diagram of the control loop;

FIG. 12 is a block diagram of the power train and operating mechanism of the rotor;

FIG. 13 is a general mechanical schematic view of the reversible kinematic chain assuring the average law Ψ_m,

FIG. 14 is a detailed schematic of phase shifter of this chain;

FIG. 15 is a schematic view of the implementation of hydraulic power means;

FIG. 16 is a partial longitudinal cross-section of the rotor through a plane P_3, and

FIG. 17 is a partial transverse cross-sectional view along a broken line P_4.

DESCRIPTION OF PREFERRED EMBODIMENTS

The aircraft shown by way of example in FIGS. 1 and 2 comprises a airframe 1 of a conventional type, on which are mounted in the example shown four rotors according to the invention, such as 2. The two front rotors of reduced dimensions are intended to permit the control of the aircraft according to the axis of pitch and play the role of the horizontal rear ailerons of conventional airplanes. These rotors are steered according to a law of incidence giving giving purely sustaining forces with respect to the relative wind ($T=0$ $P>0$). They are structurally identical to the primary rear rotors intended to develop sustaining forces and/or propulsion forces as a function of the directions from the pilot. The laws of incidence of the two primary rotors are identical in rectilinear flight and symmetrical conditions and will be differentiated by the commands in the goal of obtaining desired movements of looping and rolling.

Each rotor 2 comprises a longitudinal rotating shaft 3 (the term "longitudinal" referring to the direction of the rotor) which is carried on one side by a hub 4 connected to the airframe 1 and which is supported on the other side by a fixed profiled member 5 provided with a bearing, this member extending back and attached to the airframe 1. In the example, the profiled member 5 is provided with a wheel 7.

The airframe encloses a motor group which is common the the assembly of the rotors and of which the output shaft 8 may be seen in FIG. 4. This shaft 8 is coupled to the shaft 3 of each rotor by a mechanical transmission, assuring the rotational driving of the rotor considered at a speed ω.

Each rotor comprises five profiled blades such as 9, angularly distributed by 72° about the central shaft 3. The longitudinal spread of each profiled blade is designated by -E-.

The profiled blades 9 are carried by a carrier member comprising two flanges 10 and 11 on which they are articulated by axles such as 12, comprising a pivot connection of the axis B. The end of the axle 12 situated on the side of the airframe is driven in rotation as will be seen below for imposing a predetermined incidence to the profiled blade, while the other axle serves only as a bearing.

Shown in FIG. 5 is a cross-section of the rotor through a plane P_2 perpendicular to its axis. The profiled blades 9 are in the example symmetrical biconvex profiles, especially of the "KARMAN-TREFITZ" type, but may be of a different type following the desired performances. The internal rib structure of each profiled blade is of a conventional type, with caissons or otherwise.

The profiled blade is articulated about its axles 12 essentially in the quadrant ahead of its chord; this point constitutes approximately the center of the profile and it is with respect thereto that the aerodynamic forces generate the weakest average torque on the wing.

FIG. 5 shows for one of the profiled blades the various characteristic parameters of this blade and of its position at any given moment:

R: the distance between the axis of rotation O (axis of the shaft of the rotor 3) and the axis B of the pivot connection;

r: the distance between the axis B of the pivot connection and the point P situated essentially a fourth to the rear of the profile;

the instantaneous geometric angle Ψ defined by the chord of the profiled blade and a plane M containing the axis of rotation O and the axis B of the pivot connection;

the angular azimuth ϕ formed by a reference plane connected to the cell, for example the axis -Cel- of the airframe and by the plane M;

the aerodynamic azimuth ϕ formed by the direction of the relative wind V (in fact by the projection of the relative wind on a transverse plane perpendicular to the plane M) and by the plane M;

the angle of incidence of the profiled wing $\theta=\phi-\Psi$;

the angle of incidence of the airframe $i=\phi_A-\phi$.

The means described hereinafter with reference to FIGS. 6 to 13 permit adjustment for each profiled blade 9 of the instantaneous geometric angle Ψ of this blade in such a manner as to obtain the desired forces P and T provided by the rotor considered on the cell, these forces being functions of the external conditions encountered and of the flight conditions desired for the aircraft. This means is adapted to define the angle Ψ of each blade by the application of the relationships (1) and (8) already furnished.

The algebraic magnitudes P and T are the projections of the aerodynamic force to be created by the rotor on the airframe under the action of the fluid, respectively according to a direction perpendicular to the relative wind (lift) and in the direction of the relative wind (drag).

FIG. 6 shows the functional diagram of control of the rotor, which comprises:

data storage means specific for the rotor, comprised of a read only memory **13** in which is initially stored a table of correspondence of the values between the angles of commutation ϕ_{11}, ϕ_{12} and the magnitudes

$$\frac{P}{C\omega^2\rho} \text{ and } \frac{T}{\omega^2\rho},$$

means for measuring and determining the relative speed V of displacement of the airframe and of the volumic mass of fluid ρ, constituted by an anemometric station **14**,

means for generating control signals representative of the desired forces P, T, constituted by a conventional system of aeronautical steering **15** (center of inertia, automatic pilot, flight control and associated electronics).

The table of correspondence is obtained in a preliminary phase of calculation by means of a non-airborn calculator, providing a memory in which the following structural parameters are entered:

nE: equivalent span, equal to the product of the number n of profiled blades (five for the rotor described in the example) per their span E;

R: the distance on the chord of the profiled blade between the axis B and the point P situated essentially a fourth to the rear of the profile (in the example r is essentially equal to half of the length of the chord);

a: the coefficient of congruent transformation applied to the profile of the blade (conventional data of the profile concerned, in the example of the KARMAN-TREFTZ profile chosen of a relative thickness of 17%: a=0.2269);

$$A = 2\pi(a_1 - a^2) + S, \text{ in the example equal to } -1.258 \times 10^{-2}m^2,$$

$$B = 2\pi(a_1 + a^2 - S), \text{ in the example equal to } 4.891 \times 10^{-1}m^2,$$

$$C_1 = 2\pi\left(\frac{a_1a_2}{a^2} + \frac{a_2a_3}{a^4}\right) - \pi(A_{-1} - a_1A_1 - 2a_2A_2 - 3a_3A_3 \ldots$$

(in the example, $C_1 = 6.233\times10^{-3}m^3$), where a_1, a_2 . . . a_i are terms of the congruent transformation developed by the Laurent series, A_{-1}, A_1, . . . A_i the terms of the product of the congruent transformation and of its conjugate developed in the Laurent series and S the normal surface of the profile.

A set of sensors **16** measures at each instant the real parameters of the configuration of the rotor (ϕ_A: angular azimuth of a profiled blade of reference, Ψ_r: instantaneous real geometric angle which characterizes at each instant, each profiled blade).

Further, the system is provided with calculating means comprising a first calculator **17** called upon to determinate at each instant the commutation angles ϕ_{11}, ϕ_{12}, and common to the assembly of profiled blades, and a second calculator **18** associated with each profiled blade in order to calculate the instantaneous geometric angle Ψ of said profiled blade.

For this, the read only memory **13** stored a table or correspondence of the values between the angles of commutation ϕ_{11}, ϕ_{12} and the magnitudes

$$\frac{P}{C\omega^2\rho} \text{ and } \frac{T}{\omega^2\rho}.$$

A simplified example of said table is provided in FIG. **8** for the rotor and the KARMAN-TREFITZ profile considered.

This table is defined in the preliminary step of the aforementioned calculations by means of the non-airborn calculator, by giving to the angles ϕ_{11} and ϕ_{12} discrete values, in the example with a step of **10** degrees between 90° and 180°, and by calculating for each by calculating for each pair of values ϕ_{11}, ϕ_{12} the values of the magnitudes

$$\frac{P}{C\omega^2\rho} \text{ and } \frac{T}{\omega^2\rho}.$$

by means of the relations (2) and (3). It should be noted that $90° \leqq \phi_{11} < \phi_{12} \leqq 180°$ corresponds to forces of positive lift (lifting force) and negative drag (propulsion). The logic diagram for the calculation of this table is provided in FIG. 7.

The table of correspondence may thus be stored in the memory **13** in the form of a four column matrix corresponding to the values of

$$\frac{P}{C\omega^2\rho}, \frac{T}{\omega^2\rho}, \phi_{11}, \phi_{12}.$$

The calculator **17** receives the parameters V, p, ω, P and T from the center **14**, the sensors **16** and the generating means **15**. It calculates permanently the magnitudes

$$\frac{P}{C\omega^2\rho} \text{ and } \frac{T}{\omega^2\rho}.$$

The constant $C = V/\omega R$ is determined from the values of V, ω received by the calculator and the numerical value R, the constant integrated to the computer of the calculator **17**. This then explores the table of correspondence stored in the memory **13** while reading the two columns

$$\frac{P}{C\omega^2\rho}, \frac{T}{\omega^2\rho}$$

for identifying closest pair of calculated values and extracting the corresponding values ϕ_{11}, ϕ_{12} in the two other columns. All the magnitudes thus indicated are common to the set of profiled blades, such that the calculator **17** is unique.

By contrast, a calculator **18** is associated with each profiled blade. If arranges in its program the numerical values r and R and receives at each instant:

the angles of commutation ϕ_{11}, and ϕ_{12} issued by the calculator **17**,

the angular azimuth ϕ_A and the instantaneous real geometric angle Ψ_r, issued from the sensors **16** (attached azimuth and angle of the profiled blade considered),

the relative speed V from the center **14**,

the speed of rotation ω issued from the sensors **16**.

From these values, the calculator **18** resolves for each profiled blade the differential equation (1) for calculating the value sought of the instantaneous geometric angle Ψ.

The resolution of this differential equation is carried out at each instant by a calculation having the following steps: comparing the measured value ϕ to the angles of commutation ϕ_{11}, ϕ_{12} for determining the value of ϕ_i by the relations (5),

using the value of ϕ_i and the measured parameters, calculated or stored, C, ω, r, R, for resolving said differential equation by a RUNGE-KUTTA method.

The real value Ψ_r of the geometric angle of each profiled blade, which is measured by one of the sensors **16**, is introduced at each instant into the calculator **18** for serving as the integration constant.

The logic diagrams of FIGS. **8** and **9** illustrate the algorithms of calculation, carried out respectively in the calculators **17** and **18**.

The program is executed in a sequential manner due to the clock signals generated by a clock **20** of a high frequency with respect to the number of rotations per second of the rotor (2,000 hertz for example for speeds of rotation of the rotor on the order of 5 turns per second). At each clock pulse, the calculators **17** and **18** read the operating and measured signals, then the calculations are carried out in the time t separating two clock pulses for determining the new value of the instantaneous geometric angle Ψ called upon to serve as the operating instruction for the operating mechanism.

The angular integration step h is equal to $t\omega$ which represents the increase in the angular azimuth ϕ_A between two clock pulses.

FIG. **11** is a functional diagram of the closed operating mechanism cycle associated with each profiled blade of the rotor, which from the instantaneous geometric angle Ψ issued by the calculator **18** and the information of the relative speed V, controls the angular position of the profiled blades in such a manner as to reduce at each instant the variation between the instantaneous geometric angle Ψ calculated and the real instantaneous geometric angle Ψ_r.

In this manner, the real movement of each profiled blade (angular position Ψ_r) is obtained by addition of an average movement (average cyclic angle of incidence Ψ_m) and a complementary movement (additional angle of incidence Ψ_c).

The average movement is assured by a kinematic chain **22** common to the set of profiled blades, of which the timing of the origin Ψ_{mo} is assured by a controlled phase shifter **28**. In the example, the law of average cyclic incidence is chosen to correspond to a circular translation of the profiled blade, this law being then of the form: $\Psi_m = +\phi_A + \Psi_{mo}$. The angle ϕ_A is the aerodynamic azimuth of each profiled blade and is determined by means of a sensor **30** fixed on the flange **10** (opposite the fixed ring **42** described below). In the example described, the angle Ψ_{mo} is chosen to be equal to $-i$ such that the peak amplitude of the additional angle of incidence Ψ_c is less on each rotation. This permits the use of the actuators **25** with an amplitude of movement relatively reduced.

It should be noted that the sensor **30**, comprised particularly of a phonic wheel, also delivers a signal representative of the speed of rotation ω.

The complementary movement is assured by hydraulic means **23** associated with each profiled blade and comprising a hydraulic actuator **25** controlled with the magnitude of the control Ψ.

The operating mechanism of the hydraulic actuator **25** to the magnitude of the control Ψ is provided in a closed cycle in a manner as to reduce at each instant the angular deviation $\Psi - \Psi_r$ where Ψ_r is the real value of the angle Ψ. This value Ψ_r is furnished by a sensor **27** associated with each profiled blade. In the example, as will be seen below, the sensors **27** are phonic wheel sensors mounted on the flange **10**.

FIG. **12** is a block diagram of the power train and operating mechanism of the rotor. Shown in heavy lines in this figure are the transfers of power in the kinematic chain **22** and the hydraulic means **23**, and in finer lines, the transfers of signals and power in the powered accessories, the sensors and the calculating means. (In **50** is shown the electrical generation of the conventional type.)

The motor group shown at **21** provides the power:

in a mechanical form through the rotation of the rotor, to the kinematic chain **22** which is reversible and common the set of profiled blades and the mechanical structure of which (detailed below) is adapted to generate a rotational output according to the average cyclic law of incidence Ψ_m,

always through the rotation of the rotor, to hydraulic means **23** comprising hydraulic feed pumps **26**, a hydraulic distributor with a servo valve **24** associated with each profiled blade and fed by the pumps **26**, and the rotary hydraulic actuator **25**, which is associated with each profiled blade and which receives the power from the distributor **24**, the hydraulic structure of this means (detailed below) being adapted to generate the aforementioned complementary movement Ψ_c.

A current representative of the angular deviation $\Psi - \Psi_r$ is delivered to the hydraulic distributor **24** for the blade considered and this modulates the hydraulic power received from the pumps **26** for generating toward the corresponding actuator **25** a hydraulic power directly connected to the value of said deviation, that is, a flow as a direct function of said deviation, in the example of an actuator constituted by a rotary screw.

Each actuator **25** comprises a body **25a** movable rotationally driven by the kinematic chain **22** according to the average law Ψ_m, an output shaft **25b** coupled to the profiled blade considered for securing its angular position.

Thus, as the relative angular position of the shaft **25b** with respect to the body **25a** is defined for the angle Ψ_c, one achieves at the level of the profiled blade the summation of the angles: $\Psi_r = \Psi_m + \Psi_c$.

FIG. **13** shows the general mechanical schematic of the kinematic chain **22**, FIG. **14** the detailed schematic of the phase shifter **28** of this chain and FIG. **15** the schematic for the implementation of the hydraulic means.

In the example, the kinematic chain **22** comprises essentially:

a motor shaft **8** arranged to receive a motive driving power from the rotor,

a rotor shaft **3** arranged on the axis of rotation of the rotor and coupled by a first transmission **31** to the motor shaft **8** for rotationally driving the rotor,

a toothed wheel **32** centered on the shaft of the rotor **3** and coupled by a second transmission **33** to the phase shifter **28**, said toothed wheel driving the body **25a** of the rotary actuator associated with each profiled blade,

a flange **10** of the supporting structure, connected to the shaft of the rotor **3** and supporting the bodies **25a** of the actuators and the axles **12** carrying the profiled blades, the phase shifter **28**, of a mechanical nature, arranged to assure a relative angular shifting Ψ_{mo} between the first transmission **31** and the second transmission **33**.

Thus, the phase shifter acts in a collective manner on the adjustment of the set of profiled blades, while, through the intermediary of the flange **10** and the toothed wheel **32**, the kinematic chain operates a transfer of mechanical power from the motive profiled blades toward the receiving profiled blades. This arrangement permits a compact arrangement and is adapted to loads carried.

Further, the mechanical phase shifter **28** illustrated by way of example in FIG. **14** comprises essentially:

a reversible bead screw **34** carried by the motor shaft **8** for turning therewith and movable in translation along this motor shaft,

a screw nut **35** for the bead screw connected to the second transmission **33** and cooperating with said bead screw **34** in such a manner as to generate a rotation of said screw nut connected to the translation of the bead screw,

a screw jack **36** connected, through the interconnection of ball stops **37**, to the bead screw **35** in order to be able to move it along the motor shaft,

an endless screw **38** coupled to the screw jack **36** for actuating it, this endless screw being provided with a phase shifting control motor **39**.

The phase shifter control motor **39** is an electric motor which controls the angular position of the phase shifter as a function of the angle Ψ_{mo} adjustment issued from the calculating means **29** and of the real angle Ψ_{mor} determined from the measurement of a sensor **40** mounted on the phase shifter. The motor controls the angular position of the phase shifter, by reducing at each instant the angular deviation $\Psi_{mo}-\Psi_{mor}$.

As shown in FIG. **15**, the hydraulic distributor with the servovalve **24** which is associated with each profiled blade is connected in the example to two hydraulic feed pumps **26** of the variable cylinder type regulated at constant pressure Each pump is associated with a hydraulic accumulator **41**, in such a manner that said accumulator is loaded in case of excess power available on the pump and restored in the opposite case.

The pumps, five in number, arranged to feed each two adjacent distributors, are supported by the flange **10** in order to rotate therewith and are mechanically coupled to a fixed toothed ring **42** connected to the airframe **1** in order to rotationally drive each of said pumps.

This hydraulic system is also arranged in a conventional manner with heat exchangers **43**, compact, fixed on the flange **10**, a pressurized toroidal chamber **44** as well as an oil filter **45**. Such an architecture furnished a hydraulic system able to operate at the speeds of rotation of the rotor. For reasons of reliability, each distributor **24** is comprised of two redundant distribution members, each modulating the power furnished by the hydraulic generation with which it is associated. The arrangement of the pumps about the flange **10** permits a driving thereof at speeds required (on the order of 3,500 rpm) from the much slower rotation of the rotor.

FIG. **16** is a partial section of the rotor through a longitudinal plane P_3 passing through the axis of the rotor **3**, through the motor shaft **8** and through the axis **12** of one profiled blade, the rotor being assumed to be in an angular position such that these three axes are coplanar. FIG. **17** is a cross-section orthogonal to the preceding one along a broken line P_4.

Shown in these figures are:

the rotor shaft **3** which is hollow and provided with hollow structures and contour structures for supporting and connecting the various assemblies,

the motor shaft **8** which is orthogonal to the first and itself hollow and which receives the motive power of the motive group by the connection of a flexible coupling symbolized at **46**,

the axis **12** of the profiled blade concerned,

the second transmission **33** comprised of a pair of gears,

the phase shifter **28** mounted between the gears **33** and the motor shaft **8** with its ball screw **34**, its ball screw nut **35**, its screw jack **36**, its ball stops **37**, its endless screw **38**, its sensor **40** permitting determination of the adjustment angle Ψ_{mor}, the control motor **39**,

the first transmission **31** of the kinematic chain comprising a pair of gears,

the toothed wheel **32** coupled by the gears **33** to the screw nut **35** of the phase shifter,

the flange **10** comprising the carrier structure of the rotor, beside the airframe, secured to the rotor shaft **3**,

the actuator **25** comprised by a rotary jack composed of a body **25***a* which engages the toothed wheel **32** and a shaft **25***b*,

a pair of gears **47** mounted between this shaft **25***b* of the actuator and the axle **12** of the profiled blade,

the distributor **24** hydraulically connected to the jack **25** by a rotating connection and supported by a bearing on the body of the jack **25***a*,

one of the two hydraulic pumps **26**, associated with each profiled blade concerned, supported by the flange **10** and engaging the fixed toothed wheel **42**, said pump being connected to the distributor **24**,

the hydraulic accumulator **41** associated with the pump **26**, supported by the flange **10** and hydraulically connected to the distributor **24**,

the heat exchanger **43**, supported by the flange **10** and arranged on the return of the hydraulic circuit,

the pressurized chamber **44**, in the example of a toroidal shape, supported by the flange **10**,

the filter **45** arranged on the circuit of the pump **26**,

the sensor **27** measuring the instantaneous real geometric angle Ψ_r,

the sensor **30** for measuring the aerodynamic azimuth ϕ,

a fixed housing **48** for protection assuring the retention of lubricating oil, this lubrication being carried out by jets of oil under high pressure with the help of conventional means not shown.

The transmission of electric information from the sensors, electrical orders to the destination of the actuators, and the feeding of the sensors is carried out in a known manner by a rotating collector mounted at the output of the shaft of the rotor **3**, this transmission assuring the connection toward the corresponding electronic means mounted in the airframe **1** (calculators **17**, **18** and **29**, and sources of electric power).

I claim:

1. A process for controlling a rotor connected to an airframe movable in a fluid, for exerting at each instant on said airframe sustaining and/or propelling forces desired, said rotor comprising a carrier structure (**5**, **10**, **11**) mounted on said airframe (**1**) in such a manner as to be able to be rotationally driven about an axis of rotation (O) and at least one profiled blade (**9**) extending parallel to the axis of rotation (O) and articulated on said carried structure by a pivot connection on the axis

(8) essentially parallel to said axis of rotation (O) at a rotational speed (ω), and being characterized in that it comprises:

preliminarily storing data representative of the following structural parameters of the rotor: nE (the equivalent wingspan equal to the product of the number of profiled blades n of the rotor and the spread E of each profiled blade); R (the distance between the axis of rotation O and the axis B of the pivot connection); r (the distance on the chord of the profiled blade between the axis B and a point P situated essentially one quarter to the rear of the profile); a (coefficient of the congruent transformation of the profiled blade);

$$A = 2\pi(a_1 - a^2) + S$$
$$B = 2\pi(a_1 + a^2 - S)$$

$$C_1 = 2\pi\left(\frac{a_1a_2}{a^2} + \frac{a_2a_3}{a^4}\right) - \pi(A_{-1} - a_1A_1 - 2a_2A_2 - 3a_3A_3 \ldots)$$

where $a_1, a_2 \ldots a_i$ are the terms of the congruent transformation developed in the Laurent series, $A_{-1}, A_1, \ldots A_i$ are the terms of the product of the congruent transformation and its conjugate developed in the Laurentian series and S the surface normal to the profile,

measuring and determining at each instant the relative speed (V) of displacement of the airframe with respect to the fluid, the speed of rotation ω of the rotor and the volumic mass ρ of the fluid from measurements of the dynamic pressure, the static pressure and the temperature of the fluid,

measuring and permanently determining during rotation, the aerodynamic azimuth ϕ of each profiled wing for generating a corresponding measurement signal, said aerodynamic azimuth being the algebraic angle formed by the direction of the relative wind and the plane M containing the axis of rotation O and the axis B of the pivot connection of the profiled wing considered,

generating reference signals representative of the desired forces on the airframe (algebraic forces translated by their projections P and T respectively according to a direction perpendicular to the relative wind and according to the direction of the relative wind),

determining permanently, for each profiled wing, from the stored parameters, from the measured and determined values, and from the reference signals, the instantaneous geometric angle Ψ defined by the chord of the profiled wing and by the plane M corresponding to within ± 0.2 radians to the following relationships (all angles being defined in the trigonometric sense):

$$\text{Cos}\phi_i = C\sin(\phi - \Psi) + \cos\Psi + \frac{r}{R\omega}\left(\omega - \frac{\delta\Psi}{\delta t}\right) \quad (1)$$

$$P = \frac{\eta E}{2}\pi\int_0^{2n} - f\left\{\left[\Gamma - B\left(\omega - \frac{\delta\Psi}{\delta t}\right)\right]m - \right. \quad (2)$$

-continued

$$C_i\left(\omega - \frac{\delta\Psi}{\delta t}\right)^2 - A\frac{\delta l}{\delta t}\Big\}\sin(\phi - \Psi)\cdot\delta +$$

$$\frac{\eta E}{2\pi}\int_0^{2n} f\left\{\left[\Gamma + A\left(\omega - \frac{\delta\Psi}{\delta t}\right)\right]l + \right.$$

$$C_1\frac{\delta^2\Psi}{\delta t^2} - B\frac{\delta m}{\delta t}\Big\}\cos(\phi - \Psi)\cdot\delta\phi$$

$$T = \frac{\eta E}{2\pi}\int_0^{2n} - f\left\{\left[\Gamma - B\left(\omega - \frac{\delta\Psi}{\delta t}\right)\right]m - \right. \quad (3)$$

$$C_1\left(\omega - \frac{\delta\Psi}{\delta t}\right)^2 - A\frac{\delta l}{\delta t}\Big\}\cos(\phi - \Psi)\cdot\delta\phi +$$

$$\frac{\eta E}{2\pi}\int_0^{2n} - f\left\{\left[\Gamma + A\left(\omega - \frac{\delta\Psi}{\delta t}\right)\right]l + \right.$$

$$C_1\frac{\delta^2\Psi}{\delta t^2} - B\frac{\delta m}{\delta t}\Big\}\sin(\phi - \Psi)\cdot\delta\phi$$

$$0 \leqq \phi_{11} \leqq \phi_{12} \leqq \pi \quad (4)$$

$$\phi_i = \phi_{11} \text{ and } \Gamma = 4\pi aR\omega(\cos\phi_{11}) \text{ if } -\phi_{11} < \phi < \phi_{11} \quad (5)(a)$$

$$\phi_i = \phi \text{ and } \Gamma = 4\pi aR\omega(\cos\phi) \text{ if } \phi_{11} \leqq \phi < \phi_{12} \quad (5)(b)$$

$$\phi_i = \phi_{12} \text{ and } \Gamma = 4\pi aR\omega(\cos\phi_{12}) \text{ if } \phi_{12} < \phi < 2\pi - \phi_{12} \quad (5)(c)$$

$$\phi_i = \phi \text{ and } \Gamma = 4\pi aR\omega(\cos\phi) \text{ if } 2\pi - \phi_{12} \leqq \phi \leqq 2\pi - \phi_{11} \quad (5)(d)$$

$$l = -R\omega[\sin\Psi + C\cos(\phi - \Psi)] \quad (6)$$

$$m = R\omega[\cos\Psi + C\sin(\phi - \Psi)] - \frac{\eta}{2}\left(\omega - \frac{\delta\Psi}{\delta t}\right) \quad (7)$$

and

$$C = \frac{V}{\omega R} \quad (8)$$

and controlling the instantaneous geometric angle of each profiled wing at the value of the angle Ψ obtained for said wing.

2. A process for controlling as in claim 1, characterized in that the instantaneous geometric angle Ψ is determined by the following operations:

for the set of profiled blades:

determining preliminarily from a table of correspondence of the values between the parameters Ψ_{11}, Ψ_{12},

$$\frac{P}{C\omega^2\rho} \text{ and } \frac{T}{\omega^2\rho},$$

this table being determined by carrying out on the parameters Ψ_{11}, Ψ_{12} (called commutation angles), the discrete values arranged in a series over the range of variation (4) and calculating for each pair of values (Ψ_{11}, Ψ_{12}) the values of the solutions

$$\frac{P}{C\omega^2\rho} \text{ and } \frac{T}{\omega^2\rho},$$

of the equations (2), (3),

storing said table of correspondence,

calculating permanently the magnitudes

$$C = \frac{V}{\omega \rho}, \frac{P}{C\omega^2\rho}, \text{ and } \frac{T}{\omega^2\rho}$$

as a function of the desired forces P and T and the parameters V, ω and ρ determined,

searching the correspondence table for retrieving the couple

$$\frac{P}{C\omega^2\rho}, \frac{T}{\omega^2\rho}$$

closest to the corresponding calculated magnitudes and extracting the corresponding values of the parameters Ψ_{11}, Ψ_{12},

for each profiled blade:

resolving the differential equation (1), while giving to the parameters Ψ_{11}, Ψ_{12} the values extracted from the table, for obtaining the searched for value of the instantaneous geometric angle Ψ concerning the profiled blade considered.

3. A process for controlling as in claim **2**, characterized in that, for the set of profiled blades:

the table of correspondence is stored in the form of a four column matrix corresponding to the values of

$$\frac{P}{C\omega^2\rho}, \frac{T}{\omega^2\rho}, \phi_{11}, \phi_{12},$$

searching said table of correspondence consisting of reading the two columns $P/C\omega^2\rho$, $T/\omega^2\rho$, for identifying the pair closest to the values calculated and extracting the corresponding values of ϕ_{11} and ϕ_{12} in the two other columns.

4. A process of controlling according to claim **2** characterized in that for each profiled blade, the resolution of the differential equation (1) is carried out at each instant by a calculation having the following steps:

comparing the measured value ϕ to the angles of commutation ϕ_{11}, ϕ_{12} for determining the value of ϕ_i by the relationships (5),

utilizing the value of ϕ, ϕ_i and the measured, calculated or stored parameters C, ω, r, R, for resolving said differential equation by a RUNGE-KUTTA method.

5. A controlling process as in claim **2**, characterized in measuring permanently the real value Ψ_r of the instantaneous geometric angle of each profiled blade and introducing this real value into the calculator for serving as the integration constant in the resolution of the differential equation.

6. A controlling process as in claim **2**, characterized in that the determination of the instantaneous geometric angle Ψ is achieved, permanently, in a sequential manner while generating clock pulses of a high frequency with respect to the number of revolutions per second of the rotor, while reading the measurement and control signals at each clock pulse, and between two clock pulses, while carrying out the calculations for determining the value of the instantaneous angle Ψ.

7. A process for controlling as in claim **2**, characterized in that the control of the instantaneous geometric angle of each profiled blade comprises:

assuring an average control of the set of said profiled blades according to a average cyclic law of incidence $\Psi_m = f(\phi)$ by a reversible kinematic chain able to provide or recover energy according to the load characteristics of the profiled blades,

assuring a complementary control of each profiled blade, from the calculated value of the instantaneous geometric angle Ψ, while adjusting at each instant an additional incidence $\Psi_c = \Psi - \Psi_m$ by means of an actuator.

8. A rotor intended to be rotated in a fluid for developing on an airframe (**1**) desired lifting and propelling forces (P, T), comprising a carried member (**5, 10, 11**) adapted to be mounted on said airframe in such a manner as to be able to be driven in rotation about an axis of rotation (O) and at least one profiled blade (**9**) extending parallel to the axis of rotation (O) and articulated on the carrier member by a pivot connection about an axis (B) essentially parallel to the axis of rotation (O), said rotor being characterized in that it comprises:

means (**13**) for storing specific data about the rotor,

means (**14, 30**) for measuring and determining the relative speed (V) of displacement of the airframe, the speed of rotation (ω of the rotor and the volumic mass of the fluid (ρ),

means (**14, 30**) for measuring and determining the aerodynamic azimuth (ϕ) of each profiled blade curing the rotation,

means (**15**) for generating control signals representative of the desired forced (P, T),

means (**17, 18**) for calculating the instantaneous geometric angle (Ψ) of each profiled blade as a function of the stored data, the determined values and the control signals,

operating means (**22, 23, 28**) for each profiled blade, adapted to adjust at each instant the angular position of the blade to a calculated value (Ψ) issued from the calculating means.

9. A rotor as in claim **8**, characterized in that it comprises a sensor (**27**) for measuring the real value Ψ_r of the instantaneous geometric angle of each profiled blade, the operating means being of a closed loop type, adapted to receive the real value Ψ_r and a parameter related to the calculated value Ψ and assuring the angular adjustment of the position of the profiled blade considered tending to reduce at each instant the angular variation $\Psi - \Psi_r$.

10. A rotor as in claim **9**, characterized in that the operating means comprises:

a kinematic chain (**22**), common to the set of the profiled blades (**9**) and of a mechanical structure adapted to generate an output of rotation according to an average cyclic law of incidence Ψ_m,

a hydraulic distributor with a servovalve (**24**) associated with each profiled blade, said distributor receiving a signal representative of the angular variation $\Psi - \Psi_r$ for the profiled blade considered and being adapted to generate a hydraulic power directly related to said angular variation, and

a rotary hydraulic actuator (**25**) associated with each profiled blade and receiving the hydraulic power from the corresponding distributor (**24**), said actuator comprising a body movable in rotation (**25*a***) driven by the kinematic chain (**22**) according to the average law Ψ_m, an output shaft (**25*b***) coupled to the profiled blade considered for fixing the angular position thereof.

11. A rotor as in claim **10**, characterized in that the kinematic chain (**22**) comprises a phase shifter (**28**) adapted to permit a predetermined adjustment of the origin of the cyclic law of incidence Ψ_m.

12. A rotor as in claim **11**, characterized in that the kinematic chain comprises:

a motor shaft (8) arranged to receive driving motive power from the rotor,

a rotor shaft (3) arranged along the axis of rotation of the rotor and coupled by a first transmission (31) to the motor shaft (8) for rotationally driving the rotor,

a toothed wheel (32) centered on the rotor shaft (3) and coupled by a second transmission (33) to the phase shifter (28), said toothed wheel driving the body (25*a*) of the rotary actuator associated with each profiled blade,

a carrier structure flange (10) connected to the rotor shaft (3) and supporting the bodies (25*a*) of the actuators and the axles (12) carrying the profiled blades,

the phase shifter (28), of a mechanical nature, arranged to assure a relative angular adjustment Ψ_{mo} between the first transmission (31) and the second transmission (33).

13. A rotor as in claim **12**, characterized in that the mechanical phase shifter comprises:

a reversible ball screw (34) carried by the motor shaft (8) for turning therewith and movable in translation along this motor shaft,

a screw nut (35) connected to the second transmission (33) and cooperating with the ball screw (34) in such a manner as to generate a rotation of said nut connected to the translation of the ball screw,

a screw jack (36) connected through ball stops (37) to the ball screw (35) for being able to move it along the motor shaft,

an endless screw (38) coupled to the screw jack (36) for actuating it, this endless screw being provided with a phase shifting control motor (39).

14. A rotor as in claim **10**, characterized in that the hydraulic distributor with a servo-valve (24) associated with each profiled blade (9) is connected to at least one hydraulic feed pump (26) associated with a hydraulic accumulator (41), arranged in such a manner that said hydraulic accumulator is under load in the event of excess power available on the pump and in restitution in the opposite case.

15. A rotor as in claim **14**, characterized in that the hydraulic feed pumps (26) are carried by the carrier structure (10) in order to rotate therewith and are mechanically coupled to a fixed toothed ring (42) for rotationally driving each of said pumps.

16. A rotor as in claim **8**, characterized in that:

the profiled blades (9) are articulated on two flanges (10, 11) situated on opposite sides of said carrier structure,

said flanges are connected by the rotor shaft (3) and coupled into rotation therewith,

each profiled blade (9) is supported by axles (12) supported by the flanges (10, 11) and driven in rotation by a transmission (47), itself connected to the hydraulic actuator (25) associated with the blade considered.

17. A rotor as in claim **8**, comprising five profiled blades (9) distributed about the rotation shaft (3) of said rotor.

18. A rotor as in claim **8**, mounted on the airframe of an aircraft (1), in which the rotor shaft (3) is, on one side, carried by a hub (4) connected to the airframe of the aircraft and on the other side supported by a fixed profiled member (5) provided with a bearing, said member extending so as to be attached to the airframe.

19. An aircraft comprising at least one rotor according to claim **18** and a motor group integrated to its airframe and coupled to the motor shaft (8) of each rotor.

* * * * *

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(54) HYBRID ROTOR

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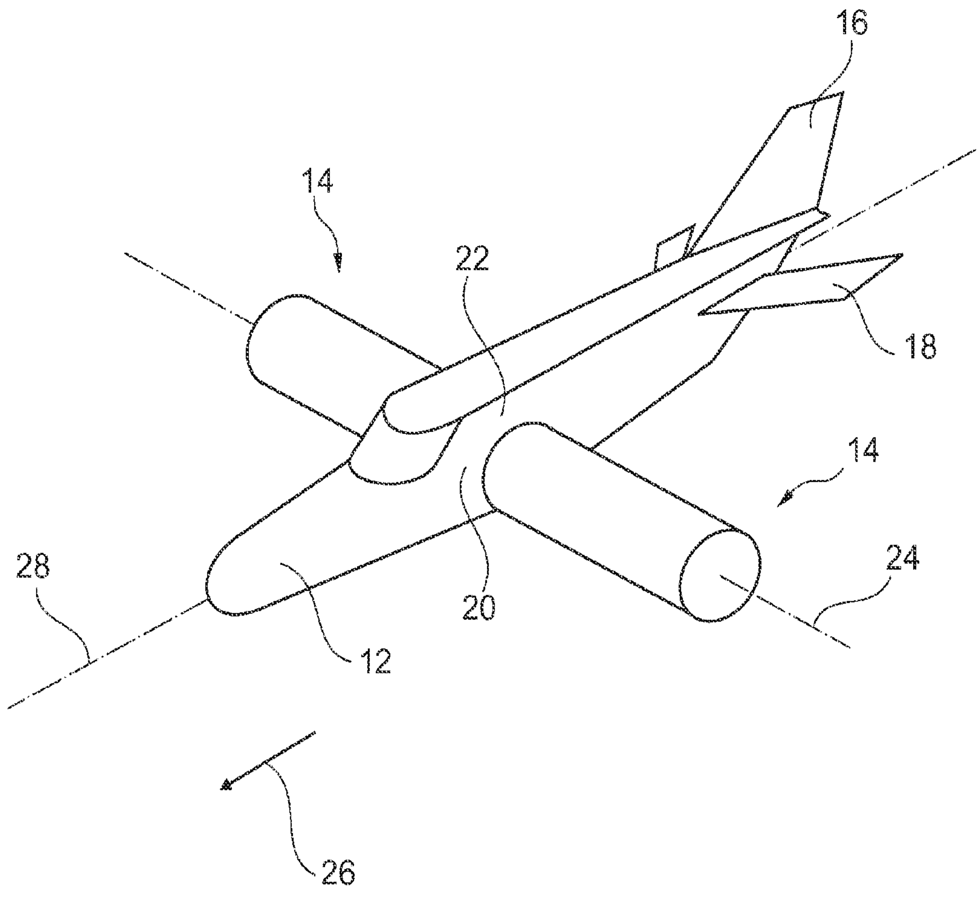
(57) **ABSTRACT**

A hybrid rotor for an aircraft includes a Magnus rotor rotatable around a Magnus rotor axis and a transverse flow rotor that is kept rotating around an axis of rotation and has a number of axially extending rotor blades that are actuatable to rotate around the axis of rotation and are configured stationary relative to the tangential angle position. The Magnus rotor is located within the transverse flow rotor and has an axis extending in the direction of the axis of rotation. The guide mechanism has a housing segment partially surrounding the transverse flow rotor in the circumferential direction. The housing segment has an adjustment mechanism and is deflectable relative to the Magnus rotor axis. The housing segment is aligned such that the transverse flow rotor generates a propulsion force and causes a transverse flow onto the Magnus rotor to generate lifting force by way of a Magnus effect.



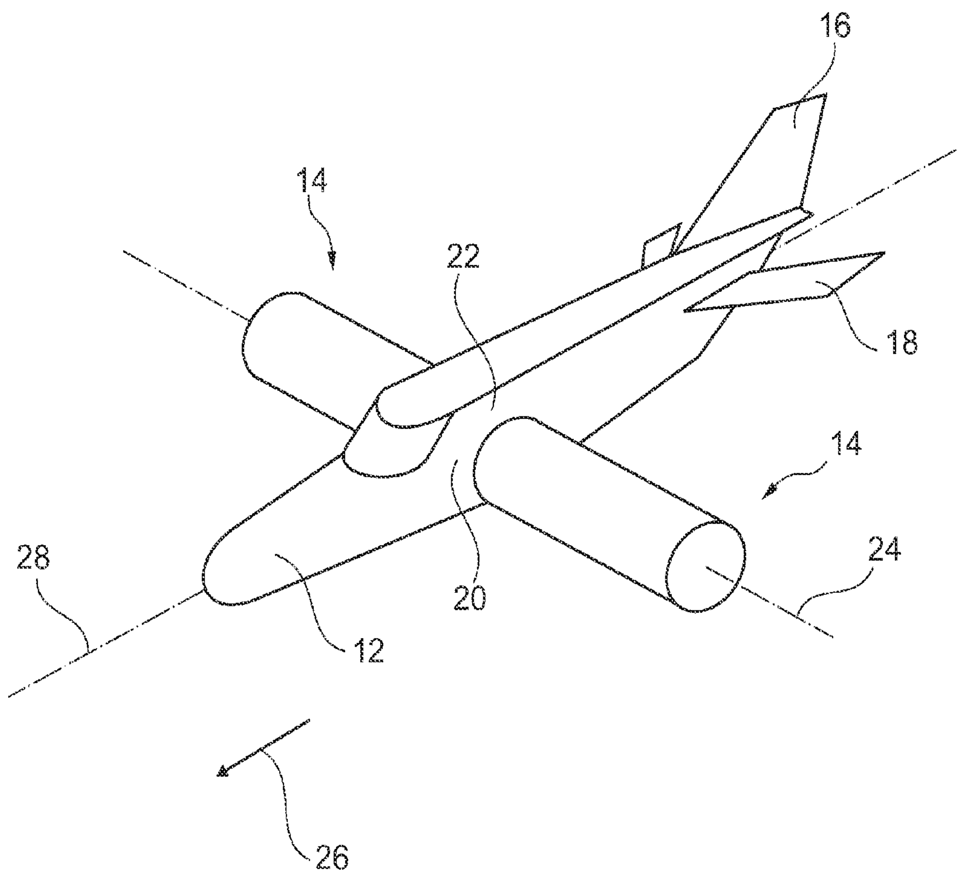


Fig. 1

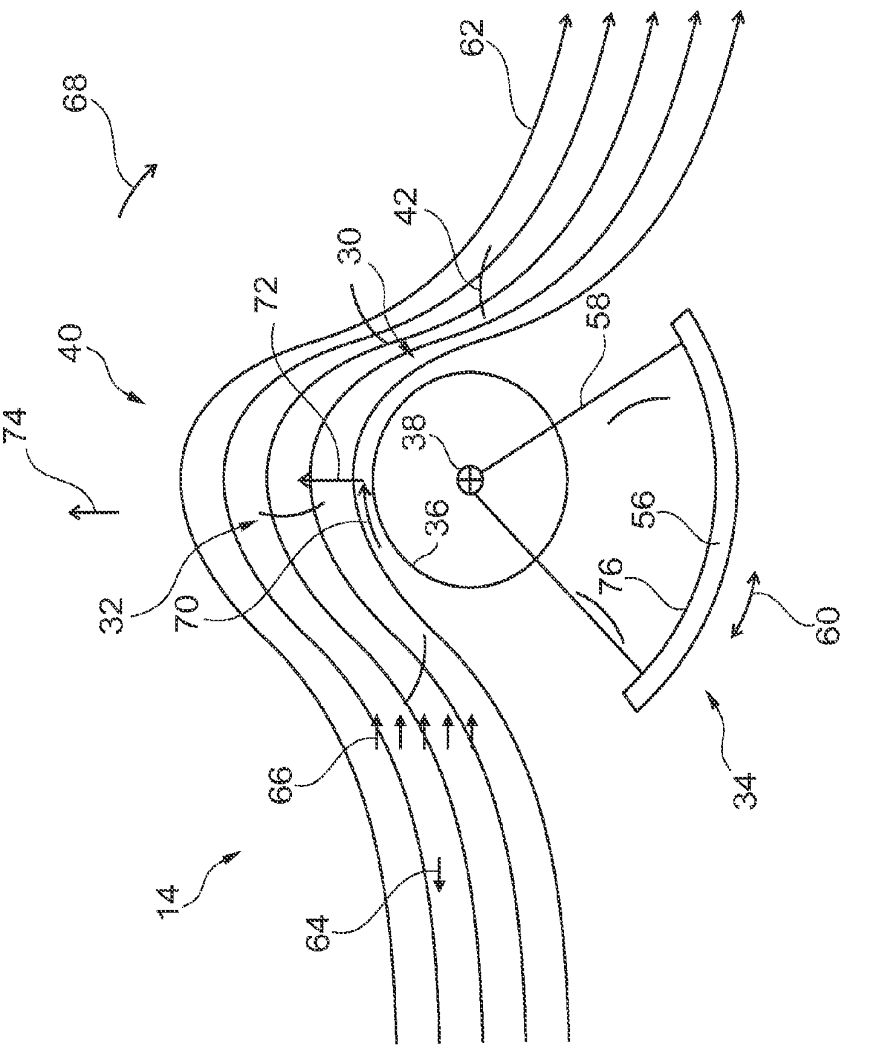


Fig. 2

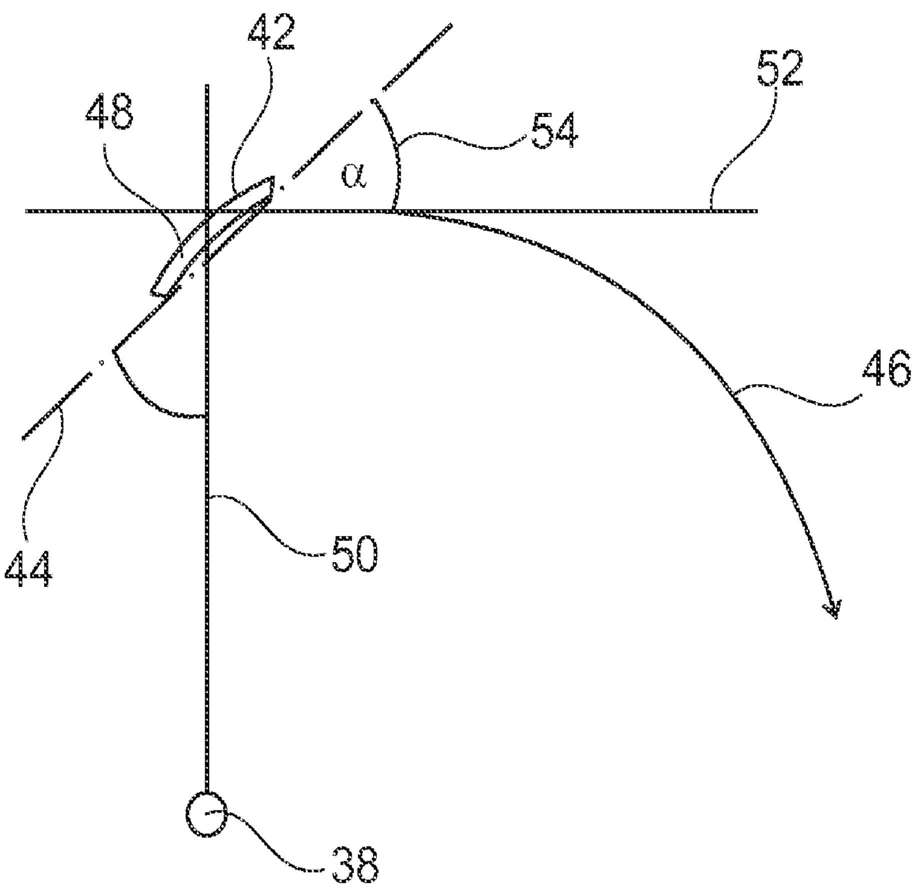


Fig. 3

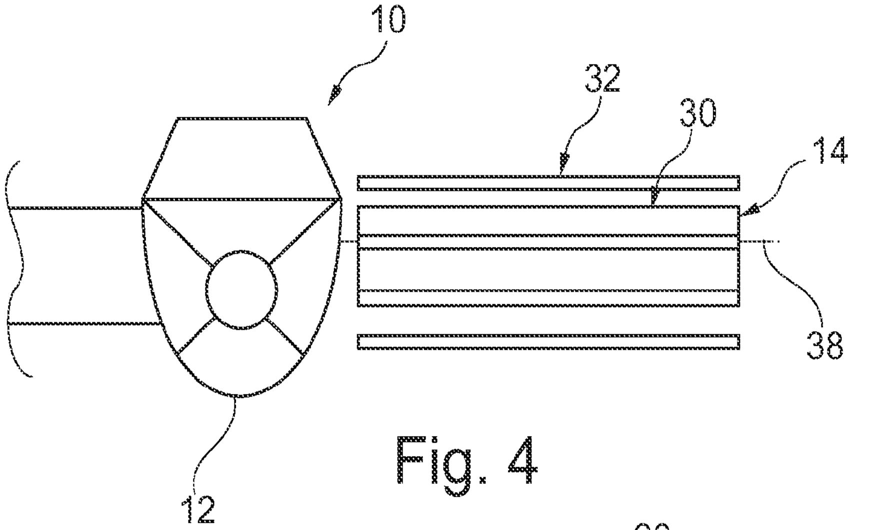


Fig. 4

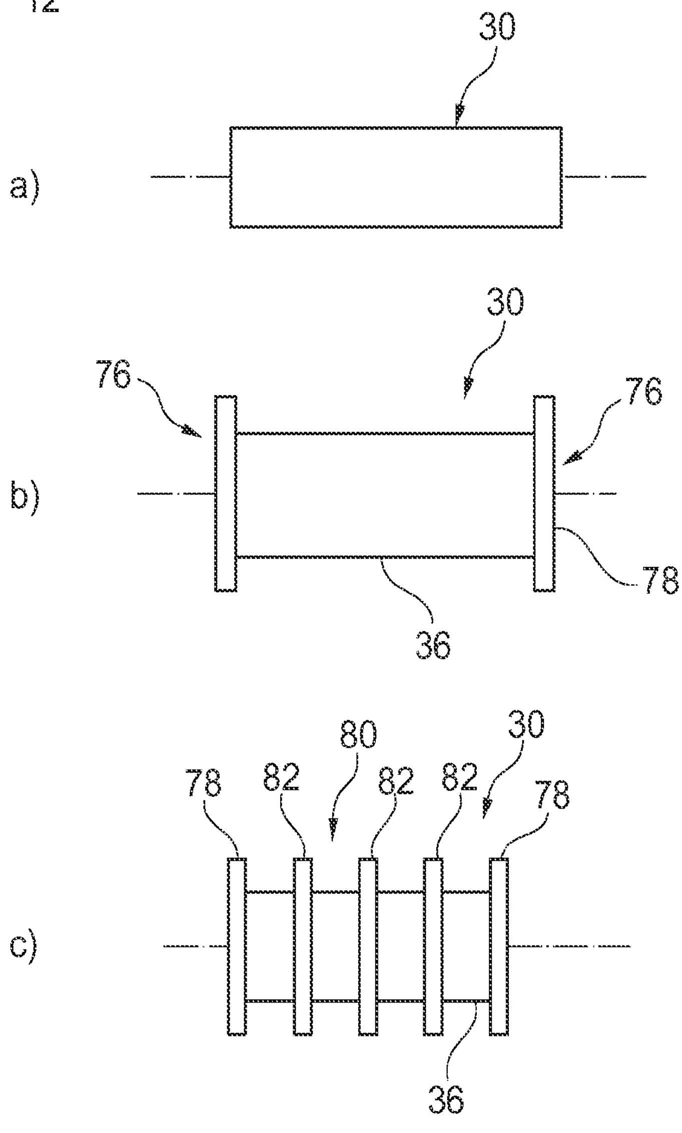


Fig. 5

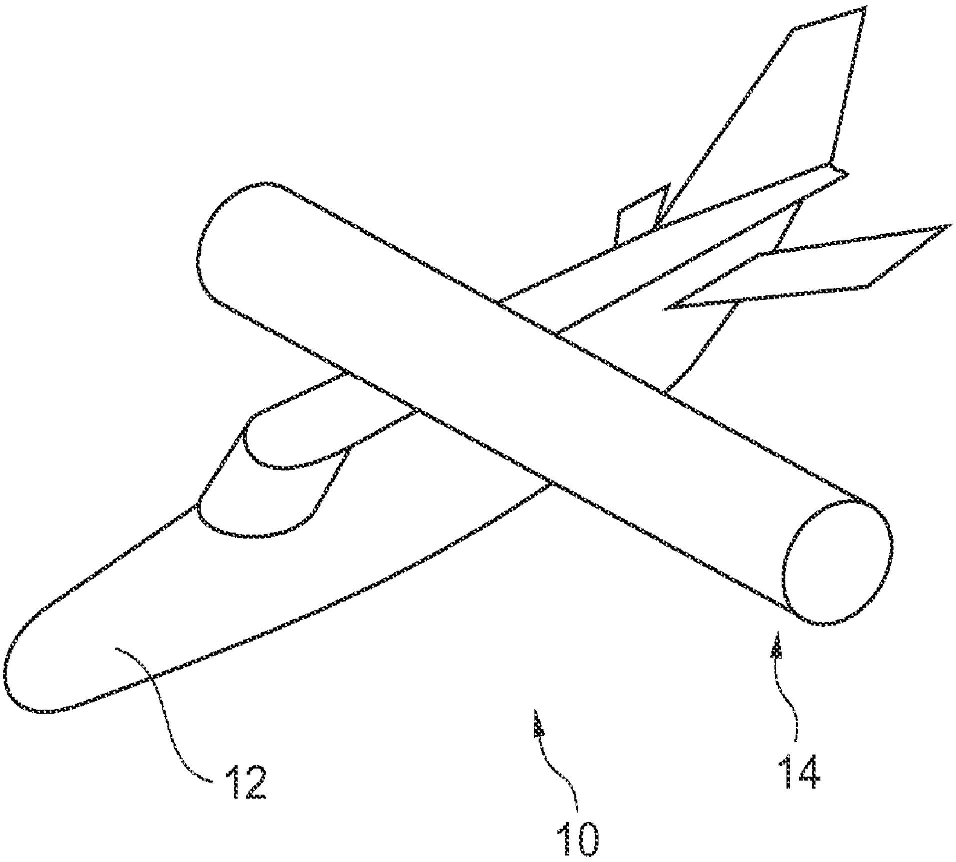


Fig. 6

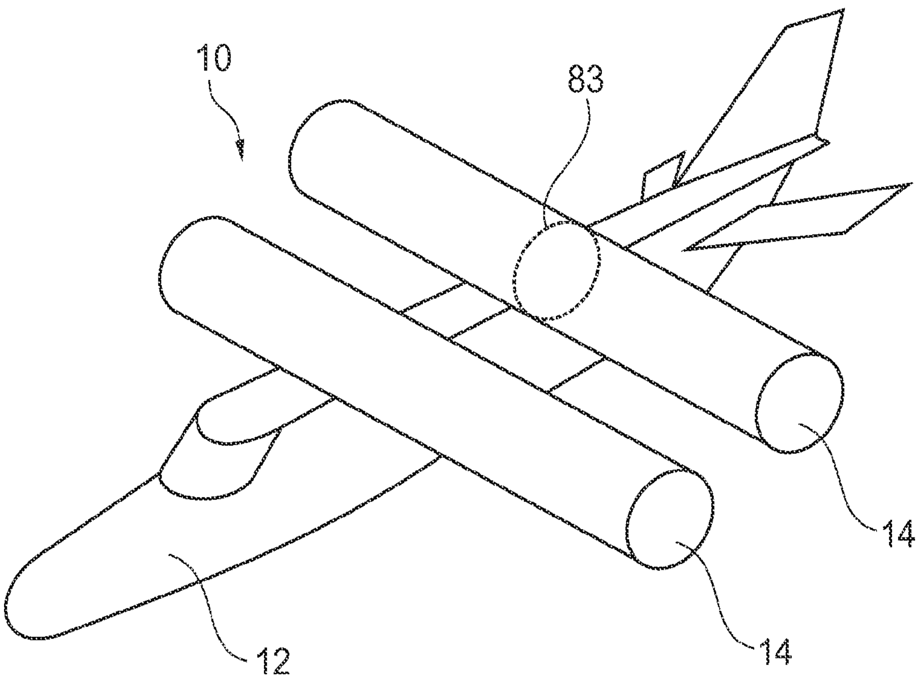


Fig. 7

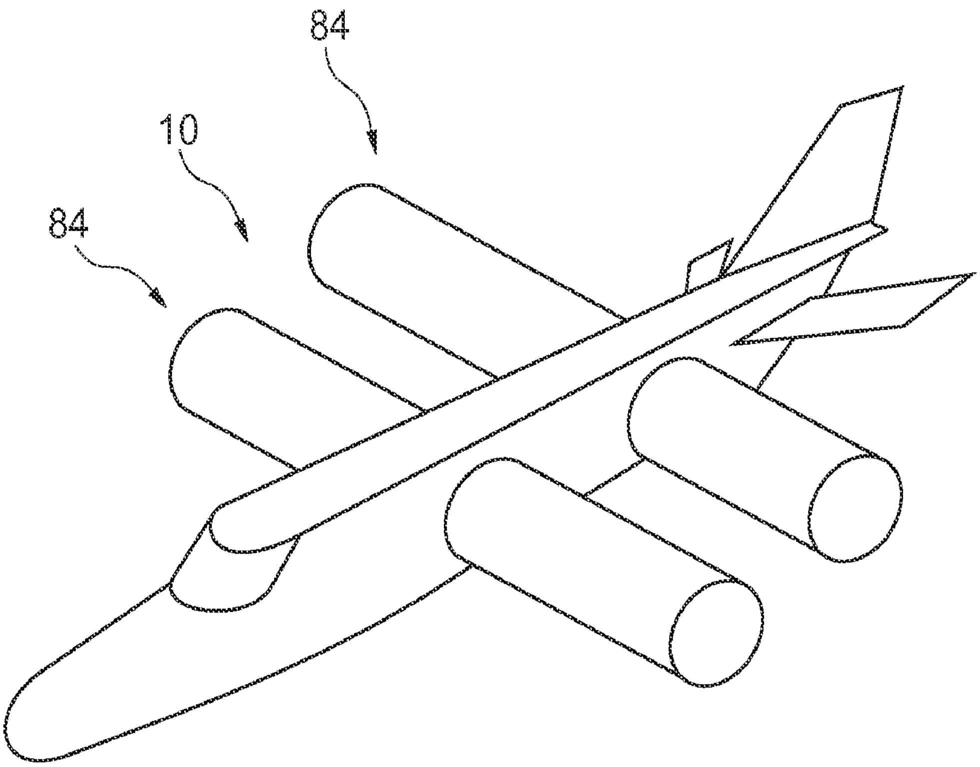


Fig. 8

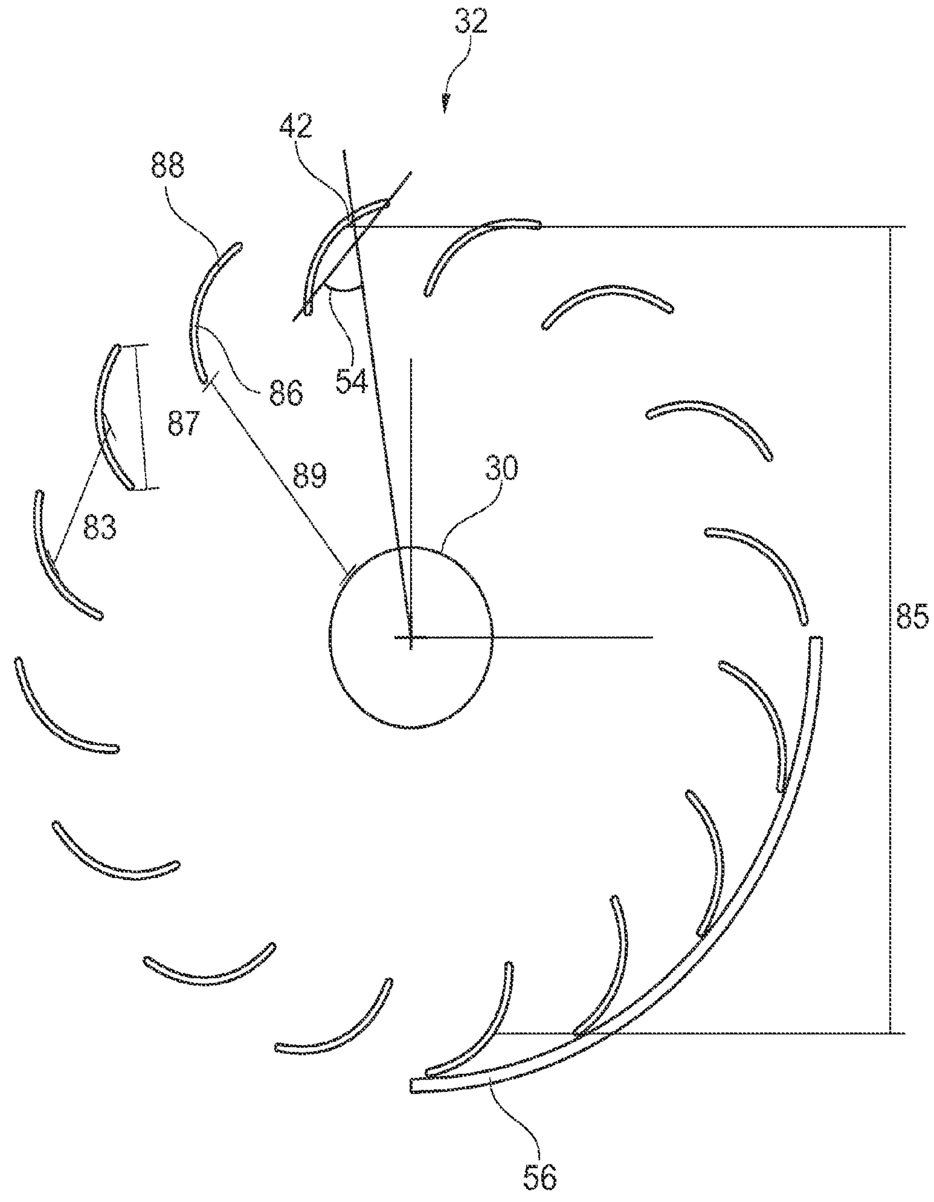


Fig. 9

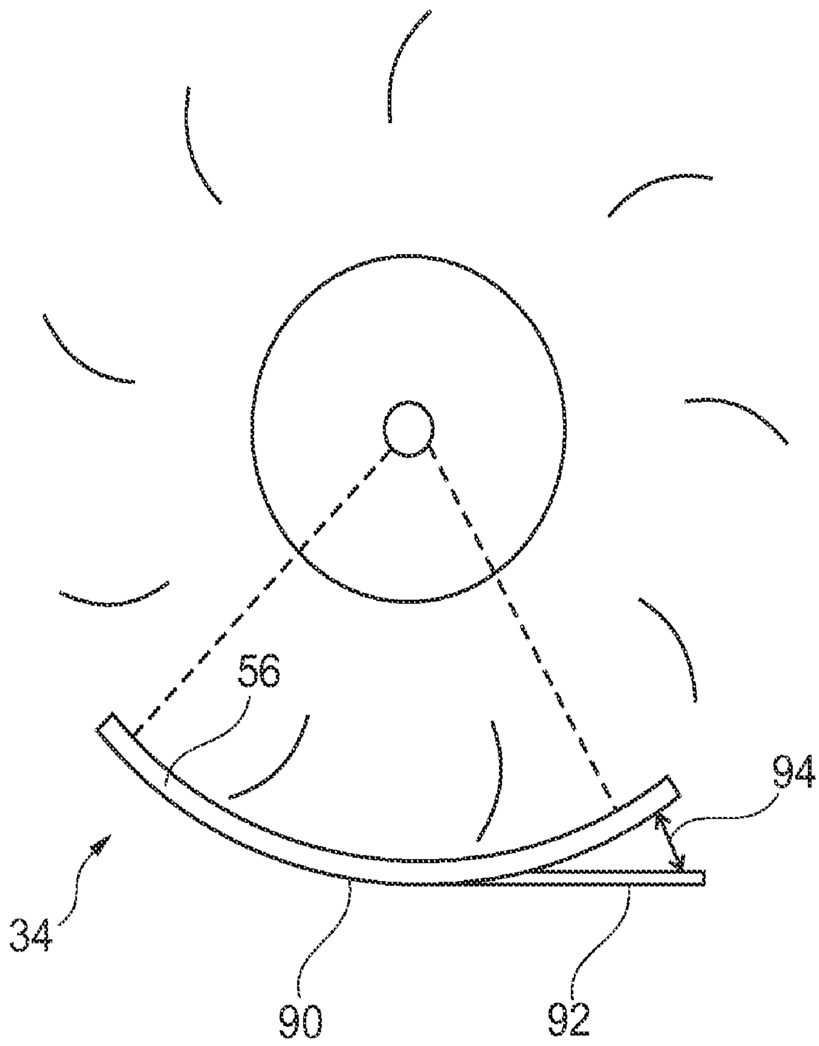


Fig. 10

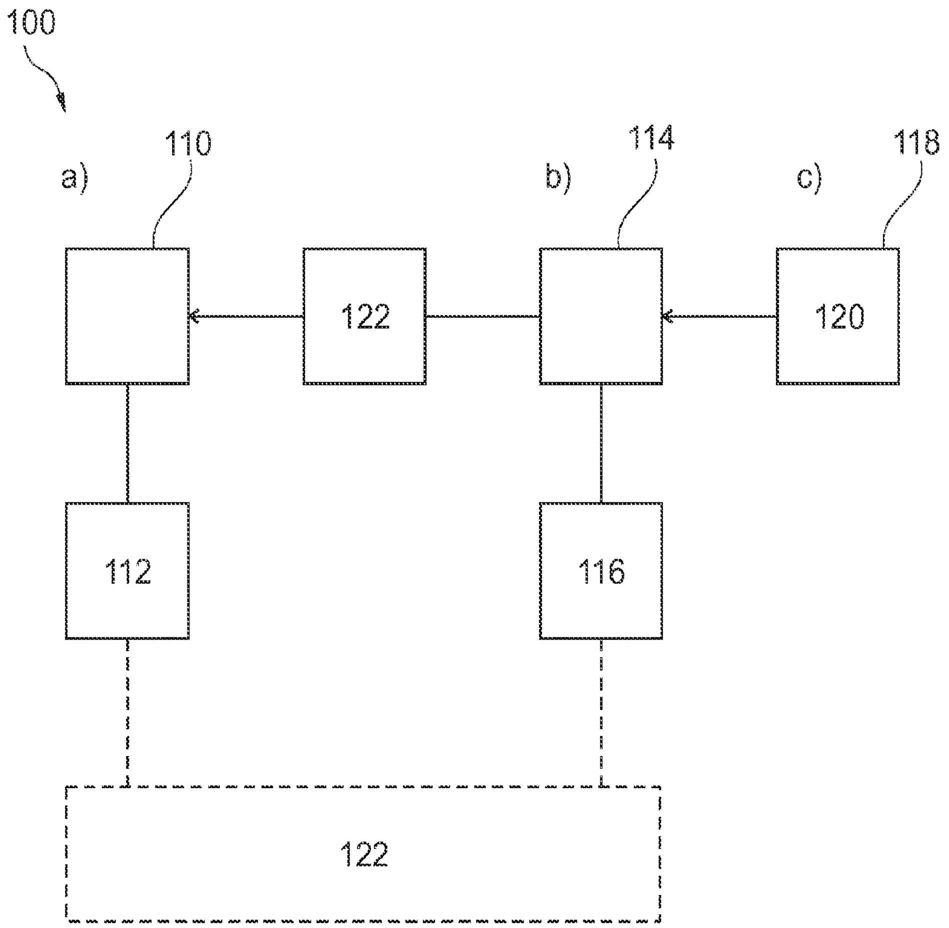


Fig. 11

HYBRID ROTOR

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] The present application claims priority under 35 U.S.C. §119 to German 10 2010 055 676.9, filed Dec. 22, 2010, the entire disclosure of which is herein expressly incorporated by reference.

BACKGROUND AND SUMMARY OF THE INVENTION

[0002] The present invention relates to a hybrid rotor for an aircraft, an aircraft having a hybrid rotor, the use of a hybrid rotor in an aircraft and a method for flying an aircraft.

[0003] A hybrid rotor, also described as a rotor that is a hybrid, represents a combination of two different rotor types or rotor systems. Hybrid rotors are used in aircraft, for example, airplanes, in such a way that the two rotor types or rotor systems perform different tasks. For example, German Patent Document DE 10 2007 009951 B3 discloses an aircraft in which a rotating cylinder delivers the lift, while a cycloid propeller is responsible for controllability and propulsion. The rotating cylinder is also known as Flettner rotor; in it, a rotating cylinder is subjected to an incident flow, as a result of which a force is generated that is aligned transverse to the direction of the incident flow. This force is generated based on the Magnus effect, and is therefore also described as Magnus force. Activation of the propeller elements of the cycloid propeller is technically complex.

[0004] Therefore, there is a need to provide a hybrid rotor that is constructed simply and is therefore also light-weight and can be produced cost-effectively.

[0005] This is provided by a hybrid rotor, an aircraft, the use of a hybrid rotor in an aircraft and by a method according to exemplary embodiments of the present invention.

[0006] According to an exemplary embodiment of the invention, a hybrid rotor is provided for an aircraft having a Magnus rotor, a transverse flow rotor and a guide mechanism. The Magnus rotor can be propelled rotating around a Magnus rotor axis by a first propulsion mechanism and has a closed lateral surface. The transverse flow rotor is kept rotating around an axis of rotation and has a number of axially extending rotor blades, which can be propelled rotating around the axis of rotation by a second propulsion mechanism, and which are designed fixed relative to the tangential angular position. The Magnus rotor is located within the transverse flow rotor and the Magnus rotor axis extends in the direction of the axis of rotation. The guide mechanism has a housing segment partially surrounding the transverse flow rotor in the circumferential direction, whereby the housing segment has an adjustment mechanism and is designed rotatable, at least relative to the Magnus rotor axis. The housing segment can be aligned in such a way that the transverse flow rotor generates a propelling force and brings about a transverse incident flow onto the Magnus rotor in such a way, that a force is generated according to the Magnus effect, which acts as aerodynamic lift.

[0007] As a result, it is possible to generate the two required forces for an aircraft, i.e., the propulsion force and the aerodynamic lift force by using a hybrid rotor. Accordingly, the transverse flow rotor, due to its fixed rotor blades that do not change their tangential angular position when the transverse flow rotor rotates and thus always having the same alignment to the rotation center of the rotor in order to move it on a circular track, are designed as simply as possible, i.e., the transverse flow rotor is to be designed simple and contributes to minimizing the weight of the rotor. In combination with the guide mechanism, the cross flow rotor has, in addition to the function of generating the propulsion force, a second function, namely, to bring about a transverse incident flow onto the Magnus rotor in order to make an aerodynamic lift that is as large as possible available as dynamic impulse generator with the rotating Magnus rotor. Due to the adjustability of the housing segment of the guide mechanism, this provides a hybrid rotor, which generates controllable aerodynamic lift forces and propulsion forces and is therefore suitable for an aircraft.

[0008] In contrast to aircraft that are capable of taking off vertically according to prior art, for example, so-called oscillating rotor configurations such as, for example, the V-22 Osprey, the aircraft according to the invention provides a simpler mechanical solution and greater flight safety, in particular in the transition phase between cruising flight and takeoff or landing.

[0009] According to the invention, the Magnus rotor is a rotation-symmetric hollow piece that causes a deflection of an air flow due to the Magnus effect.

[0010] According to this invention, the transverse flow rotor generates a circular flow. This is a rotary air flow that is simultaneously overlaid with a translational air flow which is likewise generated by the transverse flow rotor, or also by a movement of the aircraft in the air during a flight process.

[0011] A rotary air flow and a translational air flow form a combination flow that causes a Magnus effect at a geometric body that is exposed to the combination flow. Therefore, the body is also described as Magnus body or Magnus rotor.

[0012] In a combination flow, the rotary air flow can also be generated or supported thereby, that the Magnus rotor is activated by rotating. The rotation of the Magnus body or Magnus rotor can lead to a stronger development of the Magnus effect.

[0013] The relative motion between the surface of the Magnus rotor and the combination flow having the cited transverse circulating flow or transverse flow and the circular flow are decisive for the Magnus effect.

[0014] It should be noted that a stationary Magnus rotor or Magnus body, for example, a stationary cylinder, can already bring about a Magnus effect due to the rotating transverse flow rotor and the combination flow.

[0015] For example, the Magnus rotor is designed with a constant circular cross-section (diameter) extending over the axis of rotation; the Magnus rotor thus is a cylinder or cylindrical body in the geometric sense.

[0016] For example, the Magnus rotor is designed having a (circular) diameter changing uniformly, for example, a truncated cone, extending over the axis of rotation.

[0017] For example, the Magnus rotor is designed having a (circular) diameter that increases and again decreases parabolically, i.e. in the form of a sphere, extending over the axis of rotation.

[0018] For example, the Magnus rotor can also consist of different truncated cone segments or cylinder segments.

[0019] According to a further aspect of the invention, the Magnus rotor axis extends parallel to the axis of rotation of the transverse flow rotor.

[0020] According to a further aspect of the invention, the Magnus rotor is located concentric with respect to the transverse flow rotor.

[0021] According to a further aspect of the invention, the Magnus rotor axis extends at an incline to the axis of rotation of the transverse flow rotor, whereby the Magnus rotor axis spans, for example, a plane with the axis of rotation.

[0022] According to a further aspect of the invention, the hybrid rotor has a rotor axis, whereby the Magnus rotor axis of the Magnus rotor forms the rotor axis.

[0023] According to a further aspect of the invention, the Magnus rotor, for example, a cylinder, and the transverse flow rotor rotate around the rotor axis. The term rotor axis is used in the geometric sense in this context.

[0024] According to a further aspect of the invention, the Magnus rotor is propelled by a first shaft and the transverse flow rotor by a second shaft, whereby the first and the second shaft are, for example, located concentrically, for example, inside each other.

[0025] According to a further aspect of the invention, the Magnus rotor can be actuated in the direction of rotation of the transverse flow rotor.

[0026] According to a further aspect, the Magnus rotor can be actuated counter to the direction of rotation of the transverse flow rotor, for example, to generate a targeted downforce.

[0027] According to a further aspect, the transverse flow rotor and the Magnus rotor can also be actuated in opposite directions, for example, for purposes of braking.

[0028] According to a further aspect of the invention, the force according to the Magnus effect, also called Magnus force, which is generated at the Magnus rotor, is a lifting force and/or and a propelling force.

[0029] According to a further aspect of the invention, the transverse flow rotor generates a flow that extends transverse to the Magnus rotor axis.

[0030] According to a further aspect of the invention, the transverse flow rotor, together with the guide mechanism, forms a transverse flow blower.

[0031] According to a further aspect of the invention, the transverse flow blower serves as thrust generator.

[0032] According to an exemplary embodiment of the invention, the housing segment has the shape of a circular arc on the side facing the transverse flow rotor.

[0033] According to an exemplary embodiment of the invention, the housing segment has the same cross-section shape extending over the entire length of the Magnus rotor.

[0034] According to an alternative aspect of the invention, the housing segment has different cross-section shapes extending over the length of the Magnus rotor. As a result it is possible, for example, to provide additional aerodynamic properties of the transverse flow rotor, depending on the respective position relative to an aircraft.

[0035] According to a further aspect of the invention, in cross-section (i.e., seen horizontal to the Magnus rotor axis), the housing segment has the shape of a circular arc segment.

[0036] According to a further aspect of the invention, the housing segment has adjustable profile elements on the side facing away from the transverse flow rotor, by means of which the cross-section shape on the side facing away can be changed to improve the aerodynamic properties. For example, the changes take place depending on the rotation setting.

[0037] According to a further aspect of the invention, between the lateral surface of the Magnus rotor and the rotating rotor blades, a distance is provided in radial direction that depends on the diameter of the Magnus rotor.

[0038] For example, the diameter of the Magnus rotor is just as large up to twice the size as the distance of the lateral surface to the rotor blades.

[0039] According to a further example, the relationship of the diameter of the Magnus rotor and the distance to the rotor blades is 2:1.

[0040] According to an aspect of the invention, the profile depth and the angle of approach of the rotor blades can be chosen as desired, whereby these two parameters are related to each other with respect to the effect. Furthermore, the diameter of the transverse flow rotor can be specified. The number of rotor blades in turn is related to the diameter of the transverse flow rotor and the profile depth. If these dimensions are specified, the inner diameter of the transverse flow rotor is also known, i.e., the distance of the rotor blades from the center. The diameter of the Magnus rotor, for example, a cylinder, is then given by the relationship cited above, of the distance between the rotor blades and the lateral surface of the Magnus rotor to the diameter of the Magnus rotor.

[0041] According to an exemplary embodiment of the invention, in cross-sections, the rotor blades respectively have a curved shape with a concave and a convex side, whereby the convex side faces the Magnus rotor.

[0042] According to a further aspect of the invention, at least two, preferably sixteen rotor blades are provided.

[0043] According to an exemplary embodiment of the invention, in cross-section, the rotor blades respectively have an angle of 15° to 70° to the radial direction.

[0044] According to a further aspect of the invention, in cross-section, the rotor blades respectively have an angle of 30° to the radial direction.

[0045] The term radial direction relates to a connection line between the Magnus rotor axis and the center of the cross-section of the rotor blade, and the direction in cross-section relates to the tangential direction for a curved cross-section shape.

[0046] As has been cited already, the rotor blades do not change their angle during the rotation of the transverse flow rotor.

[0047] According to a further aspect of the invention, the rotor blades extend parallel to the axis of rotation in axial direction, i.e., they have a constant distance to the axis of rotation.

[0048] According to a further aspect of the invention, the rotor blades extend inclined to the axis of rotation in the axial direction, whereby the rotor blades have an increasing or decreasing distance with respect to the axis of rotation, i.e., the rotor blades respectively extend in a plane with the axis of rotation and are inclined to the axis of rotation.

[0049] According to an exemplary embodiment of the invention, the Magnus rotor is a cylinder, and in the area of its ends it respectively has an end plate that projects over the cylinder surface. The term cylinder surface relates to the lateral surface or circumferential surface of the cylinder.

[0050] According to a further aspect of the invention, the plates are formed at the facing ends of the cylinder.

[0051] According to a further aspect of the invention, the end plates rotate with the cylinder; for example, the plates are attached directly to the cylinder.

[0052] According to an exemplary embodiment of the invention, the cylinder has a number of plates that are located between the end plates, whereby the plates have a larger diameter than the lateral surface.

[0053] According to a further aspect, the plates are provided in a Magnus rotor that has a different rotation-symmetric shape.

[0054] According to the invention, an aircraft is also provided that has a fuselage area and at least one hybrid rotor according to one of the exemplary embodiments and aspects described above. The Magnus rotor and the transverse flow rotor of the at least one hybrid rotor are retained at the fuselage area. Furthermore, a first propulsion device for rotating the Magnus rotor of the at least one hybrid rotor and a second propulsion device for rotating the transverse flow rotor of the at least one hybrid rotor are provided. The Magnus rotor axis is located horizontal to the flight direction, for example, at an angle between 30° and 150°, preferably 45° to 135°, further preferred 80° to 100°, for example, 90°.

[0055] This makes it possible to provide an aircraft in which the hybrid rotor takes on the function of propulsion and the function of lift. In other words, compared with a conventional aircraft having an airfoil and, for example, a propulsion mechanism, the hybrid rotor takes on the function of the propeller for propulsion and the function of the airfoils for the lift.

[0056] According to a further aspect, additional airfoils are present.

[0057] According to a further aspect of the invention, for controlling the aircraft, an elevator unit and a fin are provided, for example, in the posterior section of the fuselage area.

[0058] According to a further exemplary embodiment of the invention, the aircraft has a longitudinal axis, and on both sides of the longitudinal axis, at least one hybrid rotor is provided respectively according to one of the preceding exemplary embodiments and aspects.

[0059] According to a further aspect of the invention, at least two hybrid rotors are provided that are located on diametrically opposed sides of the longitudinal axis, whereby the at least two hybrid rotors are at a distance to each other and form a propulsion pair or a propulsion group.

[0060] According to a further aspect of the invention, different rpms per hybrid rotor are provided for controlling the aircraft, i.e., as a result of the different actuation of the hybrid rotors, different lift and propulsion forces can be generated on the two sides of the longitudinal axis.

[0061] According to a further exemplary embodiment of the invention, at least two hybrid rotors located at a distance in the longitudinal direction are provided according to one of the preceding exemplary embodiments and aspects.

[0062] According to a further aspect of the invention, in the longitudinal direction, at least two propulsion pairs or two propulsion groups are provided.

[0063] The invention also includes the use of a hybrid rotor according to one of the previously described exemplary embodiments and aspects in an aircraft.

[0064] According to a further aspect of the invention, the use of an aircraft having a hybrid rotor according to one of the previously cited exemplary embodiments and aspects is provided.

[0065] According to a further exemplary embodiment of the invention, a method for flying an aircraft is provided that includes the following steps.

[0066] a) Rotating a Magnus rotor around a Magnus rotor axis, whereby the Magnus rotor has a closed lateral surface for generating a force according to the Magnus effect;

[0067] b) rotating a transverse flow rotor around an axis of rotation that has a number of axially extending rotor blades, which are designed stationary relative to the tangential angle position, whereby the rotation of the transverse flow rotor generates a propelling force for the aircraft, which runs transverse to the Magnus rotor axis; whereby the Magnus rotor is located within the transverse flow rotor and the axis of rotation extends in the direction of the Magnus rotor axis; and

[0068] c) aligning a housing segment of a guide mechanism that partially surrounds the transverse flow rotor in the circumferential direction by deviating the housing segment relative to the Magnus rotor axis in such a way that due to the transverse flow rotor, a transverse flow is created at the Magnus rotor by means of which the force according to the Magnus effect is generated.

[0069] According to a further aspect of the invention, rotating the Magnus rotor generates a lifting force.

[0070] According to a further aspect of the invention, rotating the Magnus rotor also generates a propelling force, which supports the propelling force generated by the transverse flow rotor.

[0071] According to a further aspect of the invention, the two rotor types generate a force that has a lift vector and a propulsion vector.

[0072] According to a further aspect of the invention, the transverse flow of the Magnus rotor is provided in such a way that a force according to the Magnus effect is generated that acts upon the aircraft.

[0073] According to a further aspect of the invention, the force according to the Magnus effect is a propelling force and a lifting force, as has already been mentioned above.

[0074] According to a further exemplary embodiment of the invention, the rotation of the Magnus rotor and the rotation of the transverse flow rotor and the deflection of the guide mechanism can be regulated separately in such a way that different lifting forces and propelling forces can be adjusted.

[0075] The concept of control thereby includes, for example, the following aspects:

[0076] 1. The rpm of the transverse flow rotor influences the speed of the air flow and thus the thrust.

[0077] 2. The rpm of the Magnus rotor influences the deflection of the air flowing against it and thus on account of the Magnus effect, the lifting force as well.

[0078] 3. The rotatable deflector plate influences the direction of the air flowing around and through the hybrid rotor and thus the direction of the total force (consisting of propulsion and lift).

[0079] The cited possibilities of regulation thus make rpm changes possible that influence the magnitude of the forces. The adjustment of the deflector plate influences the direction of the forces.

[0080] According to a further aspect of the invention, different directions of flight can be selected.

[0081] According to a further aspect of the invention, the guide mechanism is adjusted in such a way that a vertical lift and propulsion force is generated that makes a vertical takeoff of the aircraft possible, or a short start, i.e., a takeoff with an extremely short runway.

[0082] Let it be pointed out that the characteristics of the exemplary embodiments and the aspects of the devices also apply to embodiments of the method as well as the use of the device and vice versa. Moreover, even those characteristics can be freely combined with each other, for which this is not explicitly mentioned.

[0083] Other objects, advantages and novel features of the present invention will become apparent from the following detailed description of one or more preferred embodiments when considered in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0084] In the following, with the aid of the attached drawings, an exemplary embodiment of the invention will be addressed in further detail.

[0085] Shown are:

[0086] FIG. **1** shows an aircraft having a hybrid rotor according to an exemplary embodiment of the invention;

[0087] FIG. **2** shows a hybrid rotor according to the invention in a schematic cross-section;

[0088] FIG. **3** shows a cross-section of a hybrid rotor from FIG. **2**;

[0089] FIG. **4** shows a further embodiment of a aircraft having a hybrid rotor according to the invention;

[0090] FIG. **5** shows a further embodiments of the hybrid rotor according to the invention;

[0091] FIG. **6** shows a further embodiment of an aircraft with a hybrid rotor according to the invention;

[0092] FIG. **7** shows a further embodiment of an aircraft with a hybrid rotor according to the invention;

[0093] FIG. **8** shows a further embodiment of an aircraft with a hybrid rotor according to the invention;

[0094] FIG. **9** shows a further embodiment of a hybrid rotor according to the invention in a lateral view;

[0095] FIG. **10** shows a further embodiment of a hybrid rotor according to the invention; and

[0096] FIG. **11** shows a method for flying an aircraft having a hybrid rotor according to an exemplary embodiment of the invention.

DETAILED DESCRIPTION OF THE DRAWINGS

[0097] FIG. **1** shows an aircraft **10** in an angular view. Aircraft **10** has a fuselage area **12** and at least one hybrid rotor **14**. For example, two hybrid rotors are provided of which respectively one is located on one side of the fuselage area.

[0098] Aircraft **10** further has a fin **16** and an elevator unit **18** in the posterior section of the fuselage area.

[0099] Aircraft **10** shown in FIG. **1** is, for example, designed as an aircraft, whereby in addition to smaller passenger planes, wide-bodied airplanes for passengers, as well as also transport aircraft and other types of aircraft are provided.

[0100] According to a further aspect of the invention which is, however, not illustrated in further detail, the aircraft can also be a different vehicle type, for example, an airship.

[0101] With reference to FIG. **1**, hybrid rotor **14** has a Magnus rotor, a transverse flow rotor and a guide mechanism, which are, however, not labeled with reference numbers here, but will be explained in more detail in the following figures.

[0102] The Magnus rotor and the transverse flow rotor of the at least one hybrid rotor are retained at the fuselage area. Aircraft **10** further has a first propulsion mechanism **20** for rotating the Magnus rotor of the at least one hybrid rotor, and a second propulsion device **22** for rotating the transverse flow rotor of the at least one hybrid rotor. The Magnus rotor axis that is shown in FIG. **1** labeled with reference number **24** is located horizontal to the flight direction, which is indicated with an arrow **26** in FIG. **1**.

[0103] According to a further aspect of the invention, which is likewise shown in FIG. **1**, aircraft **10** has a longitudinal axis **28** and on both sides of longitudinal axis **28**, at least one hybrid rotor **14** is provided respectively.

[0104] Before any additional exemplary embodiments shown in FIGS. **6**, **7** and **8** will be addressed relative to the configuration and number of hybrid rotors, hybrid rotor **14** will be explained in further detail with the aid of FIG. **2** and those following.

[0105] In FIG. **2**, hybrid rotor **14** is shown in a schematic lateral view. Hybrid rotor **14** for an aircraft has a Magnus rotor **30**, a transverse flow rotor **32** and a guide mechanism **34**.

[0106] Magnus rotor **30** can be actuated by a propulsion mechanism to rotate around its Magnus rotor axis, and has a closed lateral surface **36**. The Magnus rotor axis is identified by reference number **38**.

[0107] It should be noted that hybrid rotor **14** includes Magnus rotor **30**, transverse flow rotor **32** and the guide mechanism **34**. The first and the second propulsion mechanisms **20**, **22** are mentioned in this connection, but in the embodiment described, they are not a direct component of hybrid rotor **14** according to the invention.

[0108] According to a further aspect, hybrid rotor **14** includes, in addition to Magnus rotor **30** and transverse flow rotor **32** and guide mechanism **34**, first propulsion mechanism **20** and second propulsion mechanism **22**. For example, Magnus rotor **30** can be actuated by first propulsion mechanism **20** that is mentioned in FIG. **1**, but not shown there in further detail.

[0109] Transverse flow rotor **32** is kept rotating around an axis of rotation and has a number **40** of axially extending rotor blades **42**, which can be actuated to rotate around the axis of rotation by a propulsion mechanism. For example, rotor blades **42** can be actuated by the second propulsion mechanism **22**, which was mentioned in connection with FIG. **1**.

[0110] Magnus rotor **30** is located within transverse flow rotor **32** and Magnus rotor axis **38** extends in the direction of the axis of rotation. For example, Magnus rotor axis **38** extends parallel to the axis of rotation. According to one aspect of the invention, Magnus rotor **30** is located concentric with transverse flow rotor **32**.

[0111] According to an exemplary embodiment that is not shown, Magnus rotor **30** is located within transverse flow rotor **32**, whereby the respective rotor axes are offset with respect to each other. Thereby, the rotor axes can have an angle with respect to each other and can lie, for example, in one plane.

[0112] Rotor blades **42** are designed stationary relative to the tangential angle position. The tangential angle position is understood to be the angle that is occupied by the rotor blades with respect to the tangential. As shown in FIG. **3**, rotor blade **42** has a connection line **44** between the two outer points of rotor blade **42** that has, for example a curved design. During the rotation of the transverse flow motor, rotor blade **42** performs a motion along a circular path **46** around the Magnus rotor axis as central point or axis of rotation. The axis of rotation or the Magnus rotor axis **38** can be connected with a virtual central point **48** of rotor blade **42**, which is shown by a radially extending connection line **50**. Perpendicular to this connection line **50**, a tangential line **52** is shown. With its alignment that is indicated by line **44**, rotor blade **42** has an angle position **54**, which is additionally identified in FIG. **3** by the symbol α.

[0113] It should be noted that the directional straight line **44** does not extend through the virtual center of the rotor blade, so that the directional straight line **44** also does not cross the tangential line **52** in center **48** of the rotor blade, however, a line extending parallel to directional straight line **44** would have the same angle **54** to tangential line **52**.

[0114] According to the illustrated exemplary embodiment, rotor blades **42** extend parallel to the axis of rotation in axial direction, i.e., they have a constant distance to the axis of rotation.

[0115] According to a further aspect of the invention that is not shown in further detail, rotor blades **42** extend at an incline to the axis of rotation in axial direction, whereby the rotor blades have an increasing or decreasing distance to the axis of rotation, i.e., the rotor blades respectively extend in a plane with the axis of rotation, but are inclined to the axis of rotation.

[0116] Guide mechanism **34** shown in FIG. **2** has a housing segment **56**, which partially surrounds the transverse flow rotor in the circumferential direction. Housing segment **56** has an adjustment mechanism **58**, with which housing segment **56** is designed rotatable at least relative to Magnus rotor axis **38**, which is indicated with a double-arrow symbol **60**.

[0117] According to a further aspect or the invention, the adjustment mechanism has one or more actuators or a different propulsion mechanism to perform the rotation or ensure the adjustment in the respectively attained position, which is, however, not shown in further detail.

[0118] As indicated in FIG. **2** by symbolic flow arrows **62**, housing segment **56** can be aligned in such a way that transverse flow rotor **32** causes a propulsion force **64**, which is shown symbolically with an arrow, and simultaneously a transverse flow onto the Magnus rotor, which is indicated with arrow symbols **66**.

[0119] As indicated in FIG. **2** by a rotation arrow **68**, the rotation of the transverse flow rotor takes place clockwise, which is otherwise also already given by the setting of the rotor blades.

[0120] Further, a Magnus rotor rotation arrow **70** indicates that the Magnus rotor in the shown exemplary embodiment likewise rotates clockwise.

[0121] Due to the transverse flow **66** and rotation **70** of the Magnus rotor, a force **72** is generated according to the Magnus effect. Force **72** brings about a lifting force **74** of the hybrid rotor in addition to the propelling force **64**.

[0122] As is not shown in further detail, the Magnus rotor is driven by a first shaft and the transverse flow rotor by a second shaft which is, for example, located concentrically, for example, extending into each other.

[0123] Transverse flow rotor **32** forms, together with guide mechanism **34**, a transverse flow blower that generates a flow, which extends transverse to the Magnus rotor axis **38**.

[0124] As can also be seen in FIG. **2**, the housing segment has a side **76** that is facing the transverse flow rotor. This side **76** that faces the transverse flow rotor has the shape of a circular arc, which is linked to the revolving rotor blades **42**.

[0125] According to an embodiment, housing segment **56** is designed with the same cross-section for the entire length of the Magnus rotor. Alternatively, it the housing segment can have different cross-section shapes extending over the length of the Magnus rotor, which is, however, not shown in further detail.

[0126] In FIG. **4**, a further exemplary embodiment is shown in which aircraft **10** is shown in a schematic and extremely simplified front view. As can be seen, hybrid rotor **14** that is located on the right in the drawing, i.e., the backboard hybrid rotor relative to the flight direction, has Magnus rotor **30** and transverse flow rotor **32**. Furthermore, guide mechanism **34** is present which is, however, not shown in further detail.

[0127] In FIG. **5***a*, hybrid rotor **14** is shown with Magnus rotor **30** which is designed, for example, as a cylinder.

[0128] According to a further aspect of the invention which is, however, not shown in further detail, the Magnus rotor is formed as a truncated cone or consists of different truncated cone and/or cylinder segments. For example, the Magnus rotor can also have other rotation-symmetric shapes or segments of other rotation-symmetric shapes, for example, spherical shapes such as a sphere.

[0129] According to a further exemplary embodiment, which is shown in FIG. **5***b*, Magnus rotor **30** is a cylinder and has, in the section of its ends **76**, respectively one end plate **78** projecting over the cylinder surface. For example, end plates **78** are formed at the facing ends of the cylinder and rotate with the cylinder.

[0130] According to a further exemplary embodiment, which is shown in FIG. **5***c*, the cylinder of Magnus rotor **30** has a number **80** of plates **82**, which are located between the two end plates, whereby plates **82** have a larger diameter than lateral surface **36**.

[0131] As shown in FIG. **5***c*, end plates **78** and plates **82** have the same diameter. According to a further exemplary embodiment that is, however, not shown, plates **82** have a different diameter than plates **78** at the end, for example, a smaller diameter. Beyond that, it is also provided that in an additional exemplary embodiment that is likewise not shown, plates **82** have different diameters, for example, they become smaller toward the fuselage area.

[0132] A further aspect is shown in FIG. **6**. According to an exemplary embodiment, aircraft **10** is designed with a hybrid rotor **14** that is, for example, provided above fuselage **12** and projects away from the fuselage area on both sides.

[0133] According to a further exemplary embodiment, aircraft **10** is designed with two hybrid rotors **14** that are at a distance to each other in the longitudinal direction. As shown in FIG. **7** schematically, two hybrid rotors **14** are located that respectively project significantly over the lateral sections of fuselage **12**.

[0134] The illustrated hybrid rotors **14** can, according to a further exemplary embodiment, also be designed as two hybrid rotors **14** located directly adjacent to each other, which is indicated in FIG. **14** by way of example by a joint **83** for posterior hybrid rotor **14**.

[0135] According to a further exemplary embodiment that has already been presented in FIG. **1**, at least two hybrid rotors **14** are provided perpendicular to longitudinal axis **28**, which are located on diametrically opposed sides of longitudinal axis **28**, whereby the at least two hybrid rotors are at a distance to each other, for example, due to the fuselage area **12** that lies between, and form a propulsion pair or a propulsion group **84**.

[0136] In FIG. **8**, an exemplary embodiment is shown in which aircraft **10** has two propulsion pairs or propulsion groups **83** in the longitudinal direction.

[0137] In FIG. **9**, a further exemplary embodiment of transverse flow rotor **32** is shown. In the illustrated exemplary embodiment, transverse flow rotor **32** has a number of 16 rotor blades **42**.

[0138] According to a further exemplary embodiment, at least two rotor blades **42** are provided, which is, however, not shown in further detail.

[0139] The rotor blades respectively have a curved shape in cross-section with a concave side **86** and a convex side **88**. As can be seen, concave side **86** faces Magnus rotor **30**.

[0140] According to a further aspect of the invention, the cross-section shape of the rotor blades changes over their length, i.e., over the width of the aircraft.

[0141] Magnus rotor **30** is only symbolically indicated in FIG. **9** and can, in particular its dimensions in relation to the transverse flow motor, also be designed differently.

[0142] As has already been explained in connection with FIG. **3**, the rotor blades have an angle **54** to the radial direction in cross-section. For example, the value of this angle **54** lies in a range of approximately 15° to 70°.

[0143] As shown in FIG. **9**, the rotor blades respectively have an angle of 30° to the radial direction, according to an exemplary embodiment.

[0144] According to one aspect of the invention (not shown in further detail), between the lateral surface of the Magnus rotor and the rotating rotor blades, a distance is provided in radial direction that depends on the diameter of the Magnus rotor.

[0145] For example, the diameter of the Magnus rotor is just as large to twice as large as the distance of the lateral surface to the rotor blades.

[0146] According to a further example, the relationship of the diameter of the Magnus rotor and the distance to the rotor blades is 2:1.

[0147] According to a further aspect of the invention, a distance **89** in radial direction is provided between the rotating rotor blades **42** and lateral surface **36**, which amounts to one to two times the size of a profile depth **87** of a rotor blade **42**.

[0148] As mentioned already, the distance according to a further example, different than that in FIG. **9**, is one time to one half the size of the diameter of the Magnus rotor.

[0149] According to a further aspect of the invention, rotor blades **42** have a diameter **85** that is five times to eight times the size of the profile depth **87** of a rotor blade **42**.

[0150] According to a further aspect of the invention, a circumferential distance **83** of rotor blades **42** is provided that is at least as large as the profile depth **87** of rotor blades **42**.

[0151] The profile depth, the circumferential distance, as well as the number of the rotor blades can, for example, be chosen freely in principle. From them are given, for example, when using the preferred relationship "distance/diameter Magnus rotor", the diameter of the Magnus rotor and the distance between the rotor blades and the lateral surface of the Magnus rotor.

[0152] As has already been mentioned above, for example, the rpm of the Magnus rotor, as well as the direction of rotation can be actuated or adjusted independent of the rpm of the transverse flow rotor.

[0153] Moreover, in FIG. **9**, deflector plate **56** is schematically indicated, in particular with respect of the dimension or the structural design.

[0154] In FIG. **10**, a further exemplary embodiment of the hybrid rotor is shown, in which housing segment **56** of guide mechanism **34** has a side **90** facing away from the transverse flow rotor that has adjustable profile elements **92**, using which the cross-section shape can be changed on side **90** that faces away, which is symbolically indicated by a double arrow **94**. It should be noted that profile elements **92** are shown only in the section on the right, however, they can also be provided in the left section, i.e., relative to the flight direction—by using the flow lines from FIG. **2**—anterior section of guide mechanism **34**. The change of the cross-section shape takes place, for example, depending on the rotation setting of the guide mechanism.

[0155] According to the invention, a method **100** for flying the aircraft is also provided, which is shown in FIG. **11**, and includes the following steps:

[0156] In one step a), a rotating **110** of a Magnus rotor around a Magnus rotor axis is provided, whereby the Magnus rotor, for generating a force **112** according to the Magnus effect, has a closed lateral surface.

[0157] In a step b), a rotating **114** of a transverse flow rotor around an axis of rotation is provided that has a number of axially extending rotor blades, which, relative to the tangential angle position, are designed stationary, whereby the rotating of the transverse flow rotor generates a propelling force **116** for the aircraft, which extends transverse to the Magnus rotor axis.

[0158] Thereby, the Magnus rotor is located within the transverse flow rotor and the axis or rotation extends in the direction of the Magnus rotor axis.

[0159] In a step c) an alignment **118** of a housing segment of a guide mechanism is provided that partially surrounds the transverse flow rotor in circumferential direction, for which a deflection **120** of the housing segment relative to the Magnus rotor axis is provided in such a way that the transverse flow rotor causes a transverse flow **122** onto the Magnus rotor, by means of which force **112** is generated according to the Magnus effect.

[0160] According to a further aspect of the invention, the three steps a), b), c) take place simultaneously, or step c) according to need.

[0161] According to a further aspect of the invention, as a result the rotating **110** of the Magnus rotor, a lifting force is generated. According to a further aspect of the invention, rotating the Magnus rotor also, or alternatively generates a propulsion force.

[0162] Thus, relative to the aircraft, two forces are generated, namely the force according to the Magnus effect **112**, and the propulsion force **116**.

[0163] According to a further exemplary embodiment, which is indicated in FIG. **11** by a dotted line and rectangle, a force **122** is generated, that has a lift vector and a propulsion vector.

[0164] According to a further aspect of the invention which is, however, not shown further in FIG. **11**, rotating **110** of the Magnus rotor and rotating **114** of the transverse flow rotor, and deflection **120** of the guide mechanism can be regulated separately in such a way that different drive and propulsion forces can be selected or different drive vectors and propulsion vector components.

[0165] According to a further aspect, this makes it possible to select different flight directions, whereby it is to be emphasized in particular, that the guide mechanism can be adjusted in such a way that a vertical lift and propulsion force is generated, which makes it possible for the aircraft to take off vertically or have a short takeoff, i.e., start with an extremely short runway.

[0166] The exemplary embodiments described above can be combined in different ways. In particular, aspects of the devices for embodiments of the method can also be used, as well as the devices and vice versa.

[0167] In addition, it is to be pointed out that "including" does not exclude any other elements or steps and "one" or "a" does not exclude several. Further let it be pointed out that characteristics or steps that have been described referring to one of the above exemplary embodiments, can also be used in combination with other characteristics or steps of other exemplary embodiments described above. Reference numbers in the claims are not to be viewed as limiting.

[0168] The foregoing disclosure has been set forth merely to illustrate the invention and is not intended to be limiting. Since modifications of the disclosed embodiments incorporating the spirit and substance of the invention may occur to persons skilled in the art, the invention should be construed to include everything within the scope of the appended claims and equivalents thereof.

What is claimed is:

1. A hybrid rotor for an aircraft, comprising:

a Magnus rotor;

a transverse flow rotor; and

a guide mechanism;

wherein the Magnus rotor is configured to be actuatable to rotate around a Magnus rotor axis by a first propulsion mechanism, and has a closed lateral surface;

wherein the transverse flow rotor is configured to be kept rotating around an axis of rotation and has a number of axially extending rotor blades that actuatable to rotate around the axis of rotation by a second propulsion device, and which are configured stationary relative to the tangential angle position;

wherein the Magnus rotor is located within the transverse flow rotor and the Magnus rotor axis extends in the direction of the axis of rotation;

wherein the guide mechanism has a housing segment partially surrounding the transverse flow rotor in a circumferential direction;

wherein the housing segment has an adjustment mechanism and is configured deflectable at least relative to the Magnus rotor axis;

wherein the housing segment is aligned in such a way that the transverse flow rotor generates a propelling force and brings about a transverse flow onto the Magnus rotor in such a way that a force is generated according to a Magnus effect, which acts as lifting force.

2. The hybrid rotor as recited in claim **1**, wherein the housing segment has a shape of a circular arc on a side facing the transverse flow rotor.

3. The hybrid rotor as recited in claim **1**, wherein the rotor blades respectively have a curved form in cross-section with a concave and a convex side, and wherein the concave side faces the Magnus rotor.

4. The hybrid rotor as recited in claim **1**, wherein in cross-section, the rotor blades respectively have an angle ranging from 15° to 70° to a radial direction.

5. The hybrid rotor as recited in claim **1**, wherein the Magnus rotor is a cylinder and it respectively has an end plate that extends over the cylinder surface in a section of its ends.

6. The hybrid rotor as recited in claim **5**, wherein the cylinder has a number of plates located between the two end plates, and wherein the plates have a larger diameter than the lateral surface.

7. An aircraft, comprising:

a fuselage area;

at least one hybrid rotor, which comprises

a Magnus rotor;

a transverse flow rotor; and

a guide mechanism;

wherein the Magnus rotor is configured to be actuatable to rotate around a Magnus rotor axis by a first propulsion mechanism, and has a closed lateral surface;

wherein the transverse flow rotor is configured to be kept rotating around an axis of rotation and has a number of axially extending rotor blades that actuatable to rotate around the axis of rotation by a second propulsion device, and which are configured stationary relative to the tangential angle position;

wherein the Magnus rotor is located within the transverse flow rotor and the Magnus rotor axis extends in the direction of the axis of rotation;

wherein the guide mechanism has a housing segment partially surrounding the transverse flow rotor in a circumferential direction;

wherein the housing segment has an adjustment mechanism and is configured deflectable at least relative to the Magnus rotor axis;

wherein the housing segment is aligned in such a way that the transverse flow rotor generates a propelling force and brings about a transverse flow onto the Magnus rotor in such a way that a force is generated according to a Magnus effect, which acts as lifting force,

wherein the Magnus rotor and the transverse flow rotor of the at least one hybrid rotor are retained at the fuselage area;

wherein a first propulsion mechanism is configured to rotate the Magnus rotor of the at least one hybrid rotor and a second propulsion mechanism is configured to rotate the transverse flow rotor of the at least one hybrid rotor;

wherein the Magnus rotor axis is located horizontal to the flight direction.

8. The aircraft as recited in claim **7**, wherein the aircraft has a longitudinal axis and on both sides of the longitudinal axis it respectively has at least one of the hybrid rotors.

9. The aircraft as recited in claim **7**, wherein at least two hybrid rotors are provided at a distance in longitudinal direction.

10. A method for flying an aircraft, comprising:

a) rotating a Magnus rotor around a Magnus rotor axis, wherein the Magnus rotor axis has a closed lateral surface for generating a force according to a Magnus effect;

b) rotating a transverse flow rotor around an axis of rotation that has a number of axially extending rotor blades that are configured stationary relative to the tangential angle position, wherein the rotating of the transverse flow rotor generates a propelling force for the aircraft that extends horizontal to the Magnus rotor axis, and wherein the Magnus rotor is located within the transverse flow rotor and the axis of rotation extends in the direction of the Magnus rotor axis; and

c) aligning a housing segment of a guide mechanism partially surrounding the transverse flow rotor in a circumferential direction by a deviating the housing segment relative to the Magnus rotor axis in such a way that the transverse flow rotor brings about a transverse flow onto the Magnus rotor by which the force according to the Magnus effect is generated.

11. A method according to claim **10**, wherein the rotating of the Magnus rotor and the rotating of the transverse flow rotor and the deviation of the guide mechanism are controllable separately in such a way that different drive and propelling forces can be selected.

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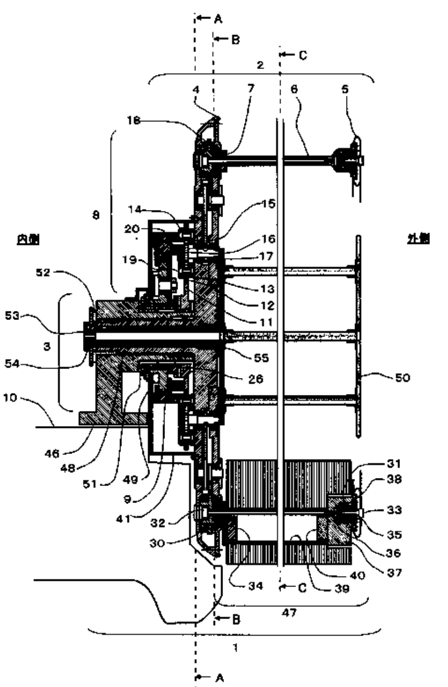
(54) 【発明の名称】平行回転翼を利用した流体機械

(57)【要約】
【課題】鳥の羽ばたき運動をピッチング回転翼に置換えた飛行機の提供。
【解決手段】鳥の羽ばたき工程を複数の要素翼に置き換え、左右軸の周りに回転する円筒の稜線上に配置した。その際、各要素翼は、歯車機構により、公転しながら同じ角度自転して戻され、基本的に平行回転する。さらに、各要素翼は周期的な迸動を加えられて、失速を防ぎながら揚力と推力を発生する。この原理の最大のネックは回転翼によって惹起されるピッチング回転の制御の難しさであった。その解決策として、回転翼の中央に、前後に貫流する空気流を偏向させる静止翼を設けた。回転翼の駆動反力は水平尾翼の外側にもうけた外側翼によってバランスを取らせた。最近の著しく進歩した制御技術を用いれば、敢えてやや複雑なままに鳥を模擬したこの飛行機は、鳥の持つ様々な飛行を可能にする。
【選択図】図１



【特許請求の範囲】
【請求項１】
機体外側の端に内歯歯形を形成した翼ピニオンの穴に、機体内側から挿入した通しボルトを、機体内側の端に翼ピニオンの内歯歯形と回動不能にスキマ勘合する外歯歯形を形成し、機体外側の端に扁平な突起部分を持つ要素翼軸を貫通させ、更に、要素翼の心金を形成する中空長穴断面を有する管であるトルクチューブを貫通させ、機体内側の端にトルクチューブに勘合する扁平な突起部分を持ち、機体外側の端にベアリングの外輪を勘合させる穴を形成したエンドケースの機体内側の端に形成されたメネジ部に締結して一体化する結合構造としたことを特徴とする平行回転翼を利用した流体機械。
【請求項２】
円筒面の稜線を回転軸とする複数の要素翼軸を回転翼盤上に配置した回転ユニットを支持ユニットの筒部に回動自在に勘着した回転翼において、それぞれの要素翼軸が、支持ユニットに連結されて静止している太陽歯車の周りを、太陽歯車と噛み合いそれぞれの要素翼軸に回転角度を伝達する歯車列によって、公転しながら同じ回転角度自転して戻るようにした平行回転翼において、支持ユニットの筒部の外筒側に太陽歯車と偏心リングを割出す機構を勘着し、筒部の内筒側に、太陽歯車と噛み合う複数の歯車列を取り付けた回転翼盤を回動自在に勘着し、各歯車列の中の複数の遊星歯車を回動自在に勘着したリテーナリングから突出されたアーム部分の先端部にジョイントピンで回動自在に勘着されたローラーを偏心リングの内筒面に接触させて、太陽歯車の中心と偏心リングの中心とローラーの中心とリテーナリングの中心とで４節リンクを形成し、回転翼盤の回転に伴って発生するリテーナリングの逓動回転を遊星歯車の逓動回転に変換し、歯車列の中で末端の翼ピニオンの逓動回転に変換し、回転円盤が１回転する間に１回転戻る翼ピニオンの回転に逓動回転を付加する機構を設けたことを特徴とする平行回転翼を利用した流体機械。
【請求項３】
外歯歯車を持った駆動歯車を太陽歯車軸に勘合させ、その外歯歯車と噛み合う中継歯車をオフセットさせて回動自在に勘着し、外周にオフセットした軸受軸面を形成した内側偏心ディスクを勘着し、中継歯車と噛み合う内歯歯車を持ち、外筒部に偏心リングを形成した外側偏心ディスクを内側偏心ディスクの軸受軸面と回動自在に結合する軸受穴面に勘着させた偏心リング割出機構とし、内側偏心ディスクと駆動歯車の軸筒をそれぞれに回転させることにより偏心リングの偏心方向と偏心量を任意に割出せる機構を設けたことを特徴とする回転翼を利用した流体機械である。
【請求項４】
偏心リングの内径側に、偏心リングの内径からローラーの外径の２倍を差し引いた外径を持ったランナーリングを、スベリ隙間を持たせて回動自在に勘着したことを特徴とする請求項１、２、３に記載の回転翼を利用した流体機械である。
【請求項５】
太陽歯車と噛み合う歯車列によって駆動されて回転する要素翼に加えて、それらの要素翼と連結されて回転する追従要素翼を追加して要素翼の枚数を増やした回転翼を取付けたことを特徴とする請求項１、２、３、４に記載の回転翼を利用した流体機械である。
【請求項６】
支持ユニットの筒部の穴に回動自在に勘着された回転翼盤の中心の穴に回動自在に勘着された中央静止翼の軸筒の機体外側の端に、内盤と外盤の間に要素翼とほぼ同じ長さの翼を挟んで一体化した静止翼ケージを固定し、軸筒の機体内側の端を回転させて回転角度位置を調節できる中央静止翼を設けたことを特徴とする請求項１，２，３、４、５に記載の回転翼を利用した流体機械。
【請求項７】
水平尾翼の機体外側の端に機体内側に向けて明けられた穴に、軸部を回動自在に勘着した外側翼を設けたことを特徴とする請求項１，２，３，４，５、６に記載の回転翼を利用した流体機械。
【請求項８】

静止翼を回転翼の下方に機体から外側に突き出して装着したことを特徴とする請求項１，２，３，４，５，６、７に記載の回転翼を利用した流体機械。

【発明の詳細な説明】
【技術分野】
【０００１】
本発明は、平行回転翼を利用した流体機械に関するものである。
【背景技術】
【０００２】
人類は、鳥の飛行術の研究から舞い上がりを得意とするヘリコプターと滑空を得意とする飛行機を実用化してきたが、鳥のように舞い上がり、そのまま滑空に移れる飛行機はまだ実用化されていない。
【０００３】
鳥類と哺乳類は共に爬虫類から進化したため骨格が良く似ているが、鳥類は省ける機能を徹底的に退化させながら飛ぶための機能を高度に、且つ、多様に進化させてきた。
【０００４】
実際、鳥の持つ機構には飛ぶために進化させたと思われる哺乳類との違いが多く見られる。特に、羽根でできた翼を羽ばたく機構は自然が作り出した最高傑作の一つであるが、かなり複雑である。従って、鳥をあるがままに模擬してゆくと、その飛行機は限りなく複雑な機構になってしまう。
【０００５】
一方、人類は哺乳類を模擬して自動車を実用化してきたが、手に負えない程の複雑さにはなっていない。従って、同じように爬虫類から進化した鳥を模擬した飛行機が、自動車と比較できないほど複雑な機械になってしまうとも考えにくい。
【０００６】
やや複雑になっても構わないから、鳥の羽ばたき機構をもう少し忠実に模擬できないであろうか。ライト兄弟の発明から１００年以上経過し、コンピューターが目覚しい発達を遂げ、流体力学が十分に実用的に利用できる現代に立って、将来を展望すれば、その試みは、無謀とは思われない。
【０００７】
ヘリコプターは上下軸の周りに複数の翼を回転させているが、この方式は鳥には見られない。しかし、複数の翼を左右軸の周りにほぼ平行を保ったまま回転させる方式は鳥の羽ばたき運動を近似的に模擬できている。
【０００８】
以下、上下に羽ばたく翼の動きを、近似的に平行回転する円運動に置き換え、工程を複数に分解して円周上に配置し、同時に回転させる回転翼の方式を、本特許願いでは、平行回転翼、ピッチング回転翼、平行ピッチング回転翼、または、単に回転翼と呼ぶ。
【０００９】
平行回転翼の原理は、特許文献２に示すように、既に、３４年前の１９７５年に、フランスで特許出願されている。平行回転、逓動付加、偏心-逓動変換、偏心リング割出しの４つの機構を組み合わせて、複数の要素翼を周期的な逓動を加えながら平行回転させるアイデアは本発明と同じであったが、実用化検討は十分でなく、原理の提案に留まっていた。
【００１０】
１９９１年には、このアイデアの回転翼を用いた飛行機の特許が、特許文献３に示すように、同じくフランス人によって日本に外国出願されている。この飛行機は実際に試作されたが、機体のピッチング回転がコントロールできず、試験飛行に失敗したと聞いている。
【００１１】
平行回転翼の原理は、潮流発電機/送水機、風力発電機/送風機、水中回転翼船、水上回転翼船、水面滑空機、飛行機など、様々な流体機械に応用できるが、その中で技術的に最も困難な応用分野は飛行機であろう。そこで、本発明活動では、困難な技術課題を早めに見

つけ出すために、応用目標を飛行機に設定した。従って、以下の記述は、飛行機への応用の形をとって進める。
【００１２】
また、図面視野としては、左側面図を基本とする。回転する要素翼の回転翼上の角度位置については上向き垂直線をゼロとし、前下げ回転方向を正に定義する。また、要素翼の迎角については、流入気流に向う線をゼロとし、翼弦が右回転方向に傾斜する角度を正と定義する。左側面図と要素翼の回転翼上の角度位置と迎角の定義を図３０に示す。
【００１３】
特許文献１の発明は、２００７年に出願されているが、連続している羽ばたき運動の工程を複数の要素翼の状態に分散し、それらを円筒面の稜線上に配置し、基本的に平行回転させながら、それぞれの要素翼の迎角を周期的に遥動させて、鳥の羽ばたき機構をやや複雑なままに、近似的に模擬している。
【００１４】
そして、いくつかの飛行条件においては、要素翼に、負の迎角や過大な迎角が生じることを示し、その処理方法について原理的な解決策を提案していた。しかし、この発明を利用するためには、更に、実用化のための課題を明らかにし、解決策を見出す必要があった。
【００１５】
渡り鳥の水平飛行では、鳥は翼面と流入気流との交角である迎角を制御しながら翼を上下に動かすことにより、飛行に必要な空気力を得ている。運動工程としては、推力と揚力を同時に発生しながら翼を下死点に向かって打ち下ろす工程と、揚力低下を防ぎながら翼を上死点に跳ね上げる工程が繰り返えされている。羽ばたき飛行中の翼に入る空気の流入角の変化を説明する模式図を、図５０、図５１、図５２に示す。
【００１６】
この時、翼の外側の部分（以下、「手の部分」と呼ぶ）では主に推力を、内側の部分（以下、「腕の部分」と呼ぶ）では主に揚力を発生している。従って、羽ばたき運動の模擬には、一つの翼の中で手と腕をどのように動かして揚力と推力を発生しているかの理解が必要となる。翼の構成と骨格の模式図を、図４９に示す。
【００１７】
また、特許文献１では、機体のピッチング回転モーメントをゼロにする方法として、回転翼の前後位置を機体重心に対して移動させるアイデアが提案されていた。しかし、この方法は、多くの鳥に用いられているとは言え、機械にした場合は大きな質量を迅速に移動させることが必要になるため、制御技術上大きな困難が予想された。そこで、これに代わる回転モーメントの相殺方法の発明が必要となった。
【００１８】
平行回転翼を用いた飛行機では、円筒面の稜線上に配置された複数の要素翼に発生する空気力の総和として、回転翼の中心軸に、揚力、推力、回転モーメントの３つが発生するが、これらは相互に密接に関係しているので、調整を取りながら制御する必要がある。
【００１９】
水平飛行時には、揚力に対しては取付け角が、推力に対しては遥動角がそれぞれ主導的な制御ファクターであるが、回転モーメントについては、特許文献１の中では、主導的な制御ファクターは明らかにされていなかった。
【００２０】
特許文献１の回転翼は、歯車とローラーを用いたやや複雑な機構となっているが、その実用化のためには、レイアウトを見直し、要素翼の剛性とその両端の結合剛性を高め、要素翼の本数を増加し、最大遥動角を拡大し、オイル潤滑を可能にする必要があった。
【００２１】
特に、４節リンク機構を用いて回転に同期した揺動回転を付加する機構における、偏心リングとローラーの接触面の倒れの防止と潤滑の方法は、重要な検討課題であった。
【００２２】
一方、飛行機としては、従来の飛行機に倣って水平尾翼と垂直尾翼を備え、主翼を回転翼

に代えていたが、飛行時の静安定性についての検討は十分ではなかった。

【００２３】

そこで、回転翼に発生する回転モーメントと機体のピッチング回転との関係を踏まえて、機体のピッチング回転に対する静安定性を確保する方法について再確認する必要があった。

【００２４】

鳥は色々な飛行モードを選び、飛行しているが、鳥の直線飛行メカニズムを模擬するために、離陸準備から、離陸、加速上昇、水平飛行、滑空、減速降下、着地、停止にいたる種々の飛行モードについて、動作を観察し、理解する必要があった。

【００２５】

タカは空中で獲物を捕まえられる強い足を持っており、地上でも確りと踏ん張れる。木の枝から飛び出す時には、枝を足で確り握っておき、大きく翼を立てて跳ね上げて、翼の上面で空気を後方に煽り出して、前方から補給される空気の流れに乗って翼を前に出しながら打ち下し、枝を蹴って前方に飛び出し、その後、強く羽ばたいて加速する。

【００２６】

アオサギは、翼を水平に広げたまま、長い足を折って斜め前上方にジャンプして飛び出し、直ぐに翼を打ち下して、水平を保ちながら、ハタハタと羽ばたいて加速する。

【００２７】

ハクチョウは助走しながら離水する。揚力は飛行速度の２乗に比例するが、水掻きで水面を蹴って助走して加速し、離水に必要な速度を得ている。

【００２８】

キジは草むらの中から突然に羽ばたきながら走り出し、助走して舞い上がる。

【００２９】

また、コウノトリは、舞い上がる時に、足を踏ん張り、翼を大きく後に傾けたまま跳ね上げて後方向に気流を起こし、次に、その翼を前に回して、前方から補給される気流に乗るように前方に動かしながらジャンプし、続けて翼を打ち下して、離陸に必要な揚力と推力を発生しているように見える。離陸の瞬間には大きな回転モーメントを発生しているが、地上に足をつけている間は、踏ん張って、その回転モーメントに耐えていると推察される。

【００３０】

アオサギは、水平羽ばたき飛行中に翼の傾斜角を大きく変化させているようには見えない。しかし、図５３に示すように、跳ね上げ工程では、手の部分の風切り羽根を弾性的に捻り、羽根と羽根の隙間を広げて空気を逃がして、実際の翼の迎角は大きく変化させているものと思われる。

【００３１】

ナベヅルの水平飛行を観察すると、図５４に示すように、跳ね上げ工程では、翼を上凸に折って、下向きの空気抵抗を減らしている。

【００３２】

タカは、目的によって、速い羽ばたき、強い羽ばたき、滑空などの飛行モードを臨機応変に選んでいる。さすがは空の王者である。足に重い獲物を鷲掴みにして飛行するときは、翼を一段と大きく捻って羽ばたいている。回転翼を用いた飛行機でも、積載重量や積載位置が変化するときは、空気力、回転モーメント、慣性力、慣性モーメント、重力、機体の空気抵抗などの関係を調節して、ピッチング回転モーメントのバランスをとって飛行姿勢を保つ必要がある。

【００３３】

トンビは、獲物搬送の時は大きく翼を捻って一段と大きく羽ばたいているが、毎分の羽ばたき回数は変えていないように見える。

【００３４】

ハトは、突風に煽られたり、急制動を掛けたり、天敵の攻撃をかわすために急降下するときなどには、翼を前後に移動させて、重心と揚力中心の距離を変えて姿勢角を大きく崩し

ている。このような挙動では、飛行機であれば乗員は乗っていられない。しかし、事故時の安定性と安全性の設計には十分に参考にすべき現象であろう。

【００３５】
タカは、目標までの距離を読んでと気流と高度と速度を選びながら、翼を止めたまま滑空して着地点を目指す。

【００３６】
トンビは上昇気流を見つけて旋回上昇し、得られた位置エネルギーを速度に変換して滑空しながら次の上昇気流のある位置に移動する。それを繰り返して、殆ど羽ばたきせずに大空を渡ってゆく。

【００３７】
カラスは、電柱に止まる時には、少し下からアプローチし、直前で翼を前に移動して体を起こし飛行方向を上向きにして速度エネルギーを位置エネルギーに変換して、狙ったポイントに速度をゼロにして止まる。

【００３８】
ハクチョウは、着水の際には水掻きを水上スキーにして体重を支えながらブレーキをかけて停止する。その際、翼を立てて制動パラシュートにして大きな抗力を発生し、体が前に倒れるのを防いでいる。水が空気に比べて１０００倍の密度をもつので、小さな水掻きでも、体を浮かせ急制動がかけられる。

【００３９】
ライト兄弟は、グライダーを用いて、空気力、静安定性、操縦性などの実験を先行させ、追いかけて、別途開発していたエンジンを搭載し、飛行機を試作し、初飛行に漕ぎ着けた。

【００４０】
回転翼を応用した飛行機の実用化も同じような経緯をたどると思われる。先ずは、静止翼のグライダーからはじめて、フリー回転翼のグライダー、モーター駆動の回転翼飛行機、ラジコン制御の電動回転翼飛行機へと検証項目を追加しながら試作を重ね、滑空、水平飛行、離陸、着陸などの飛行能力を開発していくことになろう。その間には、多くのシミュレーション、設計、試作、実験を積み重ねることになろう。

【００４１】
鳥は、生活環境に合わせてそれぞれに最適な特性を持つように、様々な種を多様に進化させてきた。それを思うと、鳥の羽ばたき機構を模擬する飛行機の開発においても、模型試作の段階では汎用性のある飛行機を目指すが、実機試作の段階では、それぞれに特徴を持った個別最適設計の飛行機の開発に方針を切り替えるのが成功への早道になると考える。

【００４２】
しかし、そのためには、様々な個別最適設計に利用できる、ユニバーサルでフレキシブルなシミュレーションプログラムの開発が必要となろう。

【００４３】
飛行機のコンピューター制御技術は、既に、十分に発達している。しかし、それを利用するためには、飛行状態を司る回転翼の制御ファクターを明らかにし、それらを機体の制御ファクターと、更に、飛行機の操縦ファクターと関係付けていく必要がある。

【００４４】
特許文献１の発明では、偏心リングにより与えられた偏心量を遥動回転に変換して要素翼の迎角を周期的に変えている。しかし、これだけでは、打ち下し工程の傾斜角と跳ね上げ工程の傾斜角を、大きさが等しく方向が反対にするところまでしか制御できない。

【００４５】
また、回転翼の後方の要素翼は、前方の要素翼が作る後流れの影響を受けるため、遥動角をゼロにしておいても、前方の要素翼と同じ迎角をとって同じ揚力を発生することはできず、回転翼に回転モーメントを発生させてしまう。この現象は実際の鳥にはなく、回転翼にして、打ち下し工程と跳ね上げ工程を前後にずらせたことによって発生しているので、何らかの方法により技術的に解決しなければならない。従って、特許文献１の複数の要素

翼のみからなる回転翼では、大きな水平尾翼をつけないと回転翼に生ずる回転モーメントを相殺して静安定性を確保することは困難であり、渡り鳥のような小さめの水平尾翼ではピッチング回転のバランスをとって飛行することはできない。

【００４６】

鳥は、腕の部分と手の部分とでは羽ばたき速度に違いが生じ、捻らなくても迎角が変わる。また、肩の関節や手首の関節で捻りを加えることもできる。鳥は、これらの作用を利用して、跳ね上げ工程と打ち下し工程で、それぞれに腕と手の部分の傾斜角を最適化な迎角となるように調節し、過大な回転モーメントの発生を防止しながら必要な揚力と推力を確保していると思われる。図５０～図５２に、羽ばたきと回転翼の間の流入気流ベクトルの違いを模式的に示す。

【００４７】

以上を踏まえると、色々な飛行モードに切り換えて鳥のように飛行するためには、一部に、鳥には無い新しい工夫も加える必要がある。鳥の持つ飛行の仕掛けを完全に模擬することはできないが、少し複雑になっても、鳥の主要な飛行モードをカバーできるところまでは模擬する必要がある。そこまで進められれば、次の実用化段階では、個別の応用形態に合わせて、鳥に習って不要な機能は退化させ、必要な機能もできるだけ簡素化し、特別に必要な機能を付加または進化させて、多様な鳥ロボットの開発への道が開かれると展望する。

【先行技術文献】

【特許文献】

【００４８】

【特許文献１】特開２００９－２３４１７　公報

【特許文献２】仏国特許出願公開第２３０９４０１号明細書

【特許文献３】特開平３－５７７９６　公報

【発明の概要】

【発明が解決しようとする課題】

【００４９】

上記の背景を踏まえて、特許文献１の発明をベースにして、回転翼の飛行機への応用をリードケースにして鳥の羽ばたき機構の実用的な模擬方法を見つけ出し、必須な機能を見極め、機構や構造を設計するための課題を明らかにした。

【００５０】

特許文献１の発明では、鳥の羽ばたき運動を、周期的に揺動しながら基本的に平行回転する複数の要素翼の運動に置き換え、平行回転、揺動付加、偏心-揺動変換、偏心リング割出しの４つの機構の組み合わせによって模擬している。

【００５１】

回転翼に発生する空気力の大きさは回転速度の２乗に比例するため、必要な回転速度を確保しなければならないが、回転速度の上限は回転体の１次固有振動数で決まるため、軽量で高い要素翼剛性と高い結合剛性を持った要素翼ケージ構造として実用的な回転速度を有する回転翼の構造にする必要があった。

【００５２】

また、回転翼に発生する空気力を効率よく発生させるためには、要素翼の本数を増やして細くし、要素翼のアスペクト比を大きくするために、より多くの要素翼を駆動できる、コンパクトで実用的な回転翼の機構にする必要があった。

【００５３】

また、内部機構の運転の信頼性を確保しながら回転翼を高速で回転するために、偏心リングとローラーとの接触部分や遊星歯車機構を含む歯車列のオイル潤滑を可能にする実用的な回転翼の構造を提供する必要があった。

【００５４】

文献１の発明では、いくつかの運転条件において、回転翼の中心周りに大きな回転モーメントが発生することが予測されていたが、それを打ち消す方法として、回転翼の位置を機

体重心に対して前後に移動させるアイデアが提案されていた。しかし、翼の前後移動は鳥が用いている常套手段ではあるが、回転翼を利用した飛行機にした場合は大きな質量の迅速な移動が必要となる。従って、この方式を飛行機の姿勢制御メカニズムに取り入れることはかなり難しいことが分かってきた。

【００５５】

そこで、回転翼の前後移動に代えて、回転翼に発生する回転モーメントを回転翼の中で小さくし、調節する方法を発明する必要に迫られた。

【００５６】

即ち、本発明には、特許文献１の発明を踏まえて、飛行機に利用でき、近似的に、鳥の羽ばたき運動を模擬しながら、回転翼の中に組入れて、その中心軸に発生する回転モーメントを飛行機のピッチング回転の制御を害さない程度に小さくするための実用的な回転翼の機構を発明する必要があった。

【００５７】

発想の手掛かりに鳥のピッチング回転制御方法を観察してみると、鳥は、肩と腕と手での捻りを利用して、腕と手の両部分の捻り角度を調節していた。そして、羽ばたき半径の違いから生ずる手の部分と腕の部分の羽ばたき速度の違いを利用して、翼に入る空気の流入角を変えていた。図４９～図５２を見よ。

【００５８】

本発明の回転翼の機構に鳥の機構をそのまま組み込むことは、実用的には極めて困難である。その代わりに前方の要素翼の後流れを切り返して、空気の流れを偏向させて後方の要素翼に流入させる方式であれば実用的であり、機能上も代替え手段として有効と推定された。そこで、その可能性を、離陸準備から、離陸、加速、上昇、水平飛行、減速、降下、着陸、停止に至る全ての直線飛行モードについて検証し、回転翼を通過する空気の流れを制御する機構を発明する必要が生じた。

【００５９】

そこで、回転翼の中央部付近に要素翼と同じ程度の長さで機体の外側に突き出した静止翼を設け、その静止翼で前側要素翼の後流を偏向させて後側要素翼に流し込めるようにし、しかもその偏向の度合いを調節できるようにするアイデアが生まれ、その実用性の検証が必要となった。

【００６０】

一方、飛行機には、飛行条件の急変や飛行モードの変化に対応して、自律的に姿勢角を立て直し、適正に保つ機構が備わっていなければならない。

【００６１】

しかし、文献１の発明では、飛行機の基礎的要件である飛行時の静安定性についての検討は十分ではなかった。

【００６２】

即ち、回転翼ユニットを左右に取り付けた飛行機で、従来の飛行機に順ずるピッチング、ローリング、ヨーイング回転に対する静安定性が確保できるかどうかの検討は十分ではなかった。

【００６３】

従来の飛行機は、基本的には、主翼とエルロン、水平尾翼とエレベーター、垂直尾翼とラダーで静的安定性を確保している。それに対して、本発明の飛行機は、主翼とエルロンに代えて回転翼を採用しているが、特に、ピッチング回転に対する静安定性を確保するためには、回転翼の運転中に推力と揚力と回転モーメントが複雑に関連して変化するため、従来の飛行機にはない特別な制御上の工夫が必要となると予想されていた。

【００６４】

そこで、本発明では、特許文献１の発明を踏まえて、従来の飛行機の主翼とエルロンに代えて回転翼を組み込んだ飛行機の状態で、従来の飛行機に順ずる静安定性を成立たせるための新たな機構を発明する必要があった。

【００６５】

即ち、本発明には、飛行中に、回転翼に発生する３次元の回転モーメントを抑えて、飛行機のピッチング、ローリング、ヨーイング回転に対する静安定性を確保するための実用的な飛行機の機構を提供する必要があった。
【００６６】
具体的には、鳥や従来の飛行機に用いられている静安定化機構を調べ、回転翼に応用できそうな機構の原理を探り出し、実用性を検討した。
【００６７】
機体のピッチング回転に対しては、従来の飛行機の水平尾翼とエレベーターに加えて、推力を発生するための回転翼の駆動に起因して回転翼中心軸に発生する回転モーメントによる機体のピッチング回転を打ち消す機能が必要なことが分かった。
【００６８】
機体のローリング回転に対しては、回転翼全体を傾けて取り付けて上反り角を付けることが検討された。また、回転翼の下側に上反り角を持った補助静止翼をつけることも検討された。
【００６９】
機体のヨーイング回転に対しては、従来の飛行機に準じて垂直尾翼とラダーを付けた。また、エルロンの機能は、回転翼の機能に含まれていると考えられたので、別にエルロンは付けなかった。また、回転翼の下側に上反り角を持った補助静止翼をつける場合は、それにも後退角を付けることが検討された。
【課題を解決するための手段】
【００７０】
　本発明は、上記課題を解決するために、特許文献１の発明をベースにして、機能を展開し、構造と機構の具体化を図ったものである。
【００７１】
請求項１に記載の発明では、機体外側の端に内歯歯形を形成した翼ピニオンの穴に、機体内側から挿入した通しボルトを、機体内側の端に翼ピニオンの内歯歯形と回動不能にスキマ勘合する外歯歯形を形成し、機体外側の端に扁平な突起部分を持つ要素翼軸を貫通させ、更に、要素翼の心金を形成する中空長穴断面を有する管であるトルクチューブを貫通させ、機体内側の端にトルクチューブに勘合する扁平な突起部分を持ち、機体外側の端にベアリングの外輪を勘合させる穴を形成したエンドケースの機体内側の端に形成されたメネジ部に締結して一体化する結合構造とし、軽量で高い要素翼剛性と高い結合剛性を持った要素翼ケージ構造として実用的な回転速度を有する回転翼の構造とした。
【００７２】
請求項２に記載の発明では、円筒面の稜線を回転軸とする複数の要素翼軸を回転翼盤上に配置した回転ユニットを支持ユニットの筒部に回動自在に勘着した回転翼において、それぞれの要素翼軸が、支持ユニットに連結されて静止している太陽歯車の周りを、太陽歯車と噛み合いそれぞれの要素翼軸に回転角度を伝達する歯車列によって、公転しながら同じ回転角度自転して戻るようにした平行回転翼において、支持ユニットの筒部の外筒側に太陽歯車と偏心リングを割出す機構を勘着し、筒部の内筒側に、太陽歯車と噛み合う複数の歯車列を取り付けた回転翼盤を回動自在に勘着し、各歯車列の中の複数の遊星歯車を回動自在に勘着したリテーナリングから突出されたアーム部分の先端部にジョイントピンで回動自在に勘着されたローラーを偏心リングの内筒面に接触させて、太陽歯車の中心と偏心リングの中心とローラーの中心とリテーナリングの中心とで４節リンクを形成し、回転翼盤の回転に伴って発生するリテーナリングの遥動回転を遊星歯車の遥動回転に変換し、歯車列の中で末端の翼ピニオンの遥動回転に変換し、回転円盤が１回転する間に１回転戻る翼ピニオンの回転に遥動回転を付加する機構を設け、より多くの要素翼を駆動できる、コンパクトで実用的な回転翼の機構とした。
【００７３】
請求項３に記載の発明では、外歯歯車を持った駆動歯車を太陽歯車軸に勘合させ、その外歯歯車と噛み合う中継歯車をオフセットさせて回動自在に勘着し、外周にオフセットした

軸受軸面を形成した内側偏心ディスクを勘着し、中継歯車と噛み合う内歯歯車を持ち、外筒部に偏心リングを形成した外側偏心ディスクを内側偏心ディスクの軸受軸面と回動自在に結合する軸受穴面に勘着させた偏心リング割出機構とし、内側偏心ディスクと駆動歯車の軸筒をそれぞれに回転させることにより偏心リングの偏心方向と偏心量を任意に割出せる機構を設け、回転翼の回転ギアーケースに内包し、太陽歯車の外周面との間から機体内側に突き出したことにより、偏心リングとローラーとの接触部分や遊星歯車機構を含む歯車列のオイル潤滑を可能にする実用的な回転翼の構造とした。

【００７４】

請求項４に記載の発明では、偏心リングの内径側に、偏心リングの内径からローラーの外径の２倍を差し引いた外径を持ったランナーリングを、スベリ隙間を持たせて回動自在に勘着したことにより、コンパクトな構造でローラーと偏心リングの接触状態の保持と潤滑を確実にし、偏心リングとローラーとの接触部分や遊星歯車機構を含む歯車列のオイル潤滑を可能にする実用的な回転翼の構造とした。

【００７５】

請求項５に記載の発明では、太陽歯車と噛み合う歯車列によって駆動されて回転する要素翼に加えて、それらの要素翼と連結されて回転する追従要素翼を追加して要素翼の枚数を増やした回転翼を取付けたことにより、より多くの要素翼を駆動できる、コンパクトで実用的な回転翼の機構を、必要に応じて選択できるように用意した。

【００７６】

請求項６に記載の発明では、支持ユニットの筒部の穴に回動自在に勘着された回転翼盤の中心の穴に回動自在に勘着された中央静止翼の軸筒の機体外側の端に、内盤と外盤の間に要素翼とほぼ同じ長さの翼を挟んで一体化した静止翼ケージを固定し、軸筒の機体内側の端を回転させて回転角度位置を調節できる中央静止翼を設けたことにより、回転翼の中に組入れて、その中心軸に発生する回転モーメントを飛行機のピッチング回転の制御を害さない程度に小さくするための実用的な回転翼の機構とした。

【００７７】

請求項７に記載の発明では、水平尾翼の機体外側の端に機体内側に向けて明けられた穴に、軸部を回動自在に勘着した外側翼を設け、機体内側から水平尾翼の内部を貫通して連結棒された連結棒の操作によりピッチング回転位置を調節し、飛行中に、回転翼に発生する３次元の回転モーメントを抑えて、飛行機のピッチング、ローリング、ヨーイング回転に対する静安定性を確保するための実用的な飛行機の機構とした。

【００７８】

請求項８に記載の発明では、静止翼を回転翼の下方に機体から外側に突き出して装着し、ローリング回転とヨーイング回転に対する静安定を得るために、上反り角と後退角を付けられるようにし、飛行中に、回転翼に発生する３次元の回転モーメントを抑えて、飛行機のピッチング、ローリング、ヨーイング回転に対する静安定性を確保するための実用的な飛行機の機構とした。

【発明の効果】

【００７９】

請求項１に記載の発明に関しては、トルクチューブにより要素翼単体の曲げ/捻り剛性を確保した。両端の結合部品である要素翼軸とエンドケースに形成された扁平な突起部分の挿入と、要素翼軸の外歯歯形を翼ピニオンの内歯歯形に回動不能に勘合することにより回転位置を合わせて廻り止めを図った。エンドケースは、翼ピニオンの内側から挿入され要素翼軸と要素翼のトルクチューブを貫通した通しボルトを、そのメネジ部で引き付け、要素翼の軸系を一体化し、曲げ/捻り剛性を高めた。エンドケースの外側のベアリングケースには与圧を掛けた２個のベアリングが装着され、回転翼端盤と要素翼との間に回転自在に高い結合剛性が得られた。このような手段により、軽量で高い要素翼剛性と高い結合剛性を持った要素翼ケージ構造として実用的な回転速度を有する回転翼の構造が提供された。

【００８０】

請求項２に記載の発明に関しては、偏心リングを拡大し、リテーナリングとローラーアームを一体にし、アーム先端に１個のローラーを回動自在に取り付け、偏心リングの内筒面に当てて回転するようにしたことにより、より多くの要素翼を駆動できる、コンパクトで実用的な回転翼の機構が提供された。

【００８１】

請求項３に記載の発明に関しては、内側偏心ディスクに外側偏心ディスクを回動自在に勘着させた偏心リング割出機構を回転ギアーケースに内包し、回転ギアーケースのディスク部の内径面と太陽歯車の軸筒外周面との間から外側に出された内側偏心ディスクと駆動歯車のそれぞれの軸筒の端を回転させることにより偏心リングの偏心方向と偏心量を任意に割出せるようにしたことにより、偏心リングとローラーとの接触部分や遊星歯車機構を含む歯車列のオイル潤滑を可能にする実用的な回転翼の構造が提供された。

【００８２】

請求項４に記載の発明に関しては、ローラーが偏心リングの内径面とランナーリングの外形面との間で、遊びを規制され、遊動スキマにと油膜を保って自転し、滑りながら公転できるようにしたので、偏心リングとローラーとの接触部分や遊星歯車機構を含む歯車列のオイル潤滑を可能にする実用的な回転翼の構造が提供された。

【００８３】

請求項５に記載の発明に関しては、歯車機構によって割出されて回転する要素翼に、それらの要素翼と連動して回転する追従要素翼を追加して要素翼の枚数を倍増でき、より多くの要素翼を駆動できる、コンパクトで実用的な回転翼の機構が提供された。

【００８４】

請求項６に記載の発明に関しては、回転翼の中央部に機体の内側に突き出された静止翼の軸筒部で静止翼の回転角度位置を調節することにより、前方の要素翼の後流れを偏向させて後方の要素翼に流入させ、後方の要素翼に発生する空気力を制御でき、回転翼の中に組入れて、その中心軸に発生する回転モーメントを飛行機のピッチング回転の制御を害さない程度に小さくするための実用的な回転翼の機構が提供された。

【００８５】

請求項７に記載の発明に関しては、水平尾翼の外側に、外側翼をピッチング回転方向に回動自在に勘着し、角度位置を機体の内側から水平尾翼を貫通する連結棒を介して調節できるようにしたため、飛行中に、回転翼に発生する３次元の回転モーメントを抑えて、飛行機のピッチング、ローリング、ヨーイング回転に対する静安定性を確保するための実用的な飛行機の機構が提供された。

【００８６】

請求項８に記載の発明に関しては、ローリング回転とヨーイング回転に対する静安定性を確保するために寄与する、上反り角と後退角を持った下側静止翼を回転翼の下方に機体から外側に突き出して装着したため、飛行中に、回転翼に発生する３次元の回転モーメントを抑えて、飛行機のピッチング、ローリング、ヨーイング回転に対する静安定性を確保するための実用的な飛行機の機構が提供された。

【００８７】

回転翼の下に同じ幅で静止翼を張り出すことは、ピッチング平行回転翼を貫流する気流が、前方から入りやや斜め後方に流出することが解析的に明らかにできたことから生まれたアイデアである。この気流は静止翼の位置と翼型を適切に選べば、静止翼上面の気流を加速するので、静止翼に大きな揚力を発生する高揚力機構が形成される。この原理は、従来の飛行機のエンジン排気やプロペラの後流れを主翼上面に当てるのと同じであるが、回転翼の後流の方が翼の上部を層状に流せるので効率を改善できる。

また気流を吹き降ろすヘリコプターではローターコーンの下に大きな静止翼を張り出すことは吹き下し流を堰き止めるので考えられる設計ではない。

【００８８】

即ち、本発明により、左右の回転翼に発生する揚力、抗力、回転モーメントを調節することによって、飛行準備から離陸、上昇、加速、水平、減速、降下、着陸、停止に至るまで

の全ての飛行モードにおいて、従来の飛行機に準じた機構で原理的に静安定性を確保できる見通しが得られた。

【００８９】

本発明は、かなり複雑な制御機構にはなったが、従来の飛行機に準じた機体のローリング、ピッチング、ヨーイング回転に対する静安定性を備え、更に、Ｕターンやピンポイント着陸のような鳥の持つ多様な優れた飛行性能と操縦性能の開発に備えることができた。

【図面の簡単な説明】

【００９０】

【図１】回転翼の機構を説明するための左側の回転翼の断面図
【図２】回転翼の機構を機体の左側から見たレイアウト図
【図３】回転翼の機構を図０１のＡ－Ａ断面矢視の左側面図
【図４】回転翼の機構を図０１のＢ－Ｂ断面矢視の左側面図
【図５】回転翼の機構を図０１のＣ－Ｃ断面矢視の左側面図
【図６】歯車列の伝導経路を説明する模式図
【図７】遊星歯車による遥動角の伝達についての説明タグ
【図８】遊動歯車による差動角度の計算式の説明図
【図９】遊動歯車による差動角度の計算式の説明タグ
【図１０】偏心-遥動変換機構の説明図
【図１１】偏心-遥動変換機構の４節リンクの説明図
【図１２】偏心リング割出機構の機体内側から見た右側面図
【図１３】偏心リング割出機構の断面図
【図１４】偏心リング割出機構の機体外側から見た左側面図
【図１５】偏心リングとローラーとライナーリングの関係の断面説明図
【図１６】偏心リングとローラーとライナーリングの関係の左側面説明図
【図１７】要素翼の取り付け部品である要素翼軸を機体外側から見た図
【図１８】要素翼の取り付け部品であるエンドケースを機体中央側から見た図
【図１９】中央静止翼を前から見た断面図
【図２０】中央静止翼の左側面図
【図２１】回転翼飛行機の外観三面図
【図２２】要素翼に入る気流の流入速度ベクトルの説明図
【図２３】６枚の要素翼を追従させた回転翼のレイアウト図
【図２４】追従させた要素翼を小さめにした回転翼のレイアウト図
【図２５】追従させた要素翼の翼型を変えた回転翼のレイアウト図
【図２６】遥動機構を省いた簡易な回転翼飛行機の外観三面図
【図２７】図２６の回転翼の機構を説明するための断面図
【図２８】図２６の回転翼の機構を説明するための左側面レイアウト図
【図２９】前上げ回転方式の理想モデルの回転翼飛行機の外観三面図
【図３０】回転翼飛行機の機体の左側面図
【図３１】試計算のために仮定した要素翼の空力特性グラフ
【図３２】中央静止翼の作動原理の説明図
【図３３】中央静止翼と外側翼の作用と要素翼の揚力の関係－１
【図３４】中央静止翼と外側翼の作用と要素翼の揚力の関係－２
【図３５】中央静止翼と外側翼の作用と要素翼の揚力の関係－３
【図３６】中央静止翼と外側翼の作用と要素翼の抗力の関係－１
【図３７】中央静止翼と外側翼の作用と要素翼の抗力の関係－２
【図３８】中央静止翼と外側翼の作用と要素翼の抗力の関係－３
【図３９】前下げ回転方式の場合の各種制御入力ファクターの影響－１
【図４０】前下げ回転方式の場合の各種制御入力ファクターの影響－２
【図４１】前下げ回転方式の場合の各種制御入力ファクターの影響－３
【図４２】前下げ回転方式の場合の各種制御入力ファクターの影響－４

【発明を実施するための形態】

【００９１】

鳥は、打ち下し工程と跳ね上げ工程を繰り返す羽ばたき運動の中で推力と揚力を得ながら、体がピッチング回転しないように制御している。

【００９２】

その間には、次のような色々なメカニズムによって必要な空気力を発生し、制御しているように見える。その様子を図４９～図５５の模式図を使って説明する。

【００９３】

・　羽ばたき運動では、翼の手の部分と腕の部分とでは翼の速度が大きく変わるため、飛行速度と羽ばたき速度のベクトル和である流入速度が変わる。図５１を見よ。

・　工程中に、翼を付ける肩と腕と手の関節を利用して翼を捩じることにより、それぞれの部分に必要な迎角を得ている。図４９を見よ。

・　工程中に、空気力による羽根の撓みと捻れを利用して、風切り羽根の隙間を広げて空気を逃がし、あるいは閉じて流れを変えている。図５３を見よ。

・　鳥を前方から見た翼の展開形状を跳ね上げ工程では上凸にして空気を外に逃がし、打ち下し工程では空気を押し下げて翼上面に巻き込む。図５４を見よ。

・　跳ね上げ工程の速度と打ち下し工程の速度を変えて、上向きと下向きとで発生する空気力を変えている。ただし、必ずしも、常に、打ち下し速度を跳ね上げ速度より速くしているわけではない。

・　鳥は、跳ね上げ用と打ち下し用で別の筋肉を使っているが、それらの筋肉の剛性の違いを利用して、翼の梁としての撓み形状を変えている。図５４、図５５を見よ。

・　軟構造を利用して手や指の曲がりや捻れのタイミングを遅らせて空気力の急変を防止している。

【００９４】

特許文献１の発明では、鳥の持つ巧妙な羽ばたき機構をそのままではないが、やや複雑なままに模擬するために、回転する円筒面の稜線上に複数の要素翼を配置し、それらを、基本的に平行を保ちながら、周期的に遥動を加えて回転させることにより、鳥の羽ばたき運動の打ち下し工程と跳ね上げ工程を近似的に模擬している。

【００９５】

流体力学の翼理論によると、翼に発生する空気力の作用点である風圧中心は翼の前端から翼弦の２５％付近にある。一方、キャンバーの付いた翼では前下げモーメントが発生するが、翼弦の２５％付近にある空力中心をとると、回転モーメントの大きさは迎角が変わっても殆ど変わらなくなる。その他に翼には遠心力と慣性力と慣性モーメントが発生する。回転中心を決めると、要素翼にはこれらに起因して回転モーメントが発生する。そのため、要素翼の回転中心は翼端から２５％の位置とは限らず、設計仕様に応じて最適な位置があると思われる。しかし、要素翼の回転中心を決める設計理論は、まだ開発できていないので、今は、要素翼に発生する空気力によって要素翼の回転中心周りに発生する回転モー

メントは回転翼を回転翼中心軸廻りに回転させる回転モーメントと比べて小さいと考えられるので、無視して、回転中心は翼弦の５０％の位置としておく。

【００９６】

一方、回転翼中心軸には、各要素翼に発生する空気力が回転翼中心軸廻りに発生する回転モーメントの総和として、大きな回転モーメントが発生する。

【００９７】

回転翼中心軸に発生する回転モーメントは飛行中の機体にピッチング回転運動を発生させるので、ピッチング回転翼飛行機の設計において、当面の最も重要な解析課題であった。

【００９８】

解析に先立ち、要素翼の操作方法に関して、次を確認しておく。

・ 太陽歯車軸の回転角を調節することで全要素翼の取付け角γを同時に同量、同方向に増減できる。

・ 偏心-遥動変換機構と遊星歯車を用いて差動させる遥動付加機構によって偏心リングの偏心量ｅを変えることによって、打ち下し工程と跳ね上げ工程で、互いに反対方向に要素翼の遥動角δを増減できる。

・ 回転翼の回転速度を変えることにより、要素翼に入る空気の流入角度を調節できる。

・ 前側の要素翼の後流れによって、後側の要素翼に流入する流れが影響を受ける。この影響は中央静止翼により流れを偏向させることにより調節できる。

【００９９】

以上を踏まえて、特許文献１をベースにして、要素翼とその駆動機構の機構を見直し、構造を簡潔にし、新たに、回転翼の中央部に、前方の要素翼の後流れを偏向させて後方の要素翼に流入させる中央静止翼を設けた。主な設計検討事項は下記の（１）から（７）の通りである。図０１～図２９を用いて説明する。

【０１００】

・ 要素翼単体とその両端の結合剛性を高めた。

要素翼を構造解析上は扁平管のトルクチューブとし、その内側の結合部品である要素翼軸を翼ピニオンに回動不能に勘合し、要素翼を当て、翼ピニオンの内側から通しボルトで貫通させ、エンドケースのメネジで引き付けて要素翼軸系を一体に結合させた構造とした。そのために設計上、以下の事項を配慮して、軽量で高い要素翼剛性と高い結合剛性を持った要素翼ケージ構造を設計した。

【０１０１】

・ トルクチューブの扁平な穴に勘合する扁平な突起部分を要素翼軸の外側端とエンドケースの内側端に形成し、合わせ面の位置決めと回転角度位置の位置決めと回転トルクの伝達を図る。

・ 翼ピニオンの外側端には内歯歯形を形成し、要素翼軸の内側端に形成した外歯歯形と回動不能にスキマ勘合して、回転トルクの伝達と位置決めを図った。

・ 翼ピニオン、要素翼軸、トルクチューブ、エンドケースを全て端面で突き当てて、通しボルトで軸方向に締め切って、要素翼系の一体化を図り、曲げ/捻り剛性を高めた。

・ 要素翼の回転中心の位置の変更が、トルクチューブの長穴の範囲で、要素翼軸とエンドケースを変えるだけで、要素翼を変えずにできるようにした。

・ エンドケースの外側端には、与圧を掛けた２個のベアリングを勘着するハウジングを形成し、回転翼端盤との間で回動自在に高い結合剛性を確保できるようにした。

【０１０２】

・ 要素翼の個数を増やせるようにした。

次の工夫により、偏心-遥動変換機構をコンパクトにし、レイアウトを改善した。その上で、歯車列で駆動された要素翼に連動する追従要素翼を追加することによって要素翼の数を倍増できる設計オプションも用意した。図０１、図０２、図２３～図２５を見よ。

【０１０３】

・ 偏心リングの径を大きくした。

・　ローラーアームとリテーナリングを一体化した。

・　ローラーを１個にして偏心リングの内周面を転導させた。

・　全てのローラーの遊びを偏心リングの中心側から規制するランナーリングを新設した。

【０１０４】

要素翼の本数の増加には次のメリットがある。

a. 要素翼が細長くなり、アスペクト比が大きくなり、翼型の空力性能が向上する。

b. 要素翼の軽量化により、回転数のアップが図れる。

c. 回転翼の脈動周波数を上げられ、回転をスムーズにできる。

d. 回転翼の中央部分に中央静止翼を設置するスペースが確保される。

e. 要素翼表面の空気の通過経路を短くし、通過時間中の迎角変化を小さくできる。

【０１０５】

なお、追従要素翼は、従来の飛行機のフラップの機能を持つようにも設計できるが、その設計スペックは、個別の開発の中でメリットとデメリットを勘案しながら決めてゆかねばならない。

【０１０６】

（３）オイル潤滑を可能にした。

そのために、次のオイル潤滑を必要とする範囲を外部からシールできる回転ギアーケースに包み込んだ。偏心リング割出機構は、そのために新設計した。図０１～図０２、図１２～１６を見よ。

・　太陽歯車から反転歯車までの歯車列

・　ローラーと偏心リングの接触点

・　偏心リング割出機構

【０１０７】

（４）軸受け方式を選定してレイアウトと構造を見直した。

ラジアル方向では、転がり軸受けとスベリ軸受けを使い分けた。スラスト方向（幅方向）では、隣接して相対運動する部品の間に潤滑スペーサーを挟んだ。図０１を見よ。

【０１０８】

（５）　剛性アップとコンパクト化のために部品構成を見直した。図０１を見よ。

【０１０９】

（６）機体のピッチング回転の制御を確実にするために、次の機能を担う中央静止翼を設定した。図０１、図０５、図１９～２１、図２６～図２９を見よ。

・　斜め後下方に流出する前側の要素翼の後流れは、そのまま後側の要素翼に流入させると回転翼に発生する回転モーメントを過大にしてしまうことがあるので、中間で流れを偏向させてその影響を補償する。

・　鳥は推力を分担する手の部分と揚力を分担する腕の部分を適度に捻ってそれぞれに最適な迎角を得ている。回転翼では、この機能を歯車機構により作り出している。即ち、打ち下し工程と跳ね上げ工程で要素翼を機械的に反対方向に運動させ、両工程で適切な迎角を持って流入気流に向かわせる機構としている。しかし、この機構の機械的な動きなので、両工程で最適な迎角になるように調節し、また、状況に応じて制御することはできなかった。それを可能にするために中間で流れを可変に偏向させる機能を追加した。

【０１１０】

（７）　飛行時の機体のピッチング回転に対する静安定性を確保するために、新たな機能を追加した。即ち、従来の飛行機では主翼の空気力を発生する位置が前後方向でほとんど移動しないので、鳥の羽ばたき翼の機能を主翼とプロペラに置き換えられ、発生する機体をピッチング回転させる回転モーメントは水平尾翼のエレベーターの操作で制御できた。

【０１１１】

ピッチング回転翼飛行機も従来の飛行機のプロペラと同じように抗力に打勝つトルクで要素翼を回転させて空気力を発生し、その成分として揚力と推力を得ている。従来の飛行機では駆動トルクの反動は機体をローリング回転させるが、長いスパンの主翼の端のエルロ

ンでバランスを取っている。ピッチング回転翼飛行機では、この駆動トルクの反動は機体をピッチング回転させる。この反動は加速や減速の際に必然的に発生するので、水平に飛行するためには、常に、バランスさせる必要がある。この機能は、従来の飛行機の水平尾翼とエレベーターの機能とは別に備えなければならない。機体の後部に迎角可変の静止翼を、従来の飛行機の水平尾翼とは別に、外側翼として新設した。図２１、図２６、図２９を見よ。

【０１１２】

飛行時のローリング回転に対する静安定性を確保するためには、鳥も従来の飛行機も主翼に上反り角を付けているが、それに倣って、上反り角を機体の重心付近の翼につけた。図２１、図２６、図２９を見よ。

上反り角は、回転翼と下側静止翼のどちらかまたは両方に付ける。下側静止翼には、オプションとして、折畳めるエキステンション（延長静止翼）を付けることもできる。

【０１１３】

要素翼の先端や中央静止翼の先端に別の補助翼をつけるアイデアも種々検討された。重心から遠い位置で流入気流や回転翼の伴流を処理すると効きのよい姿勢制御やドリフティング制御が可能になりそうである。ハチドリやヒバリのような作業用ロボット用の回転翼飛行機を狙う場合には有効と思われるアイデアが続々と出てくる。しかし、この領域まで含めると発明活動が余りに輻輳するので、今の段階では、この領域はもう一つの進化の幹と考えて、具体化の検討は留保した。

【０１１４】

また、全幅を広げ、構造を複雑にしてしまうこの領域のアイデアは、翼のスパンを従来の飛行機と比べて半減できる回転翼飛行機の商品性の特徴を著しく損なうとも判断した。

【０１１５】

飛行時の機体のヨー回転に対する静安定性は、従来の飛行機では、主翼の後退角と垂直尾翼とラダーによって確保されている。回転翼を用いた飛行機では、これに準じて、垂直尾翼とラダーは取り付けた。しかし、回転翼を後退角をつけて取り付けることは、回転翼のヨー回転コントロール特性が解明されるまで採用を留保した。カラスが水平面内でシャープにＵターンする挙動を見ると、平行回転翼には固定翼の性能を補って余りあるヨーイング回転に対する静安定性と操縦性を獲得できる新しい工夫の余地が残されていると予感している。

【０１１６】

近い将来の実用化を展望して、遥動機能を退化させた、シンプルな回転翼の検討に着手した。ハクチョウは、翼の捻り機能を退化させて、タカのような多様な飛行術を放棄して長距離飛行能力と餌を安全に豊富に採れる水上生活能力を獲得した。羽ばたきは緩慢で迎角の変化は、翼の形状や弾性変形や関節の僅かな捻れによって得ているように見える。ハクチョウの羽ばたきでの、翼や羽根の変形と動きを別の方法で模擬できれば、また、短い滑走路の使用が許されれば、ピンポイントで離着陸する機能を退化させ、実用的に大変魅力的な短い滑走路で離着陸できる飛行機が可能となるかもしれない。図２６～図２９を見よ。

【０１１７】

次に、以上のように設計した回転翼を用いて色々な飛行モードで飛行する時にどのような空力性能が得られ、どのような姿勢制御ができるかをラフな計算で定量的に検証してみた。図３０～図４８を用いて説明する。

【０１１８】

この飛行機は、走行風と回転速度のベクトル和で流入する空気を回転翼で受けて空気力を発生し、助走なしで舞い上がることもできる。また、助走が許される場合は走行速度を上げながら回転翼の回転速度も加速できる。回転翼に入るエネルギーは機体の助走運動エネルギーと回転翼の回転運動エネルギーに按分されて蓄積される。実際、鳥の助走の仕方は種によって様々である。

【０１１９】

助走なしで舞い上がる時には、回転翼は次のように操作される。図３２～図３５を見よ。
　　Ａ．回転速度を、離陸回転速度にセットし、負荷に対して駆動力を増す制御をする。
　　Ｂ．取付け角を調節して、全ての要素翼の迎角を大きくし、揚力を大きくする。
　　Ｃ．逶動角を調節して、前後の要素翼の迎角を大きくし、推力を上げる。
　　Ｄ．中央静止翼の切り返し角を調節し、ピッチング回転モーメントを制御する。

【０１２０】
鳥はそれぞれの種によって固有の羽ばたき周波数を持っていて、周波数は大きく変えずに振幅を調節して羽ばたき速度を変えている。それに対し、回転翼では振幅は変えられないが、代わりに回転数を調節して回転速度を変えることができる。図５０～図５２を見よ。

【０１２１】
それぞれの飛行モードでの飛行操作としては色々な手順がとれるが、一例を示す。
着陸地点では、推力を下げ、徐々に迎角を大きくして揚力を維持しながら抗力を上げ、飛行速度を下げて、空中に停止し、その後は、迎角を小さくしながら回転速度を上げて軟着陸する。飛行速度が十分に下がっている場合は、着陸ポイントに降下し、惰走なしで停止できる。飛行速度を残して着陸する場合は、着陸後は制動を掛けながら惰走し停止する。
地上では踏ん張れるので、負の揚力や失速で発生する大きな抗力を発生して急制動を掛けることもできる。

【０１２２】
回転翼にしたために要素翼の揚力によって発生してしまう回転モーメントは中央静止翼によって調節できることが分かった。一方、要素翼の抗力によって発生する回転モーメントは、機体をピッチング回転方向に回転させるが、揚力に起因する回転モーメントと比べて一桁小さい。しかし、飛行のために必須な回転翼駆動トルクであり、水平尾翼の外側に取り付けた外側翼に発生させる揚力でバランスを取らねばならない。図３３～図３８を見よ。

【０１２３】
従来の飛行機は、エンジンでプロペラを駆動して得られた推力と機体の抗力との差し引きで加速力を得ている。回転翼飛行機も翼理論に則って設計されているので、飛行機と同じく、エンジンで回転翼を駆動する回転トルクによって推力を得る。

【０１２４】
従来の飛行機では駆動トルクの反力はローリング回転方向でキャンセルされるが、回転翼ではピッチング方向でキャンセルされねばならない。回転翼の駆動トルク反力は、飛行機の後部の外側翼に発生させる揚力に回転翼中心までの距離を掛けた回転モーメントでキャンセルするように設計した。

【０１２５】
分かり易さのために、揚力により発生する空気力と回転モーメントは、最初、要素翼や補助翼に発生する抗力をゼロとして計算したが、その後、駆動トルクと推力と抗力の関係を定量的に理解するために、要素翼や補助翼に発生する揚力をゼロにして、抗力により発生する空気力と回転モーメントを試算してみた。図３３～図３８を見よ。

【０１２６】
これまでは要素翼の翼型については詳しく論じてきてはいないが、従来の静止翼の翼型の利用の可能性と限界を見ておく必要がある。この問題の存在は要素翼へ流入する気流ベクトルを回転翼と羽ばたき翼と固定翼で比較してみると容易に推定できる。図２２に模示するように、気流の分子（○印で示す）は、１から時間を追って２，３、、、、と順番に要素翼に流入する。更に、要素翼の周期的な逶動が重なると翼面を通過する空気が翼面によって曲げられる。そのため、それぞれの分子が要素翼から抜けるまでに要素翼を取り巻く流束の形が変わる。

【０１２７】
一方、回転翼での常用流速は、０～４０ｍ／ｓ程度に設計される。この速度は３４０ｍ／ｓの音速と比べて１／１０に近い。また、流束の変化も衝撃波を発生するような急変ではな

い。また、飛行速度が回転速度より十分大きく、要素翼の本数が多く、要素翼の翼弦が十分小さくなると、従来の静止翼の翼型が利用できるであろう。
今はまだこのような条件を踏まえた流れの解析と翼型の設計理論ができていない。従って、実務的には、翼型の開発は、設計仕様に従って迎角の変化を設計し、基準翼型を仮設計して試作し、キャンバー、翼厚、回転中心などを、できれば風洞を使って実験しながら、チューニングしてゆくことで開発できるであろう。しかし、開発効率を高めるためには流体力学の専門家の解析とシミュレーションが必須である。ピッチング回転翼のための翼型設計理論の開発は今後の最も重要な設計準備課題として残されている。

【０１２８】

回転翼の回転方向は前上がり方向に回転させても揚力と推力を発生できる。基本方式としてどちらが有利かはまだ判断できていない。回転方向を飛行中に変えることは鳥もやっておらず不自然である。回転方向は、オートローテーション時も含めて同じ方向にしたい。その可能性は、今後、見極めてゆきたい。今の時点では、理想モデルとして、前上がり回転方式を選んでおく。機能の違う水平尾翼と外側翼を分離独立させ、下側静止翼の外側には折れる補助翼をつける。要素翼の弾性効果や形状効果を進化させ、回転翼の遥動機能は退化させる。姿勢角は鳥のように進行方向に向けて飛行するモードとする。ここまで進化させられると、ピッチング回転翼飛行機は従来の小型飛行機と比較し、機能の類似と違いを明らかに主張できるようになるであろう。図２９、図４３～図４８を見よ。

【実施例１】

【０１２９】

平行回転翼の原理については、参考文献１に詳しく説明されている。それを踏まえて、本発明では、アイデアの具体化を図りながら、新たな工夫を織り込んで基礎設計を試みた。まだ中間段階であるが、これまでに得られた知見を纏めた。その概要を、次の項目に従って、図０１～図２９を用いて説明する。

【０１３０】

（１）回転翼１の要素翼６のアスペクト比の増大を狙って、枚数を増やして翼弦を小さくするために、ローラーアーム２１をリテーナリング１４と一体化し、偏心リング２０の径を大きくし、偏心-遥動変換機構２４を再設計した。図０１、図０２、図１０～図１２、図１５、図１６を見よ。

【０１３１】

（２）回転翼１の要素翼６のアスペクト比の増大を狙って、枚数を増やして翼弦を小さくするために、追従要素翼２８をオプションとして用意した。図２３～図２５を見よ。

【０１３２】

（３）回転翼１の回転速度の確保を狙って、複数の要素翼６を回転自在に結合した要素翼ケージ４７の構造を軽量化しながら高剛性にするために、軸受けの選定とその取付け構造、および、要素翼６の基本断面とその結合構造を設計した。図０１、図１２、図１７、図１８、図２７を見よ。

【０１３３】

（４）回転翼１の回転速度の確保を狙って、動力伝導系を成り立たせるために、伝導方式の使い分け方針を仮決めした。図０１、図０２、図０６、図２７を見よ。

【０１３４】

（５）回転翼１の回転速度の確保を狙って、支持系を成り立たせるために、回転部品と支持部品をレイアウトし、転がり軸受けとスベリ軸受けの方式選定方針を決めた。図０１、図２７を見よ。

【０１３５】

（６）回転翼１の回転速度の確保を狙って、歯車とローラーのオイル潤滑を可能にするために、新しい偏心リング割出機構９を設計し、回転ギアーケース４１内に収めながらシールされた軸筒を外から回転して操作できるようにした。図０１、図０２、図１２～図１４を見よ。

【０１３６】

（７）回転翼１に発生する回転モーメントの制御を狙って、前側の要素翼６から流出する後流れを偏向させて後側の要素翼６に流入させるために、新たに、回転翼１の中央付近に中央静止翼５０を新設した。図０１、図０５、図１９～図２１、図２６、図２９を見よ。

【０１３７】

（８）飛行機９０に発生するピッチング回転に対する静安定性の確保を狙って、回転翼では抑えきれないピッチング回転モーメントを制御するために、新たに、水平尾翼６７の側端に外側翼６６をピッチング回転軸廻りに回転角を割出せるように取り付けた。図２１、図２６、図２９、図３３～図３８を見よ。

（９）飛行機９０に発生するローリング回転に対する静安定性の確保を狙って、短いスパンのであることを考慮して、従来の飛行機に倣って回転翼１そのものを上反り角度分傾斜させて取り付けた。また、オプションとして、回転翼１の下方に下側静止翼７０を機体から外側に突き出して取り付けた場合には、この翼にも上反り角を付けるた。図２１、図２６、図２９を見よ。

【０１３８】

（１０）飛行機９０に発生するヨーイング回転に対する静安定性の確保を狙って、従来の飛行機に倣って、垂直尾翼６８を設定し、水平尾翼６４と外側翼６６に後退角をつけた。また、オプションの下側静止翼７０にも後退角をつけた。図２１、図２６、図２９を見よ。

【０１３９】

（１１）回転翼飛行機の現時点での理想モデルの設計。

ツルのような大型の渡り鳥の水平飛行では、翼を構成する羽根自体の弾性の非線形性や非対称形状を利用して、打ち下ろし工程で発生する揚力が跳ね上げ工程で発生する揚力より大きくなる非対称な羽ばたき運動が起されているが、この間には回転モーメントも両工程で相殺されていると推察される。

【０１４０】

機械的な遥動付加を不要にできるピッチング回転翼は非常に魅力的であるので、遊星歯車機構を一つの中間歯車に置き換え偏心-遥動変換機構と偏心リング割出機構を省き、平行回転だけの単純な歯車列とした回転翼飛行機を研究用に設計した。図２６～図２９を見よ。

【０１４１】

以下、これらの新たに織り込まれた設計項目に従って説明する。

（１）要素翼１の枚数を増すための偏心-遥動変換機構２４の再設計について、図０１～図０５、図１０～図１２、図１５、図１６を用いて説明する。

【０１４２】

本発明の回転翼１では、要素翼６の傾斜角αを周期的に変動させることにより、打ち下し工程と跳ね上げ工程を同時に発生している。そして、飛行中の飛行モードの切り替えに応じて、揚力と推力と回転モーメントを、より的確に制御するために、要素翼６のみを用いた特許文献１の回転翼に中央静止翼５０を組み込んだ。

【０１４３】

回転翼１は、回転ユニット２と支持ユニット３とから構成されている。回転ユニット２は支持ユニット３に回転自在に取り付けられている。支持ユニット３はボディー１０に取付けられる。回転ユニット２は、ボディー１０に搭載された動力源から駆動される。

【０１４４】

回転ユニット２には、回転翼盤４と回転翼端盤５との間の外周に近い円筒面上の稜線を回転軸とする複数の要素翼６が渡され、それぞれの要素翼軸７を介して翼ピニオン１８に結合されている。回転翼盤４の内部には、それぞれの要素翼６を周期的な遥動を付加しながら平行回転させる歯車列８と、遥動角を付加する偏心-遥動変換機構２４と、偏心量ｅと偏心角ηを割出して伝達するための偏心リング割出機構９が組み込まれている。

【０１４５】

回転翼盤４には、図１、図６に示すように、支持ユニット３に連結されて静止している一

つの太陽歯車１１から放射状に展開する要素翼６毎に歯車列８が組み込まれており、これによって平行回転に遥動回転を加えることができる。この機構の原理については、特許文献１に詳しく説明されている。

【０１４６】

各歯車列８の中では、太陽歯車１１に従動歯車１２が噛み合わされている。従動歯車１２には同軸に内歯歯車１３が形成されていて、その内歯歯車１３には、互いにリテーナリング１４で回動自在に連結された複数の遊星歯車１５が噛み合わされており、それらの遊星歯車１５は、従動歯車１２と同軸で遊動する反転歯車１６に噛み合わされている。反転歯車１６には同軸にオフセットさせて反転ピニオン１７が結合されており、その反転ピニオン１７から、要素翼６の一部である要素翼軸７が結合される翼ピニオン１８に、タイミングベルトＡ４２～中間ピニオンＡ４４～中間ピニオンＢ４５～タイミングベルトＢ４３からなるタイミングベルト伝導を介して回転が伝えられる。図０６を見よ。

【０１４７】

遊星歯車１５を回動自在に嵌合しているリテーナリング１４が遥動しない時には、各要素翼６が回転翼盤４に乗って回転する回転角は、それぞれの歯車列８の中で反転され、同じ回転角だけ戻される。従って、各歯車列８は、基本的に、各要素翼６を初期に設定された取付け角γを保ったまま平行回転させる機構となっている。

【０１４８】

回転翼盤４が回転すると、従動歯車１２が、支持ユニット３に連結されて静止している太陽歯車１１を駆って、回転翼盤４上で回転する。従動歯車１２と同軸の内歯歯車１３は従動歯車１２と同じ角度を回転翼盤４上で回転する。その内歯歯車１３に噛み合っている遊星歯車１５は、回転翼盤４上で止まっているリテーナリング１４に遊星歯車ジョイントピン１９で回動自在に嵌合されているので、内歯歯車１３を駆って反転歯車１６を反転させる。

【０１４９】

遊星歯車１５を回動自在に嵌合しているリテーナリング１４が遥動する時には、リテーナリング１４は、回転翼盤４の回転位置に応じて内歯歯車１３の回転と反転歯車１６の間で伝達される回転角を加減（差動）し、周期的に要素翼６の回転角度θを進め、または、遅らせる。反転歯車１６の回転は、同軸にオフセットして固定されている反転ピニオン１７に伝えられ、そこから更に、タイミングベルト伝導を介して、翼ピニオン１８に伝えられる。図６～図９を見よ。

【０１５０】

次に、この発明で大幅にコンパクト化を図った、平行回転する要素翼６に周期的に遥動回転を付加する偏心-遥動変換機構２４について説明する。この機構は、打ち下し工程と跳ね上げ工程とで要素翼６の傾斜角αを反対方向に遥動させるための機構の一部であり、偏心リング割出機構９で割出される偏心量ｅと偏心角度ηを、リテーナリング１４の遥動角ζに変換する。図１０～図１１を見よ。

【０１５１】

遊星歯車１５を回動自在に結合しているリテーナリング１４から突出されたアーム部分にはローラーアーム２１が形成されており、その先端部には１個のローラー２３がジョイントピン２２で回動自在に結合されている。

【０１５２】

ローラー２３は偏心リング２０の内面を転動し、偏心リング２０の中心の周りに回転するので、偏心量ｅと偏心角度ηは、４節リンクの動きによってリテーナリング１４の遥動回転に変換される。

【０１５３】

偏心量ｅと偏心角度ηは、別途、回転ユニット２に内包される偏心リング割出機構９によって割出された偏心リング２０の位置から検出される。

【０１５４】

リテーナリング１４の中心とそのアーム先端部のジョイントピン２２の中心とを結んだ線

と、偏心リング２０の中心とジョイントピン２２の中心とを結んだ線は、ほぼ、直角になるように設計される。そのため、偏心リング２０の内周面を転動するローラー２３の動きは、リテーナリング１４のアーム先端部のジョイントピン２２の中心とリテーナリング１４の回転中心の間の距離をアーム半径とした、リテーナリング１４の遥動回転に変換される。

【０１５５】

偏心量ｅと偏心角度ηが与えられるとリテーナリング１４は、与えられた偏心量ｅと偏心角度ηによって変形する４節リンクによって変換された遥動角ζで、遊星歯車１５の中心を結んだ円周上を周期的に遥動する。この遥動は内歯歯車１３に対して遊星歯車１５を遥動回転させ、遊星歯車１５に噛み合った反転歯車１６を遥動回転させ、反転ピニオン１７、タイミングベルト伝導を介して翼ピニオン１８に伝えられて、各要素翼６を遥動回転させる。

【０１５６】

レイアウト上、偏心リング２０の径は大きめに設定した。

【０１５７】

偏心-遥動変換機構２４は、図０１、図０２、図０３、図１５、図１６に示すように、一つの偏心リング２０の形状を、複数のローラーアーム２１が、同一平面上で、同時に追跡する機構としている。

【０１５８】

偏心リング２０の内周面を一つのローラー２３で追跡する時、ローラー２３はローラーアーム２１の遠心力によって内周面に押し付けられるが、偏心運動中の駆動反力、駆動抵抗、加速度や振動によって離れる可能性がある。そこで、全てのローラー２３に偏心リング２０の中心の側から接して自由に回転するランナーリング２７を設定し、全てのローラー２３遊びを同時に相互に規制させた。

【０１５９】

各ローラー２３とランナーリング２７との間には原理的に周期的なスベリが発生するが、オイル潤滑されるので適切なスベリ隙間を与えれば振動を抑えて焼付かずに運転できる。

【０１６０】

この新方式によって、偏心-遥動変換機構２４をコンパクトにし、ローラー２３のオフセット（ローラー２３と遊星歯車１５の間の軸方向の距離）も小さくできた。

【０１６１】

（２）追従要素翼２８のオプションについて、その一例である、図２３～図２５を用いて説明する。

【０１６２】

要素翼６に補助的に追従要素翼２８を連動させることによって、近似的に要素翼数を倍増できる。図２３は、歯車列８で駆動される６枚の要素翼６に６枚の追従要素翼２８をタイミングベルト２９で連結させて１２枚としたレイアウトを示す。図２４は、追従要素翼２８を小さめにし、タイミングベルトの噛み合いをずらして取付け角を変えたレイアウトを示す。図２５は、更に、追従要素翼２８の翼型を変えたレイアウトを示す。連結方法は、チェーンでも歯車でも構わない。また、連結方向は、追従する方向でも先行する方向でも構わない。２重に連結させれば３倍増も可能である。

【０１６３】

（３）要素翼６の軸受けの選定とその取付け構造、および、要素翼６の基本断面とその結合構造について説明する。重負荷用の転がり軸受方式と軽負荷用の滑り軸受方式の２方式について設計した。両方式の設計例を図０１、図０２、図１７、図１８、図２７に示す。

【０１６４】

転がり軸受け方式では、図０１に示すように、回転翼盤４の側と回転翼端盤５の側の双方に、２個ずつのアンギュラー玉軸受を与圧を掛けて装着し、回転は許しながら、高い倒れ剛性を持たせた。

【０１６５】

即ち、回転翼盤４の側については、２個の内側用アンギュラー玉軸受３０の内輪で翼ピニオン１８を挟み、台形バネで両外輪に与圧を掛けて回転翼盤４の穴に装着した。要素翼６に接合されている要素翼軸７は翼ピニオン１８に嵌めて通しボルト３２で引き付けて締結した。

【０１６６】

回転翼端盤５の側については、２個の外側用アンギュラー玉軸受３１の内輪を、シムを挟んでツバ付ボス３５に嵌め、リングナット３６で固定し、外輪を薄めのシムを挟んでエンドケース３７に挿入し、エンドリング３８を端面に当てて複数のボルトで締め切った。与圧は内外輪に挟んだシムの厚さの差によって掛けられる。回転翼端盤５はツバ付ボス３５の中心のメネジにボルト３３で締結した。

【０１６７】

要素翼６の基本断面としては、要素翼６の軸部分にトルクチューブ３９を形成し、その回転翼端盤５の側はエンドケース３７に突き当てた。トルクチューブ３９の周囲に翼型を形成する方法については、種々考えられるが、今の段階では、トルクチューブ３９を心金にした樹脂の射出成形を想定しておく。要素翼軸７とエンドケース３７の採用により、軸受で決まる要素翼６の回転中心とトルクチューブ３９の位置をずらすことが容易となった。

【０１６８】

外側端に内歯歯形を形成している翼ピニオン１８の中央の穴に、内側から挿入した通しボルト３２を、内側端に翼ピニオン１８の内歯歯形と回動不能にスキマ勘合する外歯歯形を形成しており、外側端にトルクチューブ３９に勘合する扁平な突起部分を持つ要素翼軸７の穴に貫通させせた。次に、要素翼６の心金を形成するトルクチューブ３９に貫通させた。更に、内側端にトルクチューブ３９に勘合する扁平な突起部分を持ち、外側端にベアリング３１の取り付け構造を形成したエンドケース３７の内側端の中央に形成されたメネジ部に締結して一体化する結合構造とした。

【０１６９】

この構造により要素翼６単体の曲げ/捻り剛性が確保された。両端の結合部品である要素翼軸７とエンドケース３７に形成された扁平な突起部分のトルクチューブ３９への挿入と、要素翼軸７の外歯歯形を翼ピニオン１８の内歯歯形に回動不能にスキマ勘合することにより回転方向の位置合わせと廻り止めが図れた。翼ピニオン１８の内側から挿入され要素翼軸７と要素翼６のトルクチューブを挟んで貫通した通しボルト３２を、エンドケース３７のメネジ部で引き付けることにより、要素翼系の一体化を図り、曲げ/捻り剛性を高めた。エンドケース３７の外側のベアリングケースには与圧を掛けた２個のベアリング３１を装着し、回転翼端盤５との間で回動自在に高い結合剛性を確保した。このような手段により、軽量で高い要素翼剛性と高い結合剛性を持った要素翼ケージ５６が得られ、高い回転速度を有する回転翼１の構造が設計できた。

【０１７０】

滑り軸受け方式では、図２７に示すように、回転翼盤Ｘ７２の側と回転翼端盤Ｘ８５の側の双方共、それぞれにツバ付ブッシュＡ７５、ツバ付ブッシュＢ７６を２個ずつ、微小な滑りスキを持たせて挿入し、回転は許しながら、撓やかな立体ラーメンの篭を形成して倒れを規制する構造とした。

【０１７１】

即ち、回転翼盤Ｘ７２の側については、２個のツバ付ブッシュＡ７５で従動歯車Ｘ８４を挟み、それらを回転翼盤Ｘ７２の穴に回動自在に勘着した。要素翼Ｘ８６に接合されたツバ付ボスＡ７９は従動歯車Ｘ８４に嵌めて通しボルトＡ７３によりエンドケース７７とトルクチューブ８９を介して引き付けて止めた。図２７を見よ。

【０１７２】

回転翼端盤Ｘ８５の側については、２個のツバ付ブッシュＢ７６を回転翼端盤Ｘ８５のフランジ部を挟んでボルトＢ７４に嵌め、リングナット７８でスキを持たせて挟んで締め切った。２個のツバ付ブッシュＢ７６の外周面は、スキを持たせてエンドリング８８で挟んだ。エンドリング８８はエンドケース７７の外側のフランジ部に切られたメネジにねじ込

み固定した。

【０１７３】

要素翼Ｘ８６の基本断面としては、要素翼Ｘ８６の軸部分にトルクチューブ８９を形成し、それを心金にして射出成形して肉部と外皮を形成した。トルクチューブ８９の回転翼盤Ｘ７２の側はツバ付ボスＡ７９に突き当てた。ツバ付ボスＡ７９とエンドケース７７の採用により、軸受で決まる要素翼Ｘ８６の回転中心とトルクチューブ８９の位置をずらすことが容易となった。

【０１７４】

（４）トルク伝導方式の使い分け方針について、図０１、図０２、図０６、図２７を用いて説明する。

歯車列８の中で太陽歯車１１から反転歯車１６までは歯車を用い、オイル潤滑可能な回転ギアーケース４１の中に収める。反転歯車１６から同軸に突き出されて取り付けられた反転ピニオン１７から要素翼ピニオン１８まではタイミングベルトを用いる。アイドラーは無しにしているが、その実用性の確立は将来の技術的な課題である。シャフト駆動とすればアイドラーは不用となるが、その代替案への採用は現段階では見合わせておく。

【０１７５】

（５）転がり軸受けとスベリ軸受けの方式選定について、図０１、図２７を用いて説明する。

【０１７６】

本回転翼は、エンジンからの駆動力を回転力で空気に伝達する機械なので、軸受け方式は主としてラジアル荷重条件と潤滑条件と結合剛性条件を考慮して選定する。伝導系の末端から見ていくと、要素翼６の両端は、高速グリース潤滑と高い結合剛性が必要となるので、それぞれに与圧を掛けた２個ずつのアンギュラー玉軸受で支持する。中間ピニオンＡ４４と同軸の中間ピニオンＢ４５は、高速グリース潤滑と支持剛性が必要となるので、皿バネで与圧を掛けて、両端から１個ずつのアンギュラー玉軸受で挟んで支持する。反転ピニオン１７も、高速グリース潤滑と支持剛性が必要となるので、皿バネで与圧を掛けて、両端から１個ずつのアンギュラー玉軸受で挟んで支持する。

【０１７７】

反転歯車１６から従動歯車１２までは、オイル潤滑可能な回転ギアーケース４１の中で相互の歯車の噛み合いによって支持される。回転翼盤４を支持する取り付け台４６の軸受は、高速回転する大荷重を受けるので、強制オイル潤滑されるメタルブッシュＡ５１とする。中央静止翼５０の支持軸５３は、高速回転する回転翼盤４の中央の穴にメタルブッシュＢ５４を介して支持されて、中央静止翼５０に発生する空気力を担って静止状態を保つので、強制オイル潤滑とする。支持軸５３は直径が大きくないので軸受のスベリ速度が低いので、レイアウト検討と詳細設計を進めればグリース潤滑の転がり軸受とするスペースも捻出できそうである。その他、設定角度調整のために低速で廻される太陽歯車１１や偏心リング割出機構９の中の２つの割出用軸筒部には薄い自己潤滑ブッシュを嵌める。オイルシールやスペーサーについては、今の段階では、必要な部品と部位の想定にとどめる。

【０１７８】

（６）新設計の偏心リング割出機構について、図０１、図０２、図１２～図１４を用いて説明する。

【０１７９】

偏心リング割出機構９は、内側偏心ディスク６０の外側に外側偏心ディスク６１を転がり軸受を介して回動自在に勘着した構造とした。外側偏心ディスク６１には内歯歯車とラジアル軸受面が偏心された軸上に形成されている。内歯歯車は、内側偏心ディスク６０に偏心して勘着された中継歯車６２と噛み合っており、中継歯車６２は外側偏心ディスク６１を駆動する駆動歯車６３の外歯歯車と噛み合っており、駆動歯車６３は太陽歯車１１の軸筒の外周に回動自在に勘着されている。内側偏心ディスク６０は駆動歯車６３の軸筒の外周に回動自在に勘着されている。

【０１８０】

内側偏心ディスク６０と外側偏心ディスク６１は共に回転ギアーケース４１の中に収納されているが、それぞれの軸筒部は機体内側に回転ギアーケース４１の穴との隙間でシールされて突き出されている。それらの突出部分に回転変位を与えることにより、偏心量ｅと偏心角度ηが自在に割出される。

【０１８１】

（７）中央静止翼について、図０１、図０５、図１９、図２０、を用いて説明する。

【０１８２】

中央静止翼５０は、中央静止翼支持軸５３を回転翼盤４の中央の穴に挿入され、回転翼盤４によってメタルブッシュＢ５４を介して回動自在に支持されているが、支持ユニット３に係止されているので回転円盤４の回転とは無関係に静止している。中央静止翼支持軸５３の機体外側の端部には、機体中央側の円盤５８と機体外側の惰円盤５９の間に複数の中央静止翼フィン５７を挟んで一体化した静止翼ケージ５６が結合されている。

【０１８３】

従って、中央静止翼５０は、支持ユニット３との間で角度位置を調節することにより、回転翼盤４の回転とは無関係に静止しており、回転角度位置を変えられる。中央静止翼５０を用いると、回転翼盤４の前側の要素翼６から流出する後流れを偏向させて後側の要素翼６に流入させられる。

【０１８４】

ここで、中央静止翼５０の作用について、図３０～図４２、図４７、図４８を用いて説明しておく。ここで、解析と説明の容易のために、回転翼１の要素翼６の枚数は上下前後の４枚とし、翼型はキャンバーなしの対象翼型と仮定しておく。

【０１８５】

回転翼中心軸４８には、要素翼６に発生する空気力の上向き成分の総和として回転翼の揚力が、後向き成分の総和として回転翼の抗力（総和が負の場合は推力）が、要素翼６に発生する空気力に起因する回転モーメントの総和として回転翼６の回転モーメントが発生する。

【０１８６】

回転翼の揚力は、主として取付け角γを変えることにより増減できる。即ち、前下がりに回転させる回転翼では、上死点の要素翼は、流入風速と回転速度のベクトル和の流入速度ベクトルの気流を受ける。揚力は流入速度の２乗に比例するので、上死点付近では、最も大きな揚力が発生する。上死点の要素翼の取付け角γを負の方向に回転してやると、跳ね上げ工程の要素翼も含めて、全ての要素翼の取付け角γが回転した分だけ大きくなる。

【０１８７】

回転翼の推力（抗力）は、空気の流入速度と回転速度を一定にした場合、遥動角を変えることにより増減できる。空気力は迎角が２０°付近で最大となりその後は失速して急に減少するので、空気の流入速度が上がっていない始動時には遥動角を大きくして、前側の要素翼の迎角を２０°付近に保ち、空気力を発生する。その後は空気の流入速度と回転速度の上り方を見て、迎角を２０°付近に保ちながら遥動角を戻していく。

【０１８８】

回転翼の回転モーメントは、図３２に模式的に示すように、回転翼を前方から後方に貫流する気流を中央静止翼によって切り返すことで調節できる。ここでは、解析と説明の容易のために、翼の抗力係数は揚力係数と比べて十分小さく無視できるとする。この条件では、上下の要素翼では、発生する空気力は揚力のみとなり、要素翼を回転させる成分がなくなるので、回転モーメントの検討では無視できる。

【０１８９】

中央静止翼がない場合は、前方の要素翼の後流れは斜め下後方に向いその角度で後方の要素翼に流入すると考える。（実際には迎角の１００％が後流れの傾斜角になるのではなく、５０％程度のようであるが、今は、基本的な現象の解釈が目的なので、大胆に、１００％流れ下ると仮定しておく。）このため後方の要素翼の迎角が小さくなり、前側の要素翼に発生する空気力の揚力成分が後側の要素翼の要素翼に発生する空気力の揚力成分より大

きくなる。この前後のアンバランスにより、回転翼の回転中心周りに、要素翼の回転半径をモーメントアームとする大きな回転モーメントが発生する。

【０１９０】

中央静止翼がある場合は、前方の要素翼の後流れは斜め下後方に向かって流出するが、中央静止翼によって適度に切り返して偏向させて水平方向に戻して後方の要素翼に流入させることができる。このときは、後方の要素翼の迎角は前方の要素翼の迎角と等しくなり、前側の要素翼に発生する空気力の揚力成分が後側の要素翼の要素翼に発生する空気力の揚力成分と等しくなる。そのため、前後のアンバランスが無くなり、回転翼の回転中心周りには回転モーメントが発生しなくなる。

【０１９１】

中央静止翼によって過度に切り返された場合は、空気は斜め上後方に偏向され後方の要素翼に流入する。このため後方の要素翼の迎角は前方の要素翼の迎角より大きくなり、前側の要素翼に発生する空気力の揚力成分が後側の要素翼の要素翼に発生する空気力の揚力成分より小さくなる。そのため、前後のバランスが逆転し、回転翼の回転中心周りに前下げ方向の回転モーメントが発生する。

【０１９２】

ただし、揚力、抗力、回転モーメントはいずれも要素翼に発生する空気力に起因しており、空気力が要素翼の回転速度と流入速度のベクトル和の２乗に比例するのでこれらの３成分の大きさは、回転速度を変えると、相互に関連しながら複雑に変化する。

【０１９３】

（８）外側翼について図２１、図２６、図２９、図３３～図３８を用いて説明する。

【０１９４】

ピッチング回転翼１を用いた飛行機では飛行中に回転翼１に回転モーメントが発生する。要素翼６に発生する揚力に起因する回転モーメントは中央静止翼５０を制御することによって小さくできるが、要素翼６に発生する抗力によって発生する回転モーメントは、飛行機９０を推進する時の駆動トルクの反力であるから、発生は避けられず、別途、バランスを取らねばならない。この機能を担う機構として、水平尾翼６７の外側に外側翼６６を設け、ピッチング回転方向の傾斜角を調節して揚力を制御することによりバランスを取る方法を採用した。この機能を、別途、設けることにより、従来の飛行機に準じた機構で水平尾翼６７とエレベーター６５により、飛行状態に起因するピッチング回転に対する静安定性を確保することが可能になる。

【０１９５】

設計仕様によっては、外側翼６６は、元々別の機能でもあるので、水平尾翼６７とは別に、最適な位置を選んで独立して設けることも必要になる。

【０１９６】

（９）上反り角のつけ方について、図２１、図２６、図２９を用いて説明する。

飛行機９０のローリング回転に対する静安定性を確保する機構としては、従来の飛行機に準じて、回転翼１を、機体外側を上げる方向に傾斜させて取り付けて上反り角を確保する設計とした。また、回転翼１の下方に下側静止翼７０を付ける場合には、この翼にも上反り角を付ける。

【０１９７】

（１０）ヨーイング回転に対する静安定性について、図２１、図２６、図２９を用いて説明する。

【０１９８】

飛行機９０のヨー回転に対する安定化機構としては、従来の飛行機に準じて、垂直尾翼６８とラダー６９を設定した。主翼の後退翼については、回転翼１のヨー回転コントロール特性が解明されるまで採用を留保した。ただし、回転翼１の下方に下側静止翼７０を付ける場合には、この翼には後退角も付ける。

【０１９９】

（１１）回転翼飛行機の現時点での理想モデルである、遊星歯車を省いた簡易型の回転翼

Ｘ８０を用いた飛行機９０について、図２６～図２９を用いて説明する。

【０２００】

遊星歯車を利用して周期的に遥動を加えることを止め、太陽歯車８２と反転歯車８３と従動歯車８４の単純な平行回転歯車列８１とする簡易型の回転翼８０を設計した。太陽歯車と従動歯車８４の歯数を同じにすれば、反転歯車８３の歯数とは無関係に従動歯車は１回転中に１回転戻され平行回転する。偏心リング割出機構９も不要になるので構造は大幅に簡略化される。

【０２０１】

ただし、この様な飛行機は、特殊で、翼を広げ過ぎて機動的な飛行ができなくなったアホウドリに当たると見ている。しかし、その難点を補う方法が見つかれば、駆動機構は単純に越したことはなく、応用範囲も広がろう。確かに殆ど翼を捻らずに飛んでいる鳥の飛行状態も多々見られるので、今の段階では研究対象からは外せない。

【０２０２】

次に、本発明の機構を用いて作り出せる飛行モードと、それぞれのモードにおける回転翼の作動について原理的に説明する。

【０２０３】

飛行機は原理的には使われる飛行モードの全てで安定性と操縦性が成り立つように設計されねばならない。そのためには、飛行中の運動を飛行モードに分解し、それぞれの飛行モードで必要な空気力と回転モーメントを発生し、それらを制御できるように設計されなければならない。しかし、鳥類は同じ飛行機構を持ちながら種類により様々に飛行モードを選んでいる。そこで、今は、基本的に必要な機構を見極める段階なので、基本的な飛行モードを仮定し、それらの飛行モードでの基本的な操作と作動について解析し、本発明の機構の有効性を確認した。図３０～図３８、図４７、図４８を用いて説明する。

【０２０４】

直線飛行に限定すると、飛行プロセスは、離陸準備、離陸、加速（上昇）、水平、滑空、減速（降下）、着陸、停止に分けられる。助走や堕走をせずに静かに水平に舞い上がるアオサギの飛行プロセスを手本に、車両姿勢は常に水平と仮定し、基本的な飛行モードを、次の４つに整理した。従って、水面で助走や制動をするハクチョウの飛行モードは、応用的な飛行モードと考えて説明を割愛する。

【０２０５】

（ａ）地上加/減速モード（離陸準備と停止）

（ｂ）舞い上がり/舞い降りモード（離陸と着陸）

（ｃ）空中加/減速モード（加速と減速）

（ｄ）滑空モード

【０２０６】

これらの４つのモードについて、以下に説明をする。

【０２０７】

（ａ）地上加/減速モードの作動について、図３３～図３５を用いて原理的に説明する。地上では機体が停止しているので、起動時の空気の流入速度はゼロであるが、回転翼の運転によって流入気流は徐々に加速され、舞い上がりに必要な回転速度と流入速度が得られ、駆動系に回転エネルギーが蓄えられる。起動時には、遥動角を最大にして回転翼を回転させ、前方から空気を吸い込み後方に送り出し、その後、遥動角を徐々に戻しながら回転速度を上げ、回転翼を貫流する空気流を加速し、舞い上がりに必要な気流速度と回転速度を確保する。この間、機体は地面に支えられており、踏ん張りが効くので、その範囲内で、大きな回転モーメントが発生しても耐えられる。

【０２０８】

この間、中央静止翼は後方の要素翼が大きめの負の迎角を取り、背面で空気を送り出すように調節される。即ち、前方の要素翼の斜め後下方向の後流れをそのまま、または、更に、下方に偏向させて後方の要素翼に流入させる。

【０２０９】

舞い上がりに必要な気流速度と回転速度が得られた状態で、負荷が増大して回転速度が低下した時に駆動トルクを増大して元の速度に戻すフィードバック制御を掛ける。気流速度を低下させないように監視しながら、遥動角を戻して要素翼の迎角を下げて必要な迎角増大マージンを確保し、舞い上がり待機状態とする。

【０２１０】

舞い降り後は、制動から停止までの間、流入気流の低下に伴う大きな回転モーメントが発生しても、地面に踏ん張って耐えられるので、舞い上がり前と逆の動作で遥動角と回転速度を徐々に戻して停止する。

【０２１１】

ここで、舞い上がり前に、地上で回転翼を前から後へ貫通する気流を作り出す過程について、図３３～図３８の試算を参考にして定性的に推定しておく。これに似た課程はヘリコプターがローターを起動して吹き下し流れを発生するときにも起こされている。

【０２１２】

取付け角をゼロにし、揺動角を８０°にして、低回転速度で前下げ方向で始動回転すると、下死点の要素翼は後方から風を受けるので抗力は前向きに発生するが、迎角が小さいので小さい。上死点の要素翼は前方から風を受け、抗力は後向に発生するが、これも小さい。前方の要素翼は下から風を受けて空気力を発生するが、その上向き成分は小さいが、前向き成分は大きい。後側の要素翼は上から風を受けて空気力を発生するが、その下向き成分は小さいが、前向き成分は迎角を持った要素翼の揚力になるので大きい。即ち、このような条件では、上下と前後の要素翼によって生ずる、回転翼を前上がりに回転させる回転モーメントは小さい。揚力も小さい。しかし、前向きの空気力は大きい。その反力で機体は前方に押されるが、駐機ブレーキを掛けて踏ん張れる範囲であれば前進はしない。その反動で、回転翼は前方から空気を吸い込み後方に押し出す。

【０２１３】

揺動角を８０°にしたまま同じ回転速度で回転を続行すると、上死点と下死点の要素翼には水平方向に僅かな抗力しか発生しない。後方の要素翼は前方の要素翼の起した後流れを受けて空気力を発生するが、流入角が揺動角に等しくなると迎角がゼロになるので空気力の発生はなくなる。その状態になるまでは回転翼を前後に通過する空気の流速は上がり続ける。即ち、この間では、上下と前後の要素翼によって、回転翼を前下げ回転させる回転モーメントと揚力と抗力が過渡的に生ずるが、それらは、大きくはなっていかない。前向きの空気力によって機体は前方に押されるが、回転翼の前方から後方に押し出される空気の流速は、更に加速されて一定値に落ち着く。

【０２１４】

続いて、揺動角を７０°にして同じ回転速度で回転すると、同じ作用が繰り返されて、回転翼の前方から吸い込まれ後方に押し出される空気の流速は、更に加速されて一定値に落ち着く。

【０２１５】

その後も遥動角を段階的に小さくしていくと前翼と後翼の迎角が小さくなり、流れをそれ以上加速できなくなる。この時の回転翼は揚力型回転ファンとでも言うべき作用で、効率よく、空気を前方から吸い込み後方に押し出している。

【０２１６】

（ｂ）舞い上がり/舞い降りモードの作動について、図３３～図３８を用いて原理的に説明する。

【０２１７】

舞い上がりには機体重量を支え上昇させる揚力を発生する必要がある。また、空中ではピッチング回転に対する踏ん張りが効かないので、回転翼に発生する回転モーメントは水平尾翼の側端に取り付けた外側翼の調節で制御できる範囲に押さえなければならない。従って、舞い上がりの瞬間には複雑で機敏でデリケートなモード切換え操作が必要となる。

【０２１８】

舞い上がり待機状態から取付け角を上げて要素翼の迎角を大きくして、回転翼に大きな揚

力を発生し、機体を舞い上がらせる。回転速度は、所定の舞い上がり待機速度を基準に調節して、上昇加速度によって変える。

【０２１９】

この時、中央静止翼は前側の要素翼に発生する空気力と前後対称な空気力を後方の要素翼に発生させるように、大きな正の迎角を取れるように調節する。即ち、前方の要素翼の後流れを切り返して上向きに偏向させて後方の要素翼に流入させる。

【０２２０】

前後の要素翼に発生する推力は互いに引き合うことになるが、垂直に上昇させるためにはそれらのバランスをとることが必要になる。このバランスは、遥動角と中央静止翼の切り替えし角を同時に変えることで調節できる。

【０２２１】

後側の要素翼から流出した空気は拡散し、減速しながら、水平尾翼の側端に付けた外側翼に流入するので、その傾斜角の調節によって、回転翼に発生する回転モーメントに起因する機体のピッチング回転が抑制される。

【０２２２】

上昇後、上昇と前後移動とピッチング回転の３つの速度が全て０になるよう制御することにより空中停止（ホバリング）が可能となる。

【０２２３】

減速飛行後は、空中停止状態に戻すと、舞い上がりと逆の操作で舞い降りることができる。

【０２２４】

（ｃ）空中加/減速モードの作動について、図３３～図３８を用いて原理的に説明する。

【０２２５】

空中での加速には揚力を発生して飛行機を空中に支えながら、前向きに推力を発生する必要がある。また、空中ではピッチング回転に対する踏ん張りが効かないので、機体に発生する回転モーメントは水平尾翼とその側端に付けた外側翼の調節で制御できる範囲に押さえなければならない。しかし、飛行機は既に空中に舞い上がっているので、空中加速モードへの移行は、比較的スムーズに行える。

【０２２６】

飛行機の上昇は、空中停止状態を基準にして、取付け角リードで回転速度、遥動角、中央静止翼の切り返し角と外側翼の傾斜角を互いに関連付けながら調節して揚力を増大することにより可能となる。

【０２２７】

飛行機を前進させるには、前後の要素翼に発生する推力のバランスを崩して、前側の要素翼の推力を後側の要素翼の反対方向の推力より大きくすることが必要になる。または、後側の要素翼の推力をゼロまたは前向きの推力にすることも、回転モーメントを過大にしない範囲であればできる。これは、遥動角リードで、中央静止翼の切り返し角、回転速度、遥動角、取付け角と外側翼の傾斜角を互いに関連付けながら調節することにより可能となる。

【０２２８】

この時、要素翼の遥動角は大きめにし、前側の要素翼に発生する空気力を大きくし、推力成分を増大させる。また、中央静止翼は、前側の要素翼の後流を後方の要素翼に迎角がゼロまたは少しマイナスで流入するように調節し、推力のバランスを変えてやる。面白いことに、この時、中央静止翼自身にも前向きに推力が発生する。中央静止翼を回転翼の中心に対して前方に取り付けると、切り返し角を付けた時に前下げ方向の回転モーメントが発生する。この回転モーメントは、回転翼に発生する回転モーメントを相殺する方向であり、利用できる。

【０２２９】

ただし、推力は、飛行機に発生するピッチング回転モーメントを過大にしない範囲に制御されねばならない。後側の要素翼から流出した空気は拡散し、減速しながら水平尾翼の側

端に付けた外側翼に流入するので、そこに発生する揚力を調節することによって、飛行機の駆動に伴って発生するピッチング回転は抑制される。

【０２３０】
以上により、上昇、前後移動、ピッチング回転の３つの速度を制御しながら空中で加速できる。

【０２３１】
空中での減速は、上記と逆の動作で制御できる。回転速度を落としてゆくと、推力と揚力が同時に下がってくるが、遥動角を調節して迎角をとり戻して降下速度を調節しながら減速降下できる。または、回転速度を維持または上げながら、迎角を小さくして揚力と抗力を同時に下げて、飛行速度と高度を下げて減速降下することもできる。

【０２３２】
目標とする飛行速度と高度が得られたら、推力と揚力を水平飛行の維持に必要なレベルにまで下げるように回転速度と遥動角を調節して巡航飛行に移る。翼面荷重を、翼型の性能設計値として無理のない、１００ｋｇ－ｗ／m^2と仮定すると、１m^2の翼面積の要素翼を4枚持った回転翼を左右に搭載した回転翼飛行機は、８００ｋｇ－ｗ程度の揚力を発生できる。

【０２３３】
（ｄ）滑空モードの作動について、図３５、図３８を用いて原理的に説明する。

【０２３４】
滑空中の回転翼の回転速度は、停止からフリー回転の間で、制動により回転速度を変えられる。操作系の電源が生きていれば、回生ブレーキ（ブレーキ発電）を掛けて、回転翼の迎角の制御や機体の姿勢の制御も可能である。回転翼の回転を止めた状態での飛行は、原理的に、複葉飛行機の滑空と同じである。

【０２３５】
実際に、揚力の大きさ、揚力の作用点、飛行機の重心、水平尾翼の位置、水平尾翼の容量などを調整すると、従来のグライダーに準じた回転翼を固定した滑空状態が設計できる。

【０２３６】
従来のグライダーでは、主翼で揚力を発生し、エレベーターで機体の姿勢角を制御して滑空する。ピッチング回転に対する静安定性は水平尾翼によって得ている。これに対して、ピッチング回転翼飛行機では、回転翼の要素翼と中央静止翼で揚力を発生し、エレベーターで機体の姿勢角を制御して滑空する。ピッチング回転に対する静安定性は水平尾翼によって得る。

【０２３７】
要素翼と中央静止翼に発生する空気力によって、回転翼の中心周りに発生する回転モーメントは、水平尾翼の外側にピッチング回転角度位置を調節できるように取り付けられた外側翼に発生する空気力によって相殺されるように制御される。

【０２３８】
従来の飛行機では、主翼の上反り角によってロール安定性が図られているが、ピッチング回転翼飛行機では、回転翼を傾斜させて取り付けることにより上反り角を得ている。

【０２３９】
最後に、基本的に往復運動である羽ばたき運動を回転運動に置き換えたために生じたもう一つの設計準備課題として、回転翼の回転方向の問題に触れておく。図４３～図４６を用いて説明する。

【０２４０】
滑空中の回転翼の回転方向については、回転翼のブレーキを解除し、フリーに回転させて滑空させることもできる。この時の回転方向は、中央静止翼の切り返し角を調節することにより、前下がり回転から前上がり回転に切り替えることができ、フリー回転の速度を調節することもできる。

【０２４１】
フリーに回転する場合は要素翼に発生する空気力が変わり、回転翼の揚力も増大する。オ

ートジャイロやヘリコプターのオートローテーションのような飛行の可能性が期待されるが、鳥の飛行モードにはない現象でもあり、今の初期の机上検討段階ではその可能性は定性的にしか推定できていない。操作方法を選ぶことにより一方向回転にできるか、どのような滑空制御ができるかは、飛行機の安全性と信頼性設計の基本に係るので、当面の最も興味ある研究課題の一つである。

【０２４２】

本回転翼では、ヘリコプターのように空気を下に押し出してその反動で揚力を得るのでなく、前側から吸い込んだ空気を後斜め下方に偏向させる反動で揚力を得ている。この原理的特長があるので回転翼の下側に下側静止翼を取り付けることが許される。この翼には上反り角や後退角も付けることができるので、滑空時の揚力を増大し、静安定性の向上にも寄与させられる。

【０２４３】

また、この下側静止翼は、レイアウト上、および、商品性上極めて大きなメリットを生む。即ち、この下側静止翼の中は、従来の飛行機の主軸で実用性が実証されているように、前輪の収納、燃料の搭載、バッテリーの格納などに利用でき、その分、居住空間を拡大できる。また事故時のクラッシュでは衝突エネルギーを大きく吸収させることもできる。

【０２４４】

回転翼を駆動するトルクと推力の関係を定量的に理解するために、揚力をゼロにして、抗力により発生する空気力と回転モーメントの関係を試算した。一例を図３６～３８に示す。

【０２４５】

なお、本発明に係る回転翼は、以上、説明した実施形態に限定されるものではなく、本発明の趣旨を逸脱しない範囲内において種々変更を加え得ることは勿論である。

【産業上の利用可能性】

【０２４６】

ビジネス開発の観点からは、ピッチング回転翼飛行機は、回転翼だけで揚力と推力の両方を発生し、空中静止も可能な飛行機であるが、従来の飛行機やヘリコプターに代わるものではなく、新しいビジネス分野を切り開く材料となりそうである。

【０２４７】

ヘリコプターのホバリングでは空気は上から吸い込まれ下に押し出される。これに対して、ピッチング回転翼飛行機のホバリングでは、空気は前から吸い込まれ斜め後下方に吐き出される。この状態は、流れるプールで流れを作りながら泳ぐのに似ている。従って、離着陸時の砂塵の巻き上げ方はヘリコプターと比べてかなり違ったものになる。

【０２４８】

ヘリコプターは、大きな垂直上昇力と等方向性の水平移動能力という、ピッチング回転翼飛行機には真似のできないリフト能力を持っている。しかし、軽量級の空飛ぶタクシーにすればヘリコプターとは一味違う便利な飛行機となるかも知れない。ヨーコントロールとロールコントロールとジャイロ効果に苦しみながら現在の飛行技術を確立したヘリコプターを思うと、やや複雑ではあるが、鳥に近い飛行原理を持つこの飛行機の実用化は、比較的容易かもしれない。

【０２４９】

無線操縦のホビー用や作業用飛行ロボットへの応用も有望であろう。この場合は、人が乗らず、使用場所を限定でき、製品安全上や航空法規上の制約も少ないので、制御技術と並行して機構と構造の開発を進めれば商品化の道は早めに開かれるかもしれない。

【０２５０】

ホビー用としては、従来、弾性膜を張った羽ばたき翼の鳥ロボットが商品化されている。しかし、弾性膜翼では、バタバタして翼型が定まらないので、安定した精度の良い飛行を機械的に再現することは難しいと思われる。本発明は剛性のある複数の要素翼を機械的に回転させ、少し多めの補助翼を用いて操作する機構となっているため、制御ファクターが多く、しかもそれらを複雑に関連付けて操作しなければならない。それをシミュレートし

てマイコンを開発してゆくのはかなり難しいタスクとなるが、克服されれば、鳥のように自由に飛行させられる模型飛行機が多様に開発されるようになる。

【０２５１】

商品開発の観点からは、設定目標の有人鳥ロボットの実用化までには最短で２０年は掛かる。基礎設計は、自動車を基準に、安全、重量とコスト、燃費とエミッション、騒音性能、デザインについて性能目標を設定して開発を進めることになろう。オートローテーション機能とその制御能力が安全性のカギを握っている。重量は半減したい。ボディー系の強度メンバーは全て高張力アルミ板にし、ボディーパネルは全て樹脂化し、シャシー系のメンバーはＣＦＲＰ　主体にする。軟構造化を進め、動的挙動を解析し、弾性変形や振動特性を設計に確りと織り込むことになる。コストは２倍以下に押さえたい。最近の自動車のエコ対応への挑戦は先行技術開発として大いに期待できる。排気騒音の点からジェットエンジンは使えない。エンジンは、最初はバイオ燃料のロータリーハイブリッドとなるのかもしれない。それまでには、ロータリーエンジンのローターとエキセントリックシャフトは中空かセラミックにしたい。タイヤ音は無くなるが、風切り音が発生する。しかし、翼型も機体形状もどこまでも鳥に近づけていけるので空力性能の向上を図りながら風切り音は低減してゆける。外観デザインとしては、鳥をイメージしたコンパクトで美しい形が原理的に約束されている。

【０２５２】

ピッチング回転翼飛行機は僅かな助走で離陸し、そのまま飛行状態に入ることができる。従って、将来は、ピッチングコントロールの難しさを克服し、回転翼の制御方法を確立し、機体の静安定と操縦性を確立し、離陸準備、急速上昇、水平飛行、旋回、滑空、制動などの飛行モードをスムーズに切り換えて飛行し、精度良くピンポイントで着陸できるようにしたい。

【０２５３】

本発明は、今は、ヘリコプターに近い水平維持飛行をする飛行機としているが、鳥や従来の飛行機のように飛行方向に機首を向け、違和感なく自然なフィーリングで加速度を感じて飛行することが可能となるように配慮して機構の設計を進めている。鳥は空中で空気力と重力と慣性力のバランスを取りながら姿勢角を自由に変えて飛行しているが、将来は、鳥ロボットの胸に乗り込んだドライバーが人鳥一体となって自由に姿勢を変えて自在に操縦できるようにしたい。

【０２５４】

技術開発の観点からは、ピッチング回転翼を用いた飛行機の開発は、まだ、設計原理を解明し設計理論を準備している段階である。次の段階では、ラジコン名人達に教えてもらってオリジナルラジコン模型の開発を楽しみながら、操縦システムの基本設計にすすみたい。これまでに分かった機能・性能・構造要件とレイアウト要件を踏まえて、遥動機構を省略または簡略化した単純な平行回転翼を試作し、フリー滑空させてみることから着手したい。

【０２５５】

遊星歯車を用いた差動機構により要素翼を周期的に遥動させる機構は、自動車で言えば、駆動系のディファレンシャルギヤーを利用した動力配分技術に相当する。それに対して、中央静止翼と外側翼を用いて回転翼に発生する回転モーメントをバランスさせて機体のピッチング回転の静安定性を確保しようとする機構は、シャシー系のサスペンション技術に相当しよう。次の段階では操縦システムの原理設計に進むが、ローリング回転とヨーイング回転に対する静安定性を確保するための機構の確認が先となろう。シャシー系のステアリング、タイヤ、ダンパーに相当する技術領域が、未だ発明されずに残されていると感じているが、それはまだ見えていない。そこまでゆければボディーの原理構造も見えてこよう。従って、自動車のエンジン、ボディー（艤装、内外装を含む）に相当する技術領域については、今はまだ絵に描いた餅の状態である。

【０２５６】

偏心リング割出機構と遊星歯車を用いた偏心-遥動変換機構はかなり複雑になったが、今

のところ比較すべき代替案は見つかっていない。ヘリコプターのスワッシュプレートに相当する機構なので、信頼性の確保には多くの困難が予想されるので機体や回転翼とは別にユニットレベルのプロジェクトを立てて開発を進めたい。

【０２５７】

回転ドラムケース内のオイル潤滑システムの設計は、具体的に試作テストでドライ潤滑の限界を見極めながら進めるべきであろう。また、将来、実用化される段階では、オイル潤滑を必要とする高性能飛行機とは別に、オイル潤滑を必要としない回転翼飛行機の開発も進めるべきである。ドライ潤滑の回転翼の開発は、実用性の高い量産機の範囲を広げるので、実用上最も価値ある技術開発テーマの一つである。

【０２５８】

要素翼を駆動するベルトやチェーンには、現在の通常の技術では張りを調整する機構が必要である。しかし、回転するディスクに組み込むので、この機構は不要にしたい。このテーマは、将来、材料技術と製造技術の革新でブレークスルーすべき、当面、見通しを得たい最優先の技術開発課題の一つである。

【符号の説明】

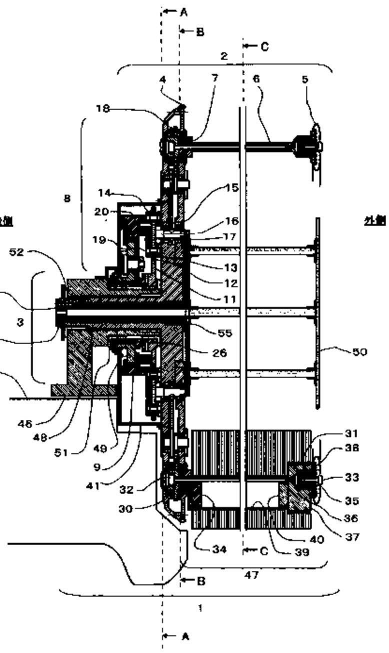
【０２５９】

１　回転翼
２　回転ユニット
３　支持ユニット
４　回転翼盤
５　回転翼端盤
６　要素翼
７　要素翼軸
８　歯車列
９　偏心リング割出機構
１０　ボディー
１１　太陽歯車
１２　従動歯車
１３　内歯歯車
１４　リテーナリング
１５　遊星歯車
１６　反転歯車
１７　反転ピニオン
１８　翼ピニオン
１９　遊星歯車ジョイントピン
２０　偏心リング
２１　ローラーアーム
２２　ジョイントピン
２３　ローラー
２４　偏心-遥動変換機構
２５　差動機構
２６　太陽歯車軸
２７　ランナーリング
２８　追従要素翼
２９　タイミングベルト
３０　内側用アンギュラー玉軸受
３１　外側用アンギュラー玉軸受
３２　通しボルト
３３　ボルト
３４　タングＡ

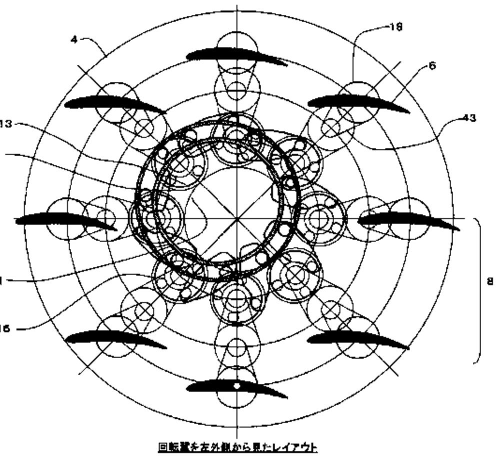
３５　ツバ付ボス
３６　リングナット
３７　エンドケース
３８　エンドリング
３９　トルクチューブ
４０　タングＢ
４１　回転ギアーケース
４２　タイミングベルトＡ
４３　タイミングベルトＢ
４４　中間ピニオンＡ
４５　中間ピニオンＢ
４６　取り付け台
４７　要素翼ケージ
４８　回転翼中心軸
４９　スラストパッキン
５０　中央静止翼
５１　メタルブッシュＡ
５２　メタルブッシュＣ
５３　中央静止翼支持軸
５４　メタルブッシュＢ
５５　メタルブッシュＤ
５６　静止翼ケージ
５７　中央静止翼フィン
５８　円盤
５９　楕円盤
６０　内側偏心ディスク
６１　外側偏心ディスク
６２　中継歯車
６３　駆動歯車
６４　偏心ディスク転がり軸受
６５　エレベーター
６６　外側翼
６７　水平尾翼
６８　垂直尾翼
６９　ラダー
７０　下側静止翼
７１　下側静止翼エキステンション
７２　回転翼盤Ｘ
７３　通しボルトＡ
７４　ボルトＢ
７５　ツバ付ブッシュＡ
７６　ツバ付ブッシュＢ
７７　エンドケース
７８　リングナット
７９　ツバ付ボスＡ
８０　回転翼Ｘ
８１　歯車列Ｘ
８２　太陽歯車Ｘ
８３　反転歯車Ｘ
８４　従動歯車Ｘ

８５　回転翼端盤Ｘ
８６　要素翼Ｘ
８７　トルクチューブ
８８　エンドリング
８９　機体
９０　飛行機
e　偏心量
η　偏心角度
α　要素翼の傾斜角
β　偏心軸傾斜角
γ　取付け角
δ　要素翼の遥動角
ζ　リテーナリングの遥動角
Ｖｔ　飛行速度
Ｖｒ　要素翼の公転速度
θ　要素翼の公転角度

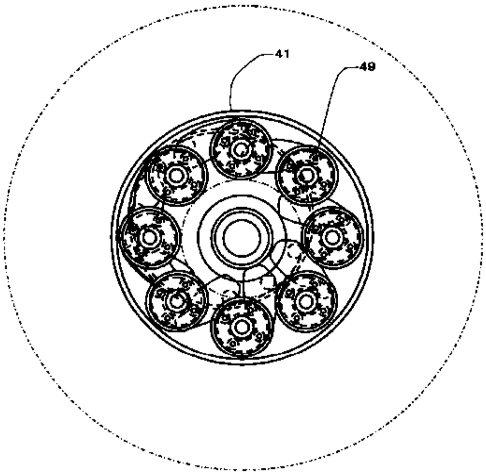
【図１】



【図２】

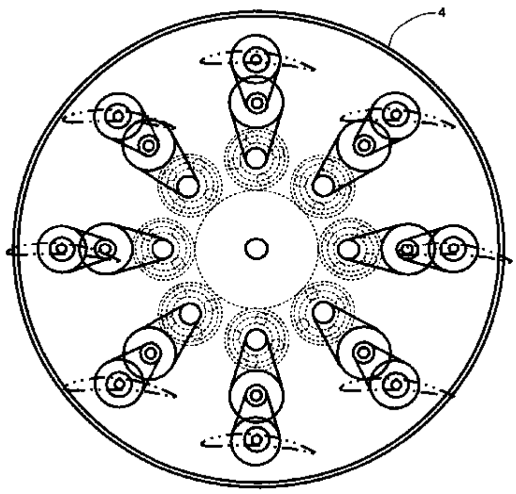


【図３】



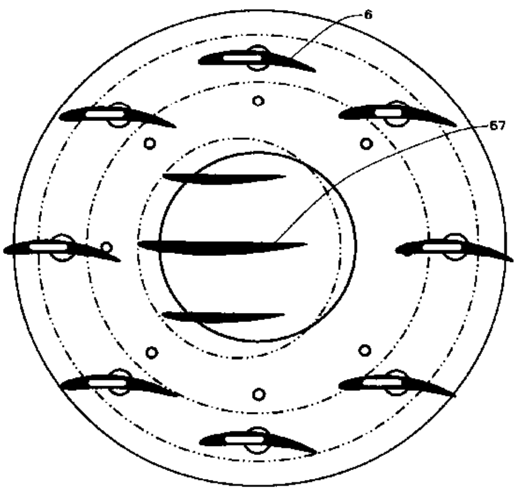
A-A 断面矢視

【図４】



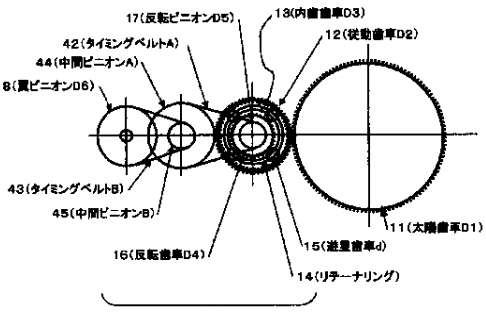
B-B 断面矢視

【図５】



B-B断面矢視

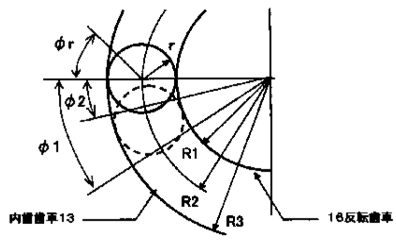
【図６】



【図７】

遊星歯車による運動角の伝達について
反転ピニオンのピッチ円半径；R5
翼ピニオンのピッチ円半径；R6
反転ピニオンの運動回転角：ϕ_5
翼ピニオンの運動回転角：ϕ_6
とすると、
$\phi_6 = \phi_5 \times R_5/R_6$
反転歯車と反転ピニオンは同軸に固定されているので、反転歯車がϕ_1だけ運動回転すると反転ピニオンも同じ時$\phi 1$だけ運動回転する。従って、
$\phi_5 = \phi_1$
$\phi_6 = \phi_1 \times R_5/R_6$
試算
R5=40mm、R6=80mmとした場合、
反転歯車の運動回転角ϕ_1=46.8° のときの翼ピニオンの運動回転角は、
$\phi_6 = 46.8 \times R_5/R_6 = 46.8 \times 40/80 = 23.4$
となる。
リテーナリングの運動角は、遊星歯車によって増幅して反転歯車に伝えられるが、その後、反転ピニオンから翼ピニオンへは、縮小されて伝えられる。

【図８】



【図９】

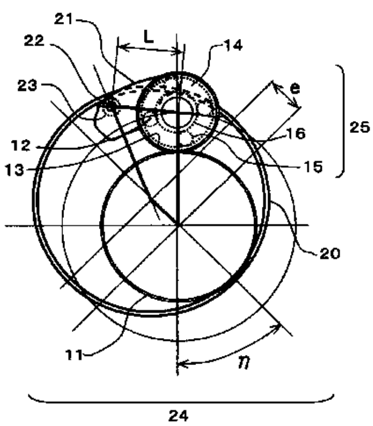
遊星歯車のピッチ円半径：r
内歯歯車のピッチ円半径；R3
遊星歯車中心の移動する円の半径；R2
反転歯車のピッチ円半径；R1
遊星歯車の回転角；ϕr
リテーナリングの運動回転角：$\phi 2$
反転歯車の運動回転角：$\phi 1$

内歯歯車を固定して、リテーナリングを$\phi 2$ラジアン運動回転させると、
反転歯車の運動回転角$\phi 1$は、
$\phi 1 = \phi 2 + \phi 2 \times R3/R1 = \phi 2 \times (1 + R3/R1)$

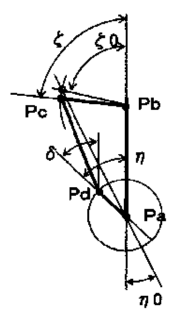
遊星歯車を小さくして、R1≒R3に近づけると、
$\phi 1 \fallingdotseq \phi 2 \times 2$

試算
r=30mm、R1=40mm、R3=70mm とした場合、
偏心ランナーによりリテーナーが、
$\phi 2$=17° 運動回転すると、
反転歯車の運動回転角$\phi 1$は、
$\phi 1 = 17 \times (1 + 70/40) = 17 \times 2.75 = 46.8°$
となる。

【図１０】



【図１１】



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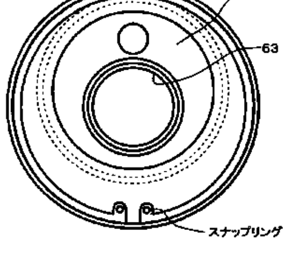

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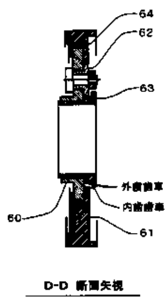

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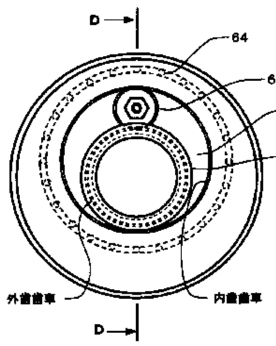

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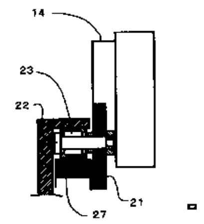

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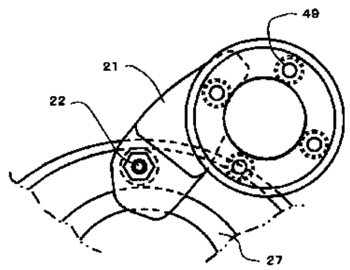

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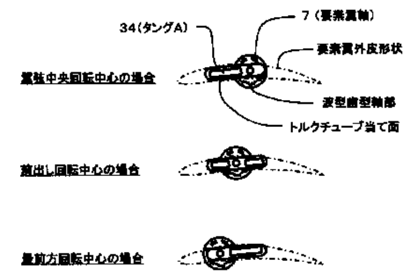

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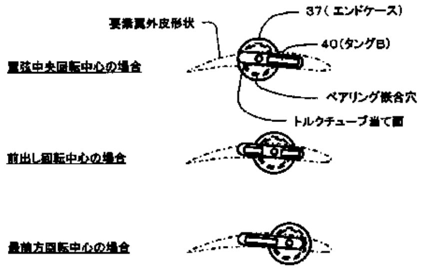

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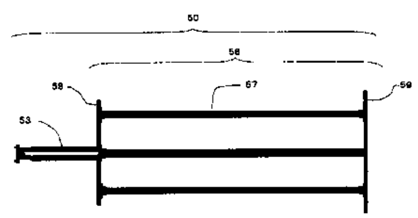

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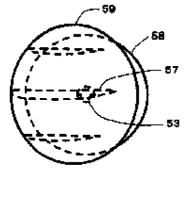

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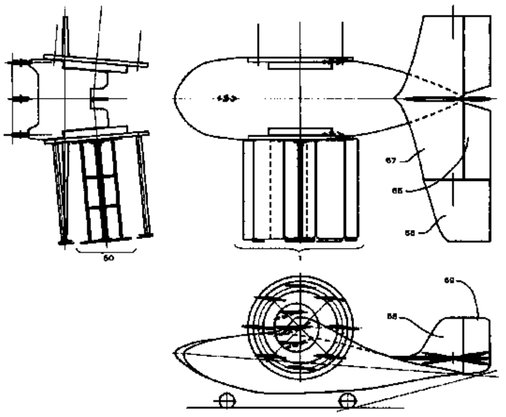

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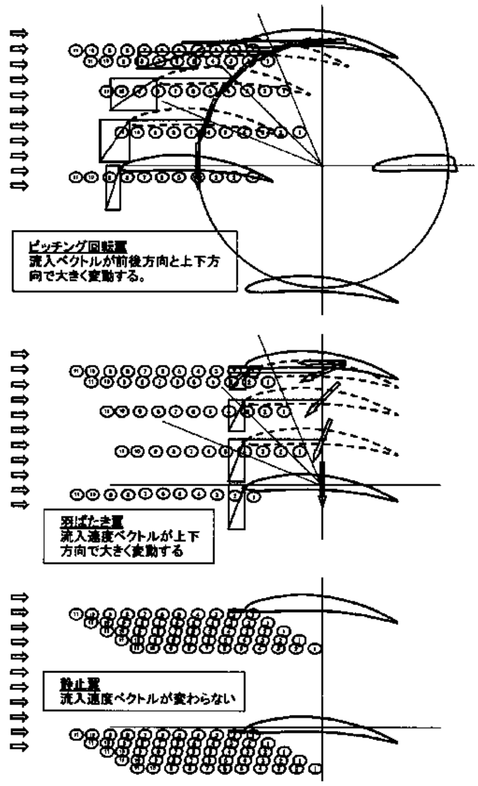

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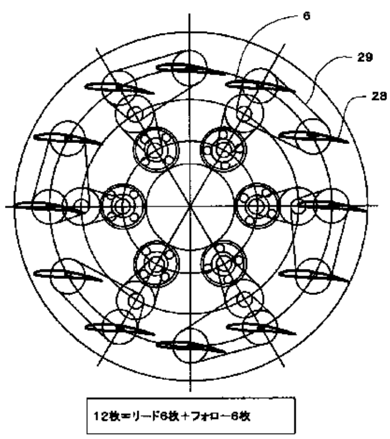

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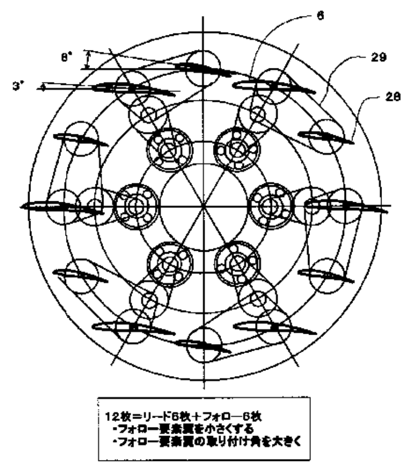

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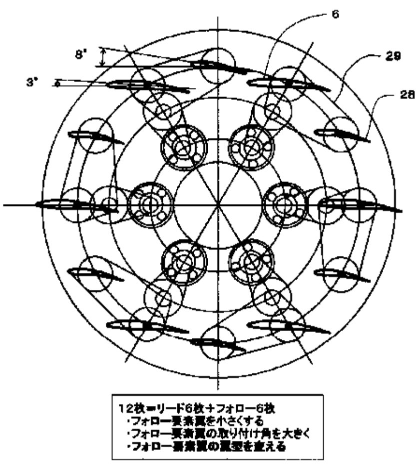

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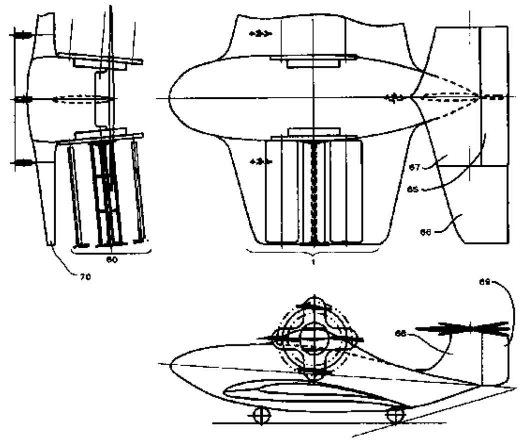

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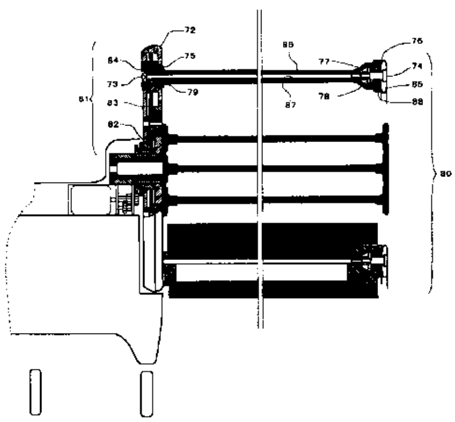

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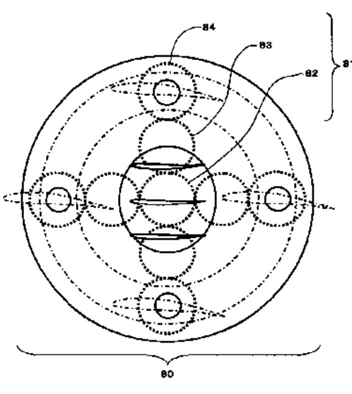

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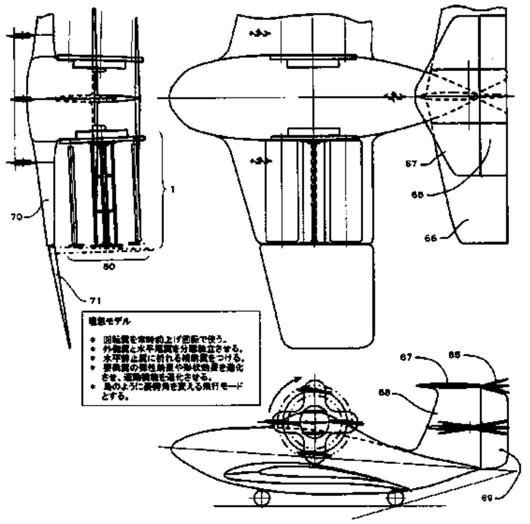

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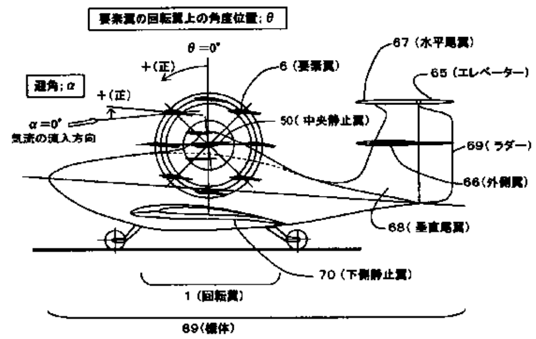

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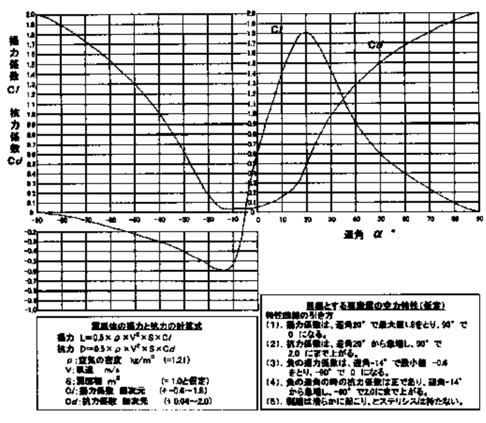

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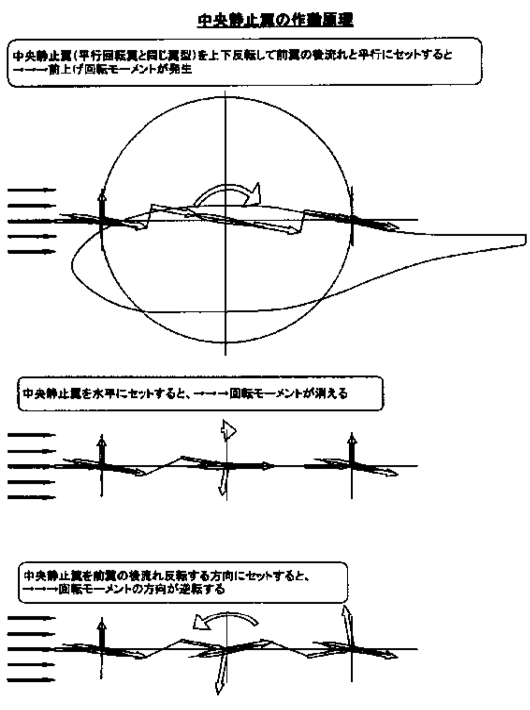

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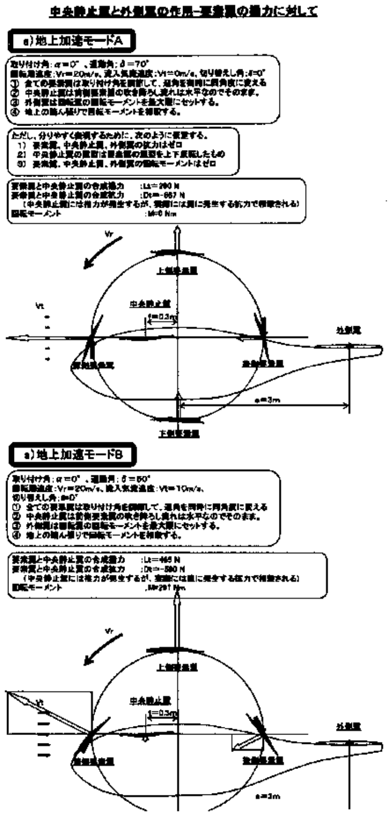

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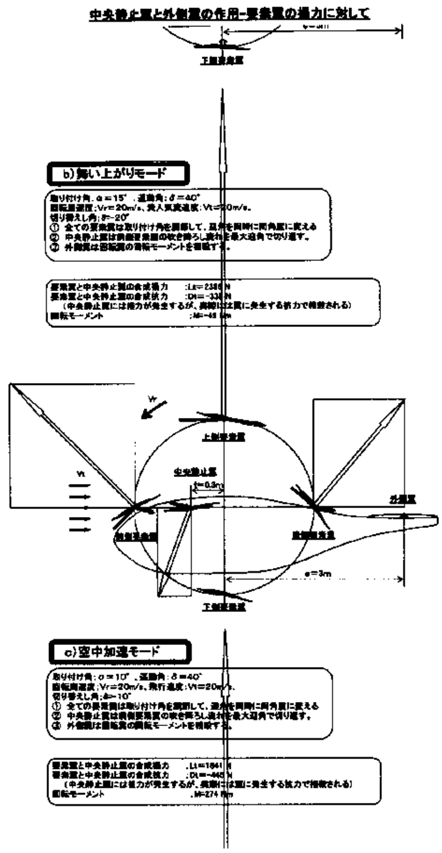

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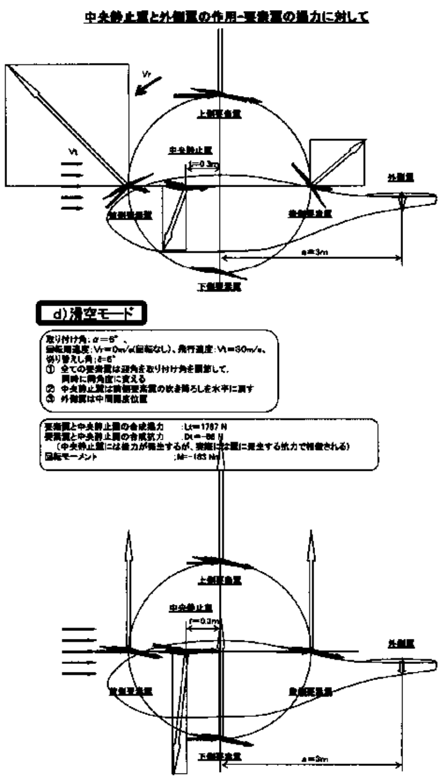

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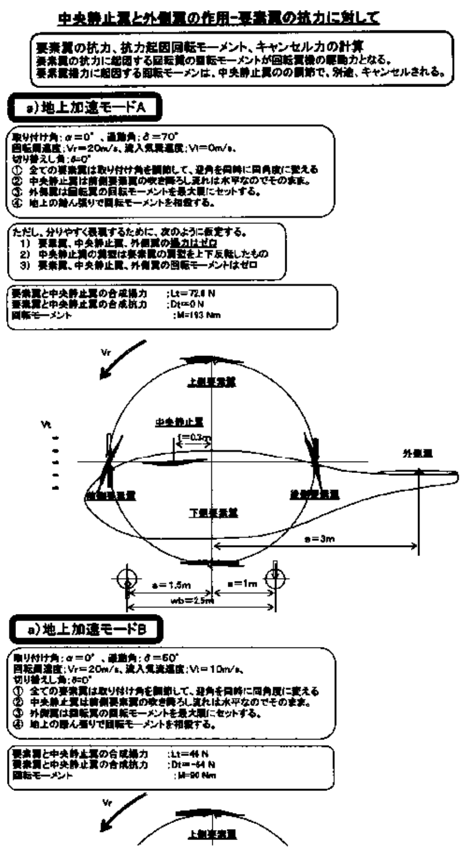

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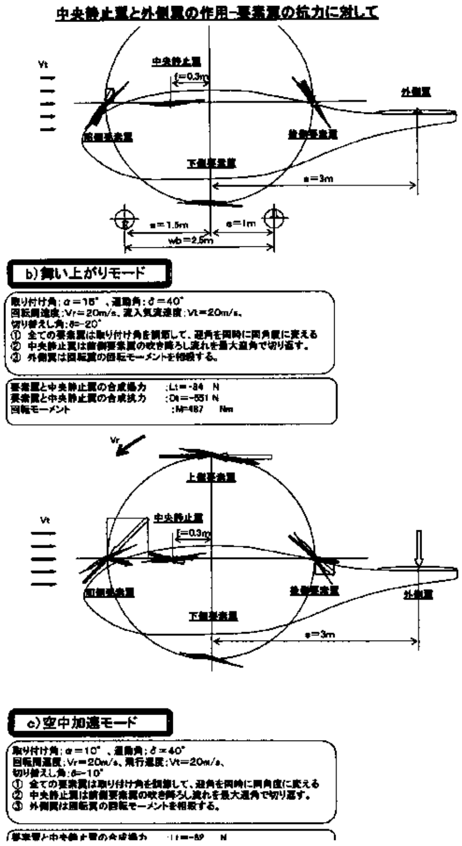

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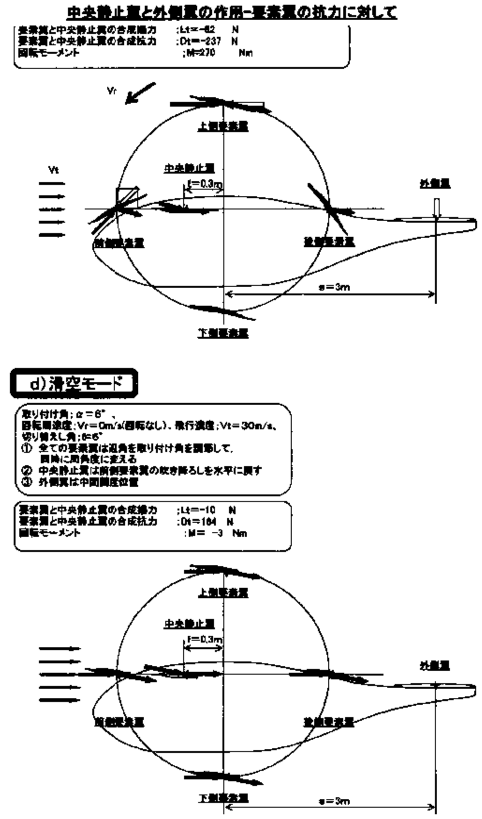

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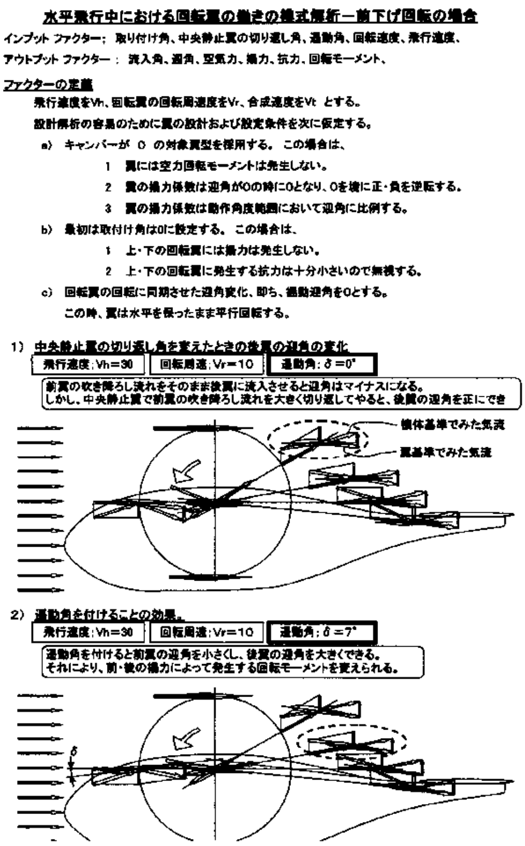

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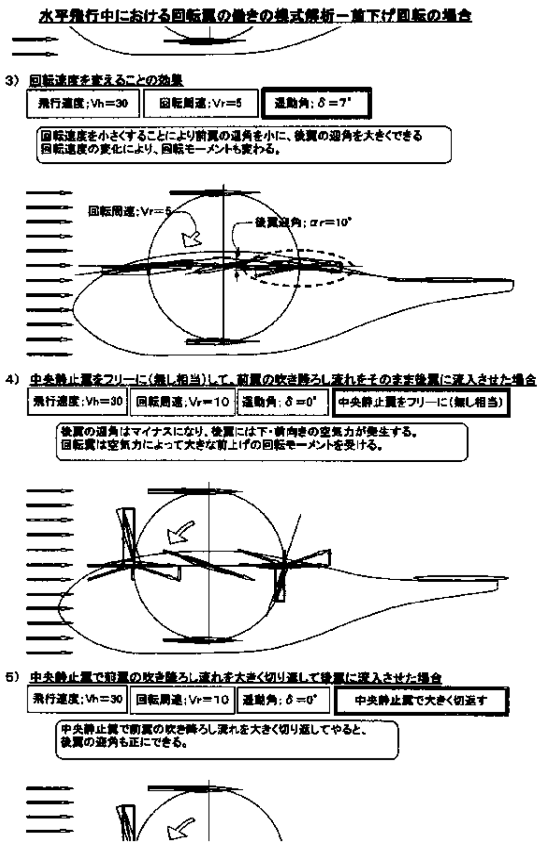

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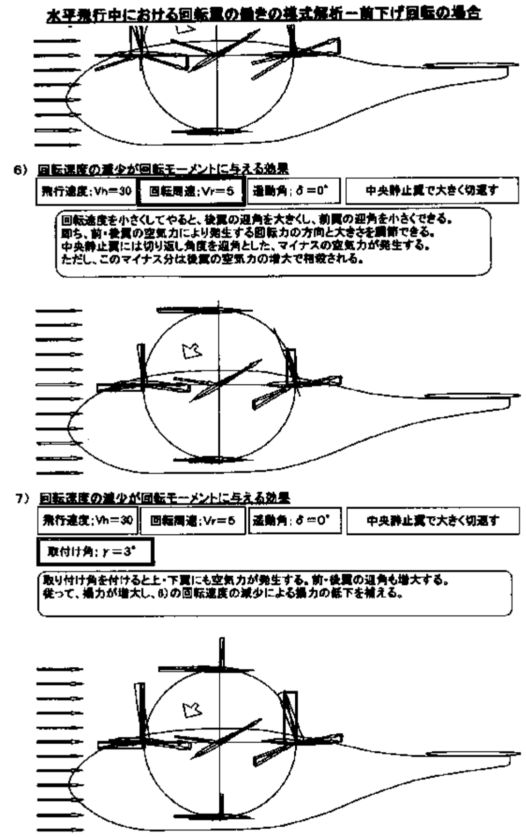

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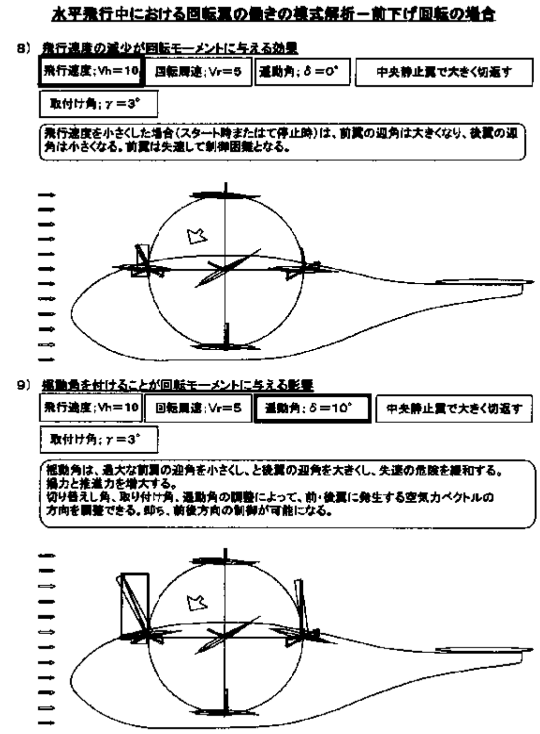

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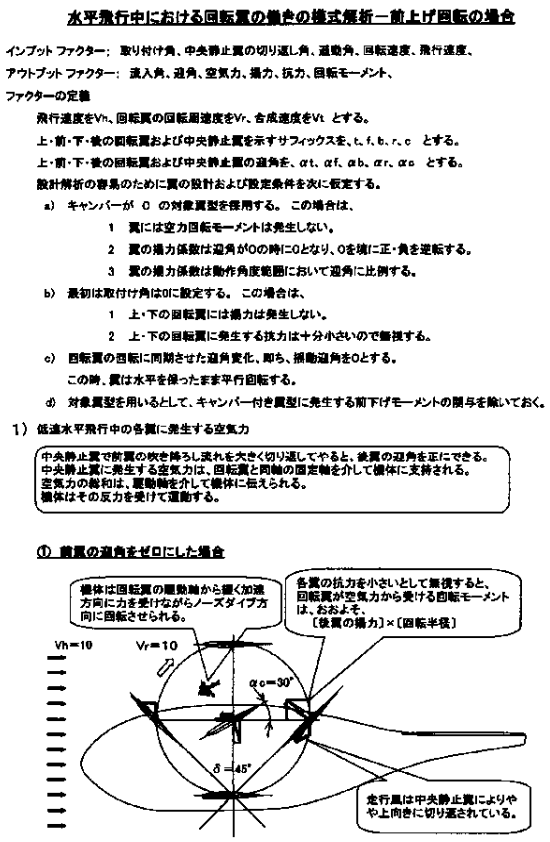

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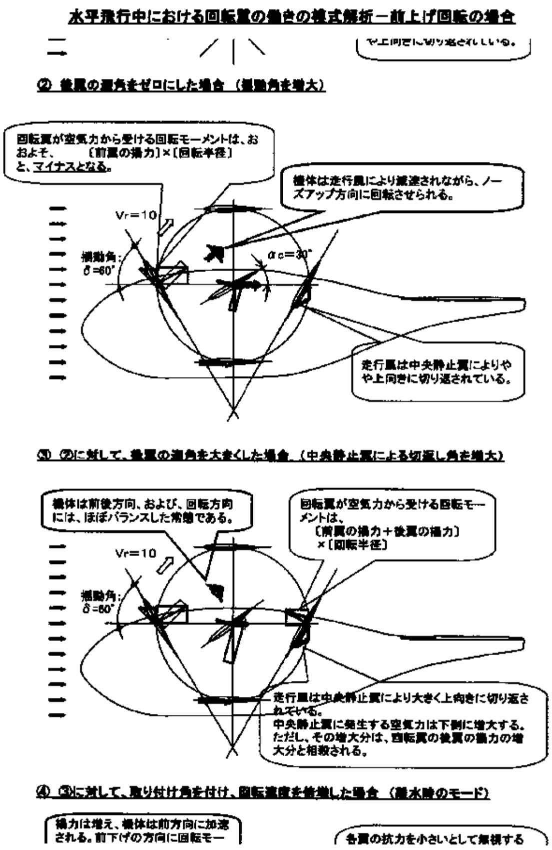

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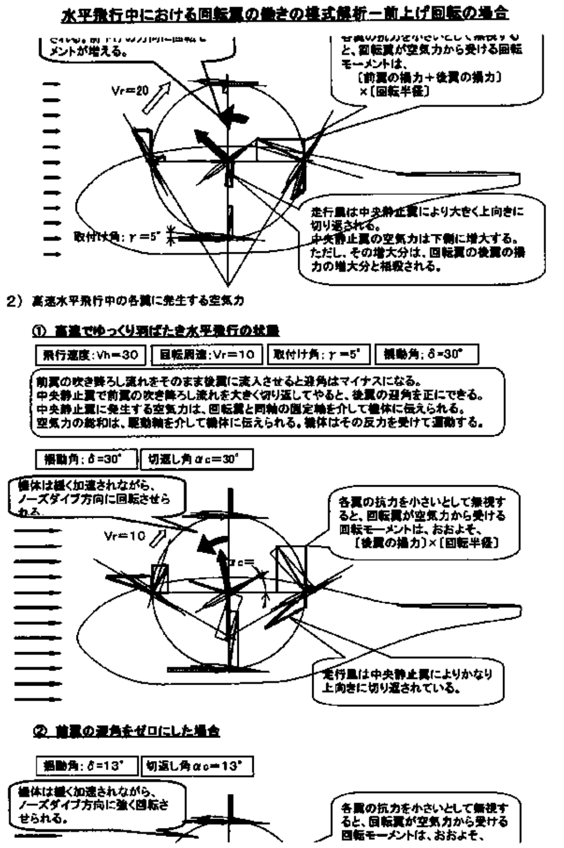

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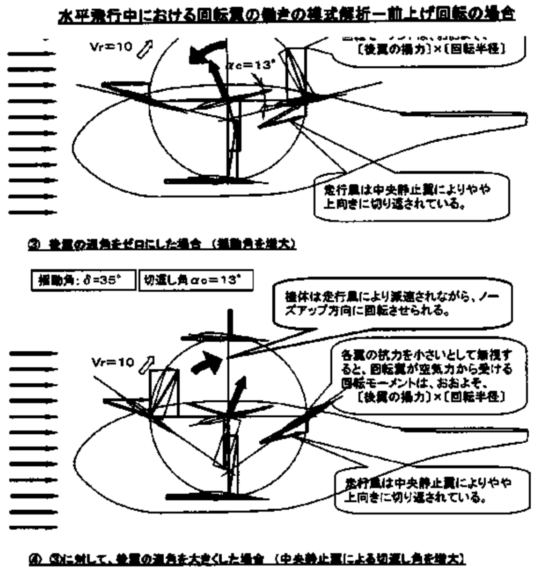

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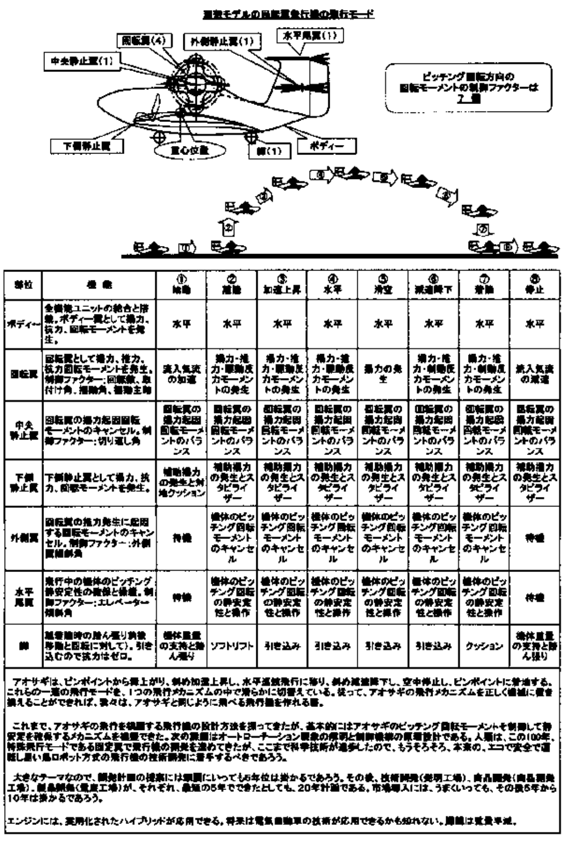

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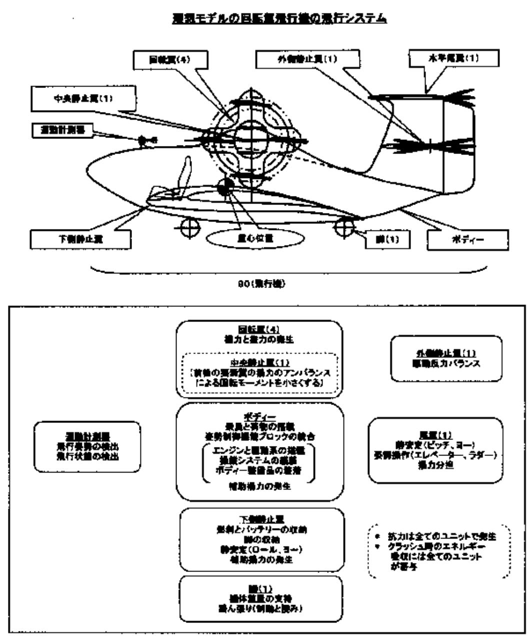

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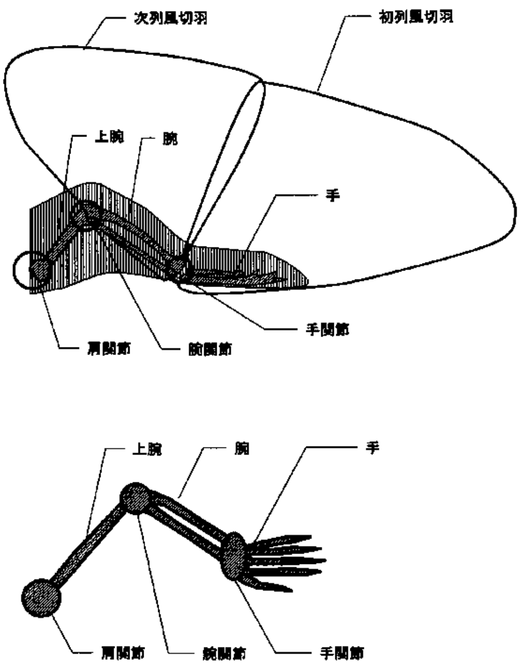

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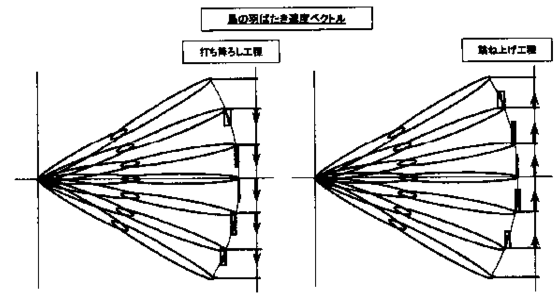

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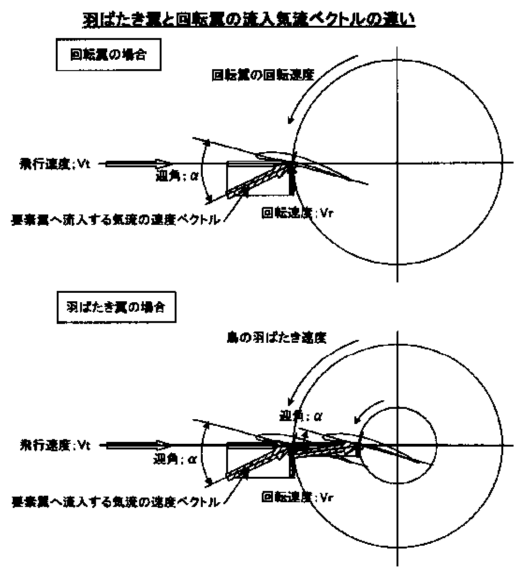

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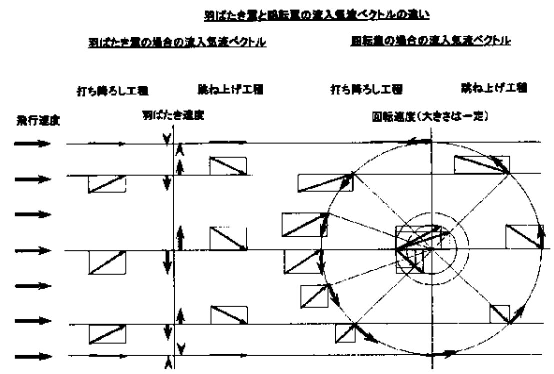
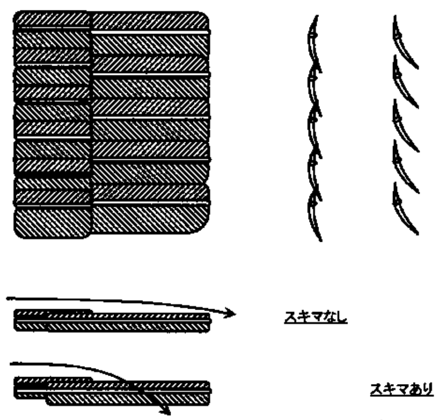


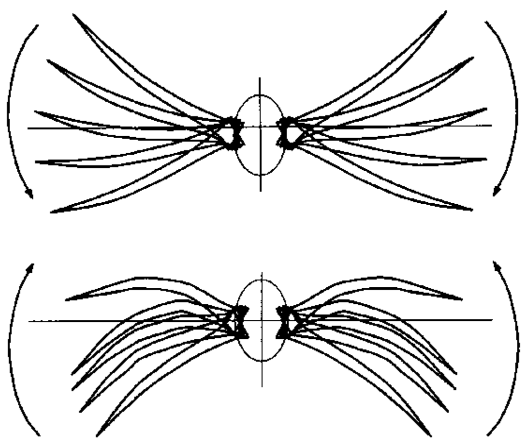
【図５３】

鳥の羽根のスキマ開閉機構



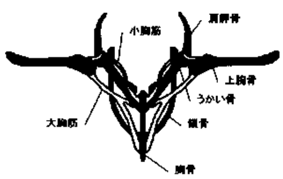
【図５４】

鳥の羽ばたき中の翼の折からの一例



【図５５】

鳥の胸の骨格と胸筋



US006016992A

United States Patent [19]

Kolacny

[11] Patent Number: 6,016,992

[45] Date of Patent: Jan. 25, 2000

[54] **STOL AIRCRAFT**

[76] Inventor: **Gordon Kolacny**, 514 W. 29th St., Loveland, Colo. 80538

[21] Appl. No.: **08/844,532**

[22] Filed: **Apr. 18, 1997**

[51] **Int. Cl.**[7] **B64C 15/00**; B64C 27/22; B64C 3/50

[52] **U.S. Cl.** **244/12.6**; 244/9; 244/12.1; 244/215; 244/219

[58] **Field of Search** 244/9, 10, 12.1, 244/12.5, 12.6, 19, 20, 215, 219, 70, 101, 105, 106

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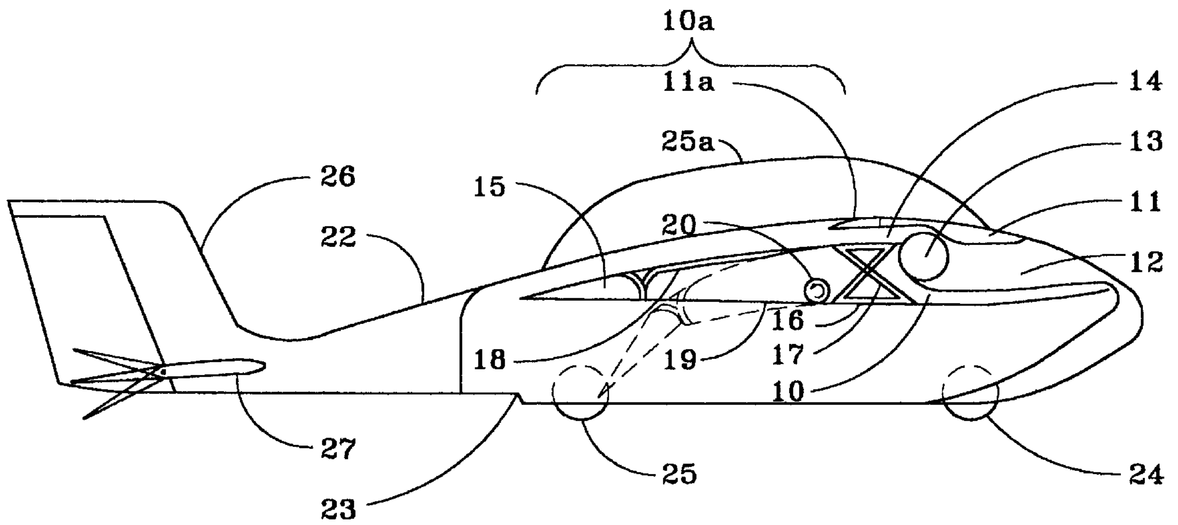
Primary Examiner—Charles T. Jordan
Assistant Examiner—Theresa M. Wesson

[57] **ABSTRACT**

A STOL aircraft has a fuselage **22** vertical **26** and horizontal **27** rear stabilizers and at least one wing made up of a lower primary airfoil **10** and an upper complementary airfoil **11** which, between them, form the inlet **12** and exhaust **14** air ducts. The craft is propelled by one or more cross flow fans **13** contained in a housing(s) **63** (FIG. **7**) between the primary **10** and complementary **11** airfoils. The primary **10** and complementary **11** airfoils can be extended and flexed downwardly, by various means.

11 Claims, 7 Drawing Sheets



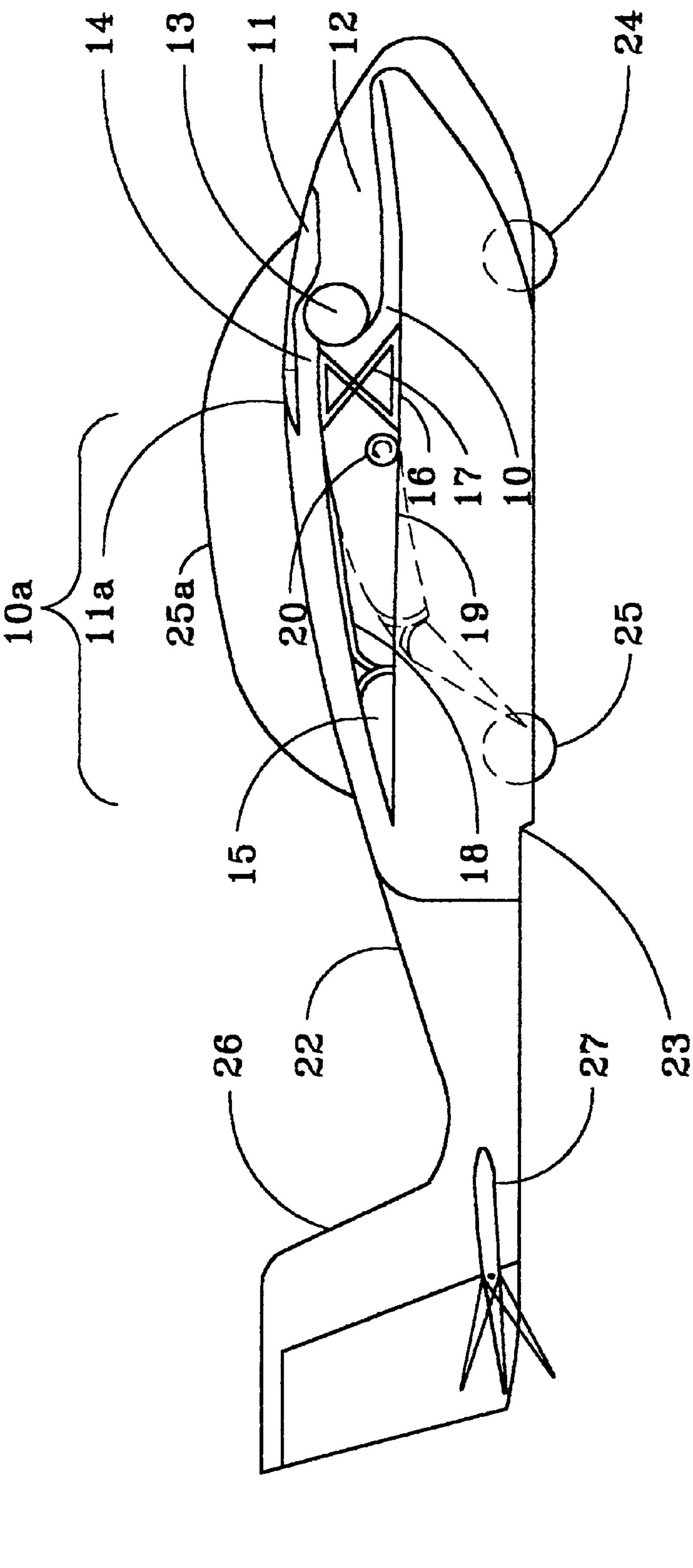


Figure 1

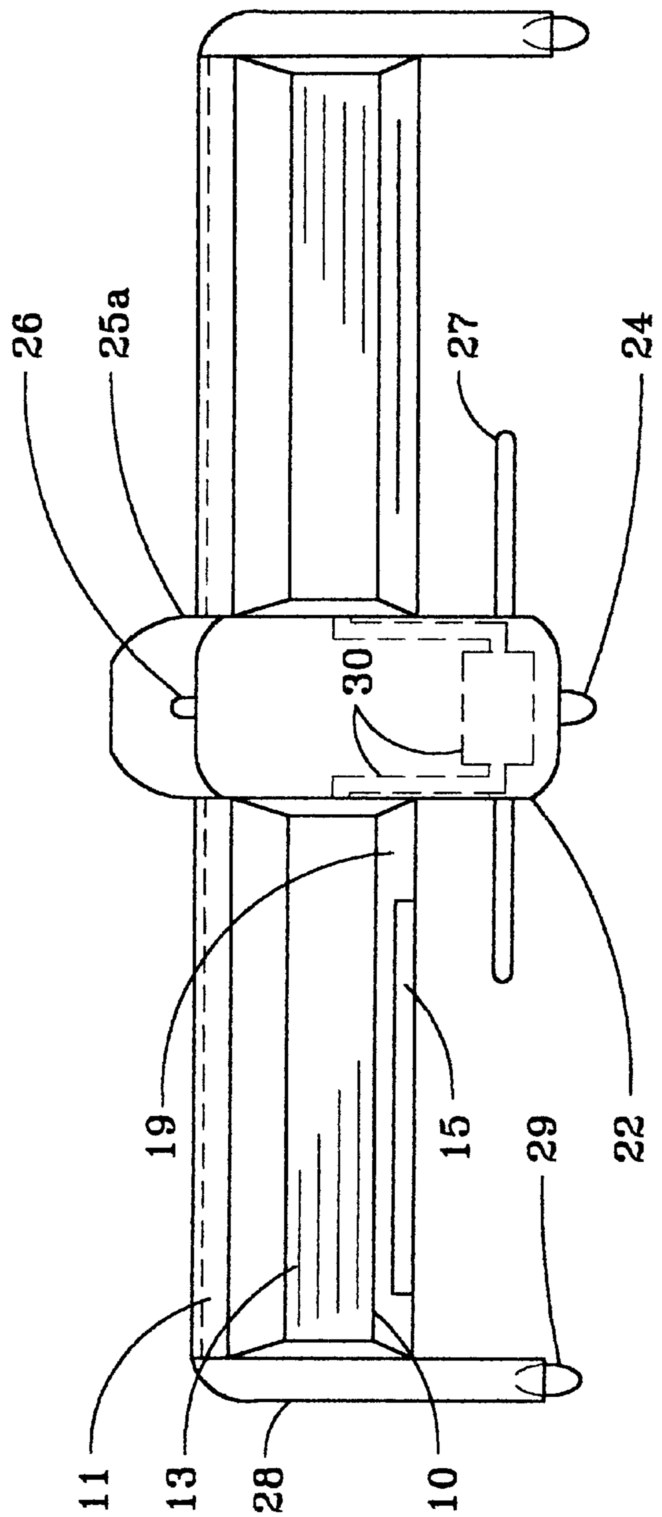


Figure 2

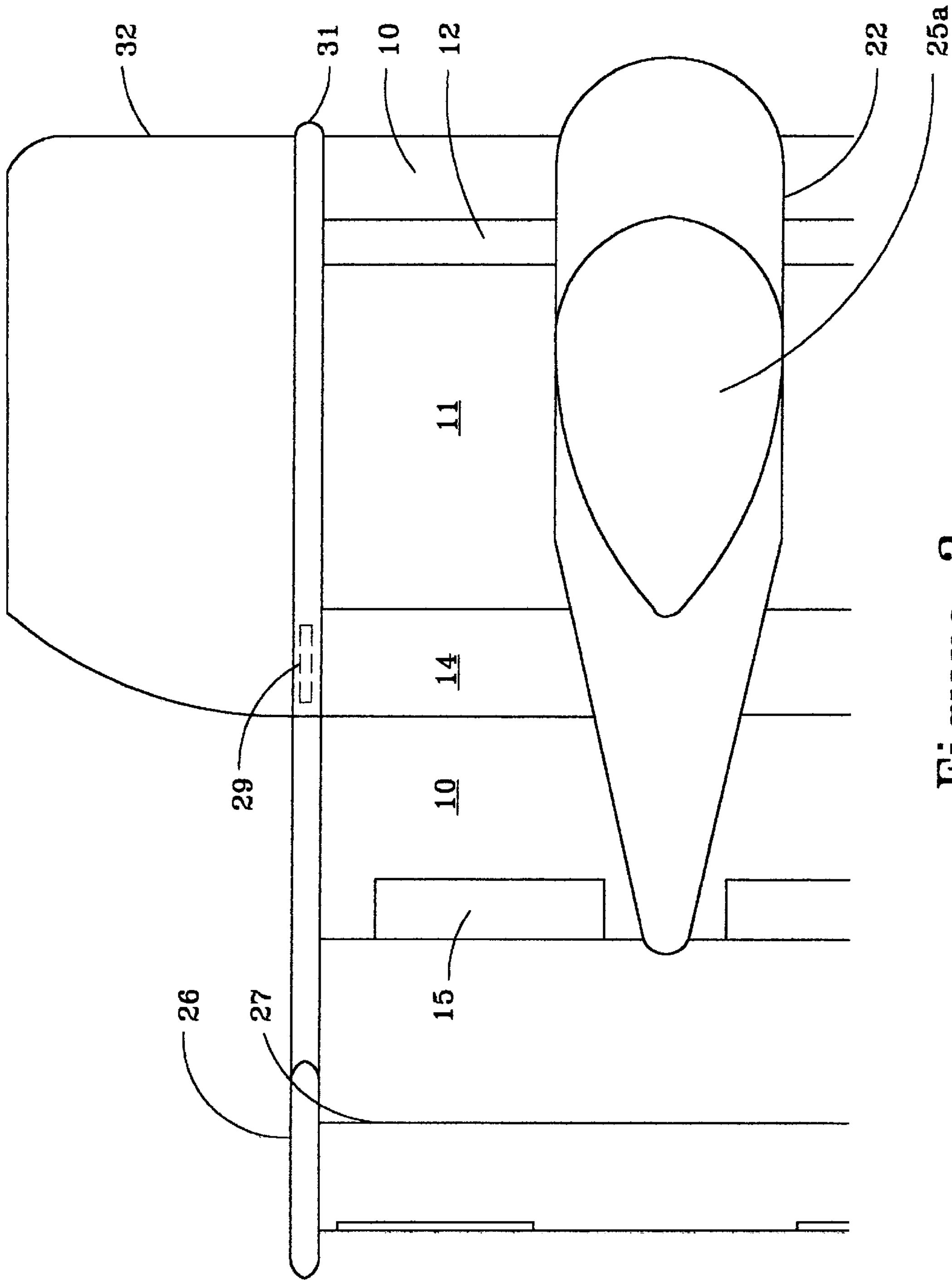


Figure 3

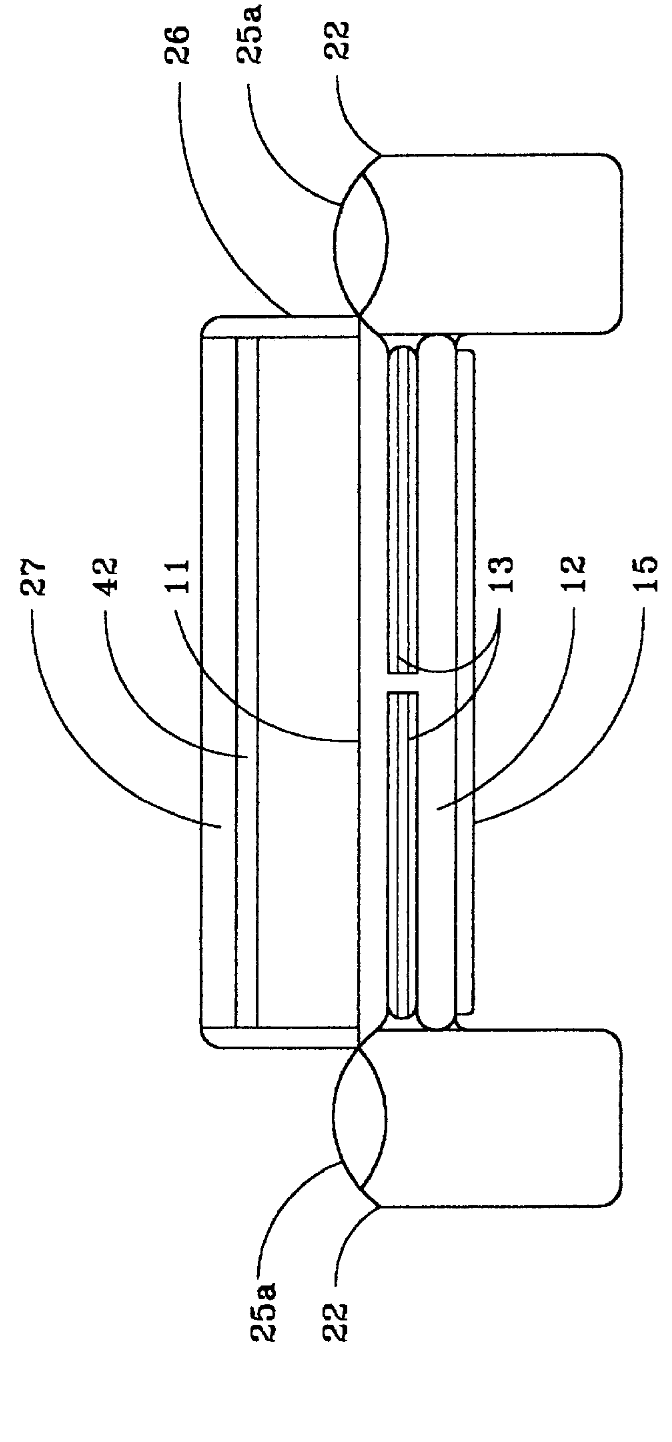


Figure 4

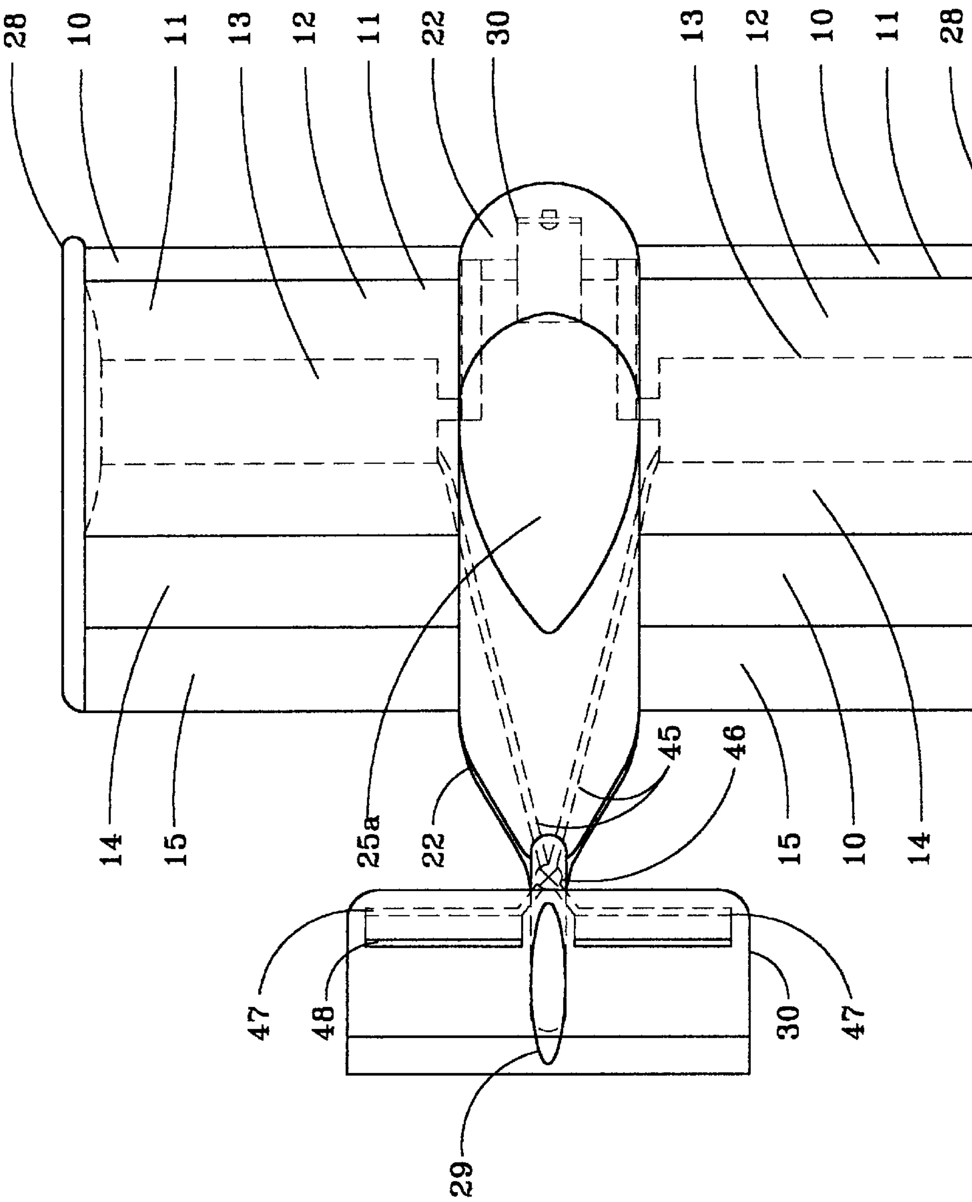

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Figure 5

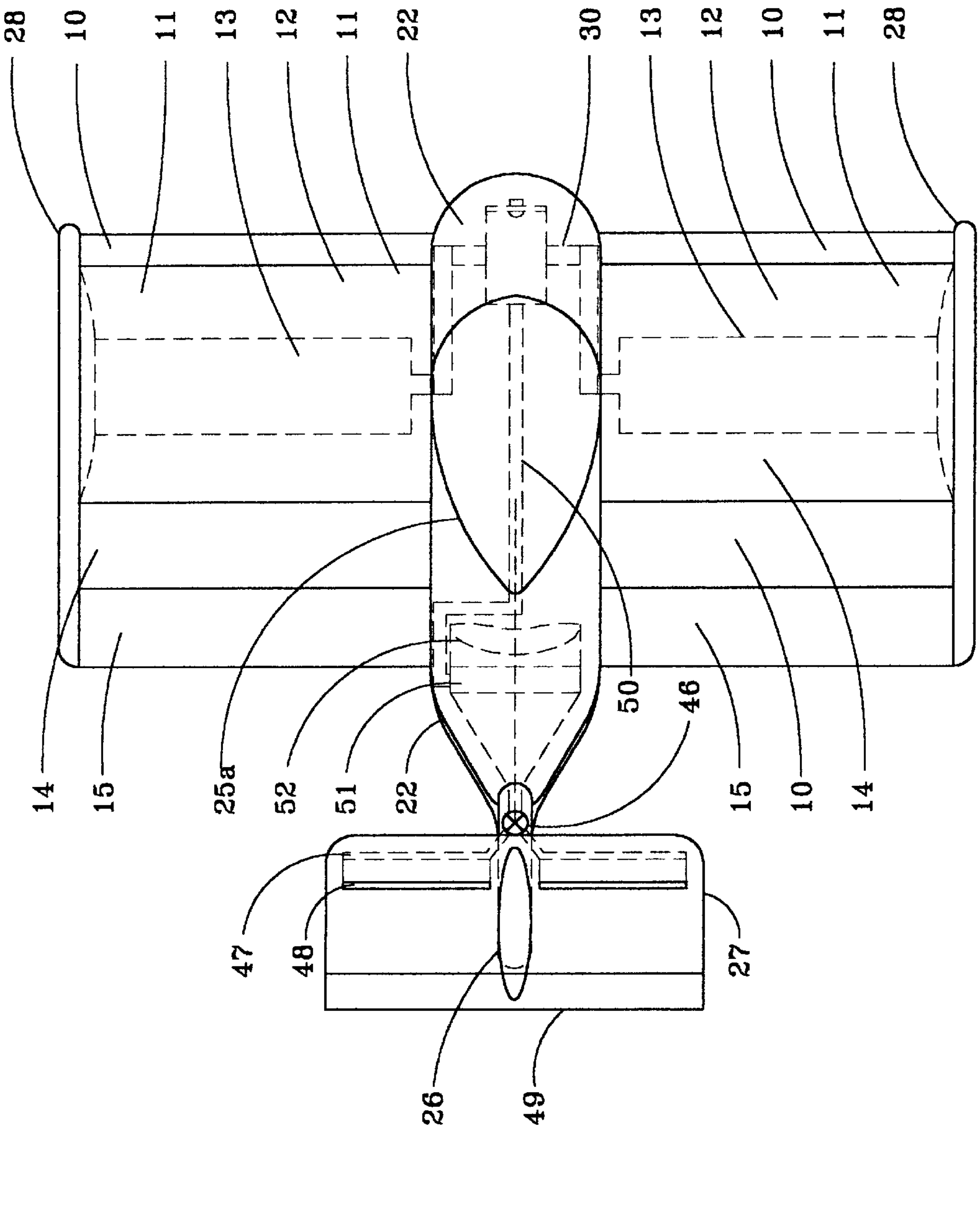
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Figure 6

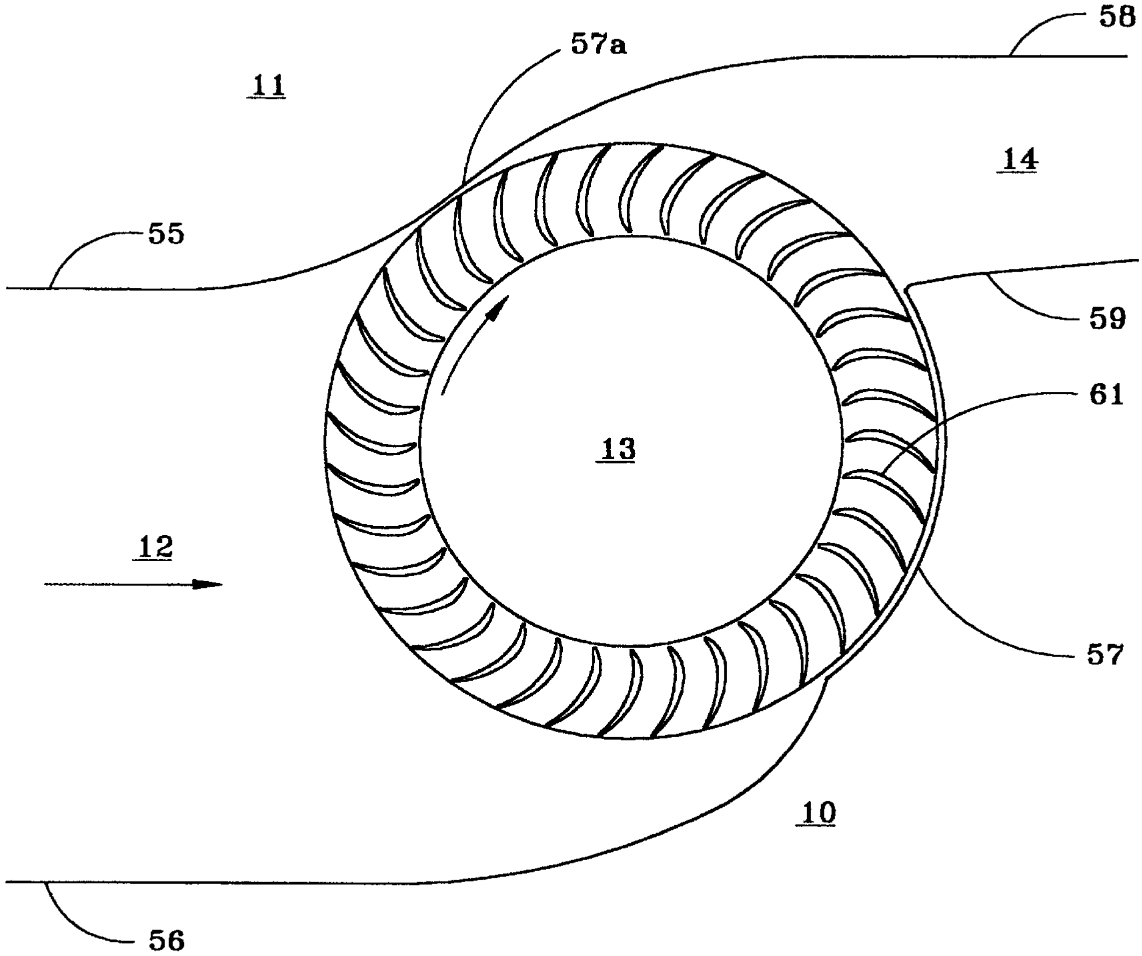

Figure 7

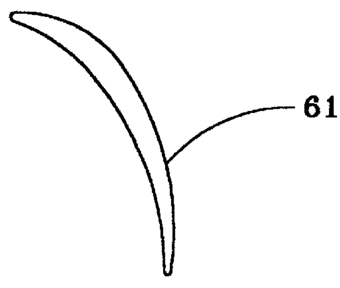

Figure 8

STOL AIRCRAFT

BACKGROUND OF THE INVENTION

Many airfoil modifications have been considered in the century since the Wright brothers flight at Kitty Hawk. Matthew Orr, U.S. Pat. No. 1,787,321 introduced complementary airfoils. H. P. Massey, U.S. Pat. No. 1,82,919, taught the use of fans and complementary airfoils on wing and horizontal tail surfaces to provide an aircraft which can hover. C. DeGanhal, U.S. Pat. No. 1,881,142, taught the use of slots and engine exhausts to provide boundary layer control on upper wing surfaces.

Variable camber airfoils are taught to be useful by Serge Trey, U.S. Pat. No. 2,478,793; G. D. Bryant et al, U.S. Pat. No. 3,109,613; D. G. Lyon, U.S. Pat. No. 3,179,357; E. M Wright, U.S. Pat. No. 3,332,883; A. W. Smith, U.S. Pat. No. 3,361,386; R. C. Frost et al, U.S. Pat. No. 4,247.066; and S. K. Ferguson, U.S. Pat. No. 4,582,278.

While the concepts taught in much of the referenced prior art were appropriate for their purpose, most of these references failed to make an impact on aviation. The present invention provides an air craft utilizing cross flow fan(s) and better over-the-wing boundary layer control for good STOL applications.

SUMMARY OF THE INVENTION

The short take-off and landing (STOL) vehicle of this invention combines several elements to accomplish the desired result. A primary airfoil(s) with a variable rear configuration combines with a complementary airfoil(s) to form the air intake duct(s), cross flow fan housing(s) and exhaust duct(s) necessary for propulsion and boundary layer control. During the take-off maneuvers, the rear of the primary airfoil(s) is flexed downwardly to enhance the formation of an air cushion. The rear edge of the complementary airfoil can also be extended to aid in boundary layer control. Preferably, the STOL vehicles have pontoon(s) or laterally positioned air dams and secondary airfoils to enhance lift and/or air cushion formation.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** depicts a single fuselage, amphibian craft with a section of the primary and complementary airfoils and a cross flow fan within the wing.

FIG. **2** is a front view of a preferred craft with pontoons.

FIG. **3** is a partial top view of a second preferred craft.

FIG. **4** is a front view of a double hulled craft.

FIG. **5** is a top view of a craft equipped for both wing and rear horizontal stabilizer boundary layer control.

FIG. **6** depicts a craft with a separate rear cross flow fan for enhanced horizontal stabilizer boundary layer control.

FIG. **7** depicts, schematically, a preferred cross flow fan and ducting configuration.

FIG. **8** depicts a preferred cross flow fan blade configuration.

DETAILED DESCRIPTION OF THE DRAWINGS

The same numbers are used in several of the figures for analogous elements where possible.

FIG. **1** is a side view of a light weight amphibian aircraft. The sectioned wing is made up of a primary airfoil **10** and a complementary airfoil **11** which form the air inlet ducts **12**. Duct(s) **12** direct the intake air into a cross flow fan **13**. The upper surface of primary airfoil **10** and the lower rear surface of complementary airfoil **11** also form the exhaust duct **14**.

The rear **10***a* of primary airfoil **10** is made, in part, of a flexible, light weight material such as sheet metal or sheet polyaramides. It includes flaps **15** to provide necessary air craft control. The rear **11***a* of complementary airfoil **11** is extensible and can be moved downward to better direct the exhaust air flow over a depressed rear of the primary airfoil flaps **15**.

Internal spars and struts **16** and **17** create the necessary rigidity for the central portion of the primary airfoil structure. When the craft "flares" for landing, the rear of the airfoil **10** is deformed. The upper ribs **18** are or can be flexible and bend downwardly when skin **19** is rolled around reel **20**. Other ribs, not shown, provide the stability required to ensure a desired rib conformation. The extensible rear **11***a* and airfoil **11** act as an air braking mechanism when flexed downwardly.

The fuselage **22** has a step **23** to facilitate take-offs from water. Nose wheel **24** and main wheels **25** retract into the fuselage **22** during flight and during water surface operations. The fuselage **22** has the usual cockpit **25***a* and vertical **26** and horizontal **27** stabilizers in the tail assembly.

FIG. **2** shows a craft similar to that of FIG. **1**. Pontoons **28** with retractable wheels or skids **29** provide additional lateral stability on land and flotation on water. Power plant and drive train **30** are positioned below the center of lift for greater stability.

FIG. **3** provides a top view of a twin boom **31** craft with secondary airfoils **32** extending beyond booms **31** which form the top of pontoons **28** at the forward end of the booms. Booms **31** can extend above the airfoils, as shown, to form air dams. Servomotor, or hydraulically actuated flaps, **15** can be extended and angled downwardly to facilitate landings while reducing landing speeds.

The craft of this Figure is also designed with hinges and locking mechanisms (not shown) so that the secondary airfoils **32** can be unlocked and rotated upwardly and/or rotated backward and upwardly to reduce the hanger "footprint" area.

The craft of FIG. **4** has two fuselages **22** and a single flap **15** on the rear of primary airfoil **10**. Both utilize servomechanisms for human assisted or computer controlled flight to provide desired lift and boundary layer control.

FIG. **5** schematically shows ducts **45** used to convey high pressure air off fans **13** through valving **46**, manifolds **47** and through slots **48** for increased boundary layer control over the rear horizontal tail surfaces during landings and takeoffs.

FIG. **6** shows an amphibian modification of the craft of FIG. **5**. The power from the engine **30** is transferred, via drive train element **50** to a cross flow fan **13** within a cowling **52** to provide added thrust and/or boundary layer control by forcing compressed air from fan **51** through valving **46**, manifolds **47** and out through slot **48** and over the upper rear surface of horizontal stabilizer **27** and flaps **49**. A separate engine can be substituted for the element **50**. Both provide better performance during aerodynamic fight.

FIG. **7** schematically shows a section of a preferred configuration for the cross flow and ducting configurations utilized in the craft of the other figures. The lower surface **55** of complementary airfoil **11** acts as the upper surface of the air intake **12**. The upper surface **56** of a primary airfoil **10** provides the lower surface. A cross flow fan housing is formed by segment **57** and "point" segment **57***a*, to provide the compression necessary for successful flight. The surfaces **58** and **59** form the exhaust duct **14**. Inlet duct **12** encloses about 180 degrees of the fan surface while the exhaust duct **14** encloses approximately 100–105 degrees.

The number of blades in the fan can vary from about 24 to about 44. The efficiency of the fan increases with increasing numbers of blades. This fan design is preferred because of its low cost, adaptability and its operational efficiency at a wide range of revolutions per minute.

The ram air traveling through the inlet duct is further compressed within the rotating fan. Energy is added by the centrifugal forces exerted by the fan blades. The fan diameter, length and blade configuration will depend on the aircraft in which it is to be used. The usage can be in under-the-wing exhaust designs, e.g., for hovercraft, as well as the over-the-wing craft of this application.

FIG. **8** is a preferred configuration for the blades **61** of a cross flow fan **13**. They provide, when attached within a cross flow fan **13**, air velocities which range up to 2.5–3 times blade tip speeds. Preferably, the blade angles within the cross flow fan are controllable for noise control as well as performance control.

Blades **61** similar to those of FIG. **8** are assembled into the fan of FIG. **7** with, preferably, an 80 degree forward curve. The rotating blade angles change with respect to the air stream flowing through the inlet air ducts. As the angle changes, the inlet air is compressed and subjected to a centrifugal force thereby causing compressed air to be discharged through the exhaust duct at air speeds which preferably range from about 2 to about 3 times the blade tip speeds.

The ratio between the chord of a blade **61** and radius of the fan **13** is approximately 1:5 with the blade biting into the air stream at angles of about 60 degrees and a blade arc of about 70 degrees. The air flow across the center of the fan is minimized. This approach reduces the formation of vortices and other nonplanar air flow problems.

Preferably, the blade angles are controllable to provide improved noise control at low altitudes.

I claim:

1. In an aircraft having at least one fuselage, at least one engine, at least one wing and at least one rear stabilizer, the improvement comprising:

at least one primary airfoil with the upper side of each such one airfoil forming the lower surface of an air intake duct, exhaust duct and a portion of a cross flow fan housing, and a rear portion of the primary airfoil which can be flexed downwardly, and

at least one complementary airfoil extending over a portion of the primary airfoil with the lower side of each such complementary air foil forming the upper surface of the air inlet duct, the exhaust duct and a portion of the cross flow fan housing, and

a cross flow fan positioned within each of the at least one cross flow fan housing.

2. The craft of claim **1** having multiple fuselages.

3. The craft of claim **1** further including pontoons.

4. The craft of claim **1** further including air brake means.

5. The craft of claim **1** further including secondary airfoil means for providing additional lift.

6. The craft of claim **1** further including an air dam on each wing.

7.The craft of claim **1** wherein the rear of each of the at least one primary airfoils includes reel means for modifying the rear portion at the rear of the at least one primary airfoils.

8. The craft of claim **1** wherein each of the at least one primary airfoils includes a rear extensible portion and rotationally operable flaps.

9. The craft of claim **1** further including means for conducting compressed air from at least one of the cross flow fans to the at least one rear horizontal stabilizer and to slots in each upper surface of the at least one rear horizontal stabilizer.

10. The craft of claim **1** further including within the forward portion of the rear horizontal stabilizers an additional intake air duct, cross flow fan housing, exhaust duct and cross flow fan positioned within the fan housing for exhausting compressed air over the upper surface of the rear horizontal stabilizers.

11. The craft of claim **1** wherein each of the at least one fuselage is stepped.

* * * * *

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(54) **CYCLOIDAL VTOL UAV**

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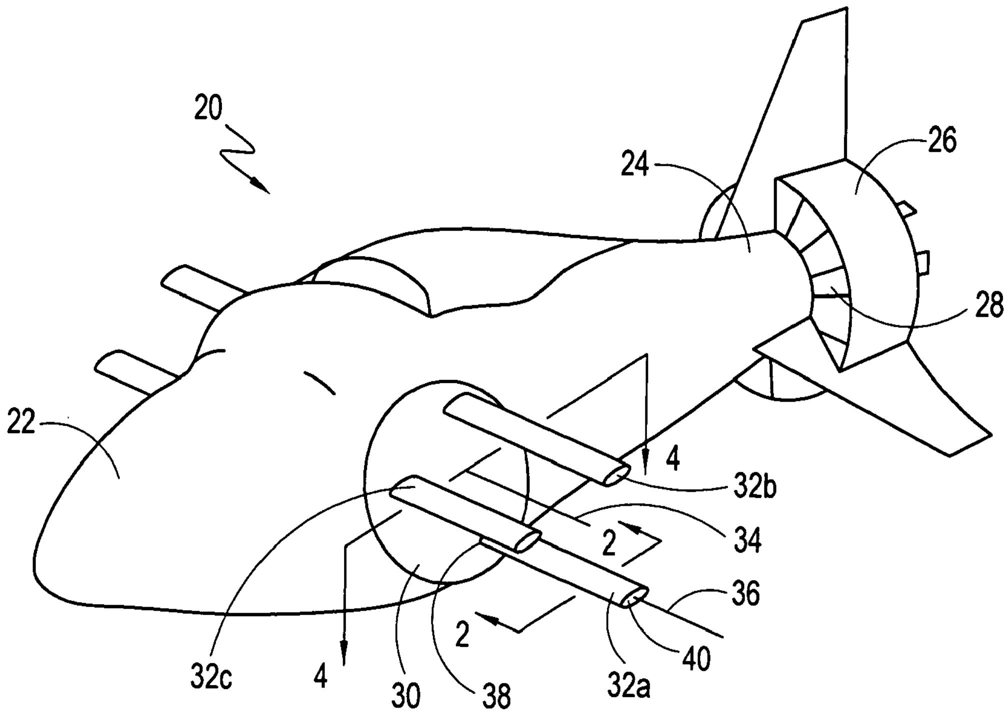
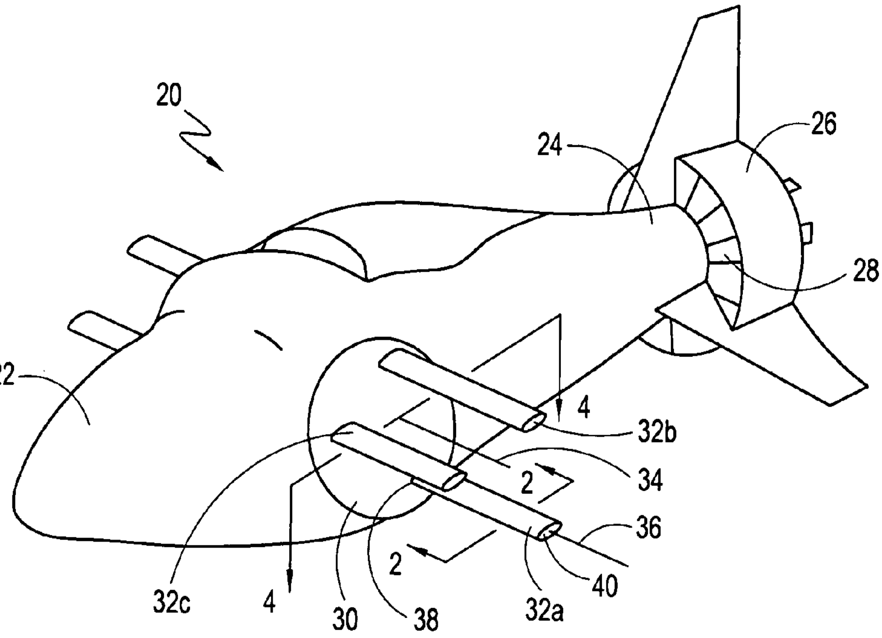
(52) **U.S. Cl.** **244/20**

(57) **ABSTRACT**

A system and method for moving an aerial vehicle along a flight path includes rotatable hubs mounted on opposite sides of the vehicle. Elongated airfoils are mounted on the hubs parallel to a common hub axis for rotation about the hub axis on a blade path. Each airfoil defines a chord line and the system includes a gear assembly changeable, during hub rotation, between a first modality wherein airfoil chord lines remain tangential to the blade path (curtate flight), and a second modality wherein airfoil chord lines remain parallel to the flight path of the vehicle (prolate flight). Also, rotation of the hub can be stopped and the airfoils used for fixed wing flight.




20
24
26
28
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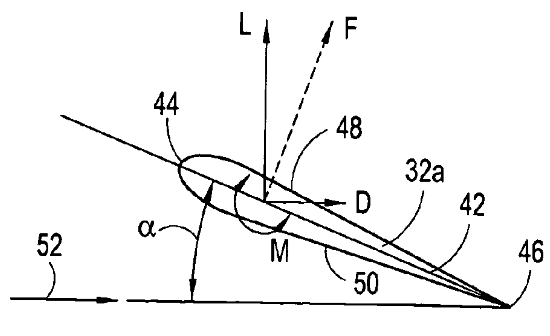
32a

Fig. 1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32a
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Fig. 2

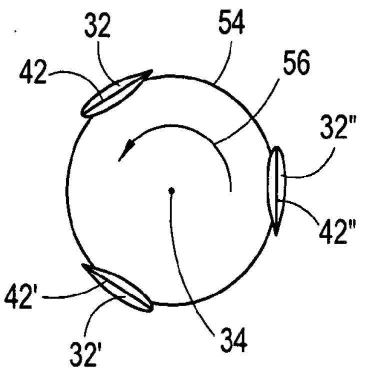

Fig. 3A

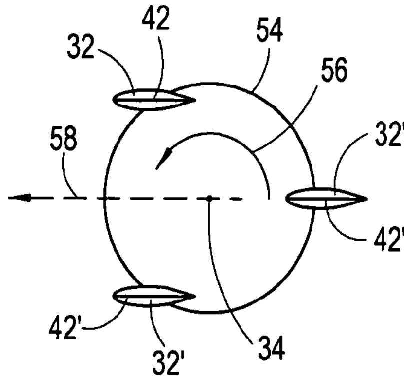

Fig. 3B

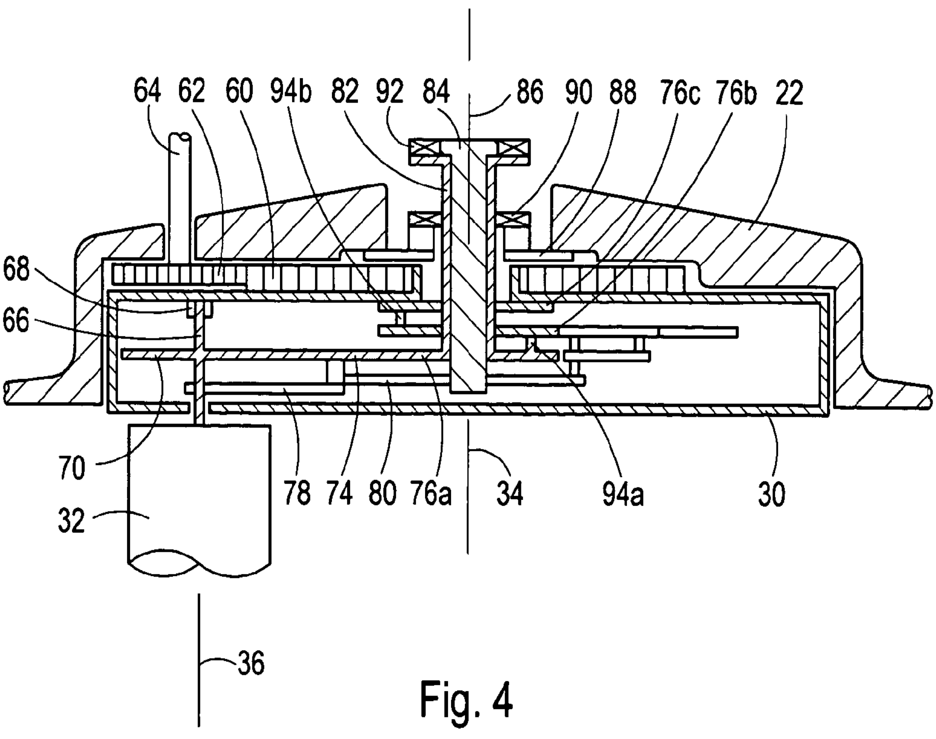

Fig. 4

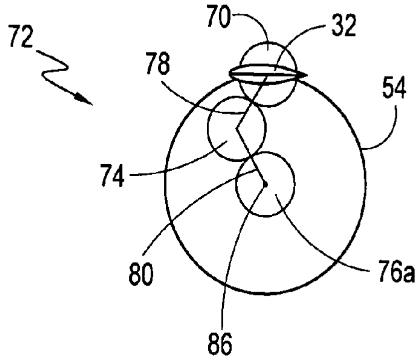

Fig. 5

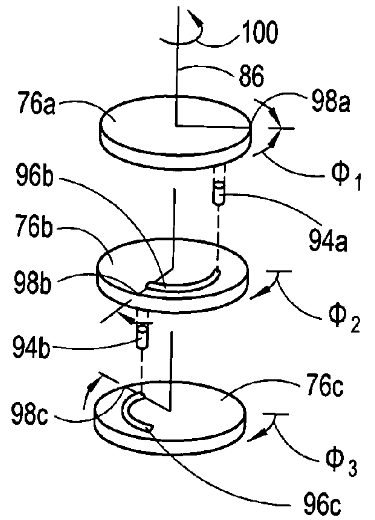

Fig. 6A

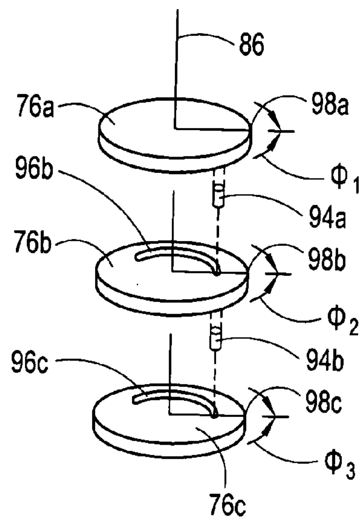

Fig. 6B

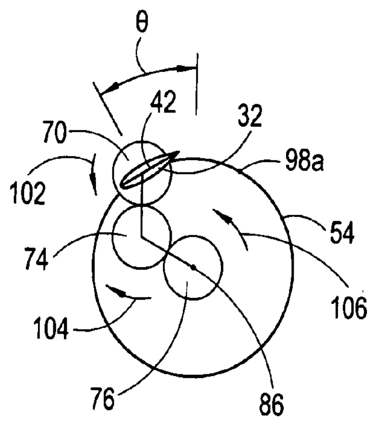

Fig. 7A

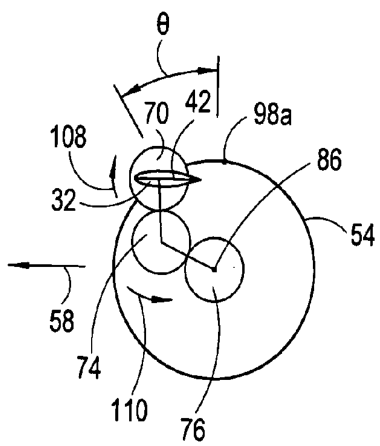

Fig. 7B

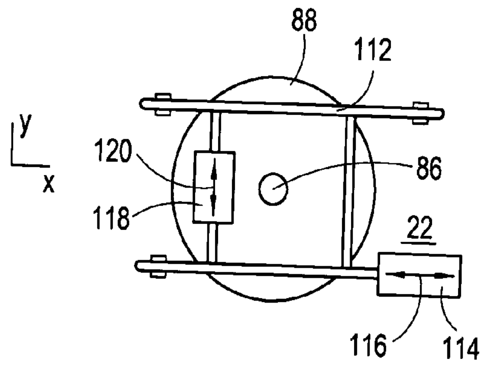

Fig. 8

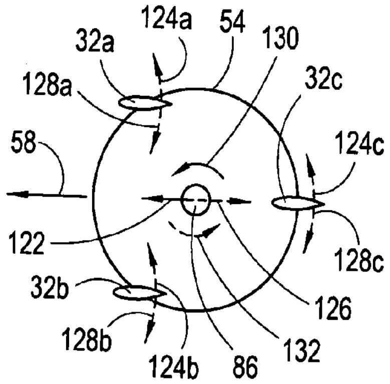

Fig. 9A

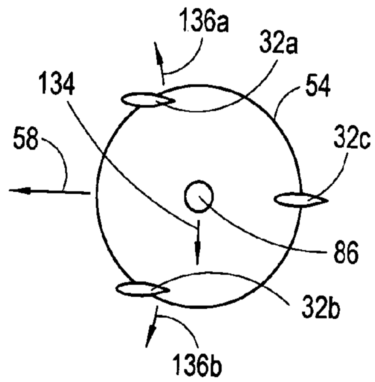

Fig. 9B

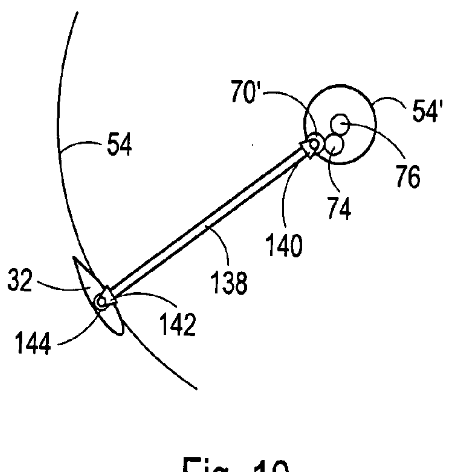

Fig. 10

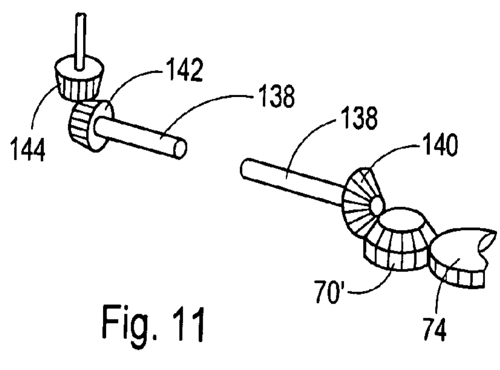

Fig. 11

CYCLOIDAL VTOL UAV

FIELD OF THE INVENTION

[0001] The present invention pertains generally to propulsion and flight control systems for heavier-than-air and lighter-than-air vehicles. In particular, the present invention pertains to propulsion and flight control systems that incorporate airfoils which can be held stationary or rotated in different rotational modes. The present invention is particularly, but not exclusively, useful as a system and method for in-flight transitions of an aircraft's propulsion and control system between a fixed wing flight mode and selected rotating wing flight modes.

BACKGROUND OF THE INVENTION

[0002] For atmospheric flight by heavier-than-air vehicles, it is well known that airfoils can be used in various ways to either propel or control the flight of the vehicle. For example, propellers are airfoils; the wings of airplanes are airfoils; and the rotor-blades of helicopters are airfoils. Broadly defined, an "airfoil" is a part or a surface, such as a wing, a propeller blade or rudder, whose shape and orientation control the stability, direction, lift, thrust, or propulsion of an aerial vehicle. For the purposes of the present invention, an airfoil is to be generally considered as an aerodynamically shaped, elongated blade that defines a longitudinal axis which extends from the root of the blade to its tip. The blade also defines a chord line that extends from the leading edge of the blade to its trailing edge, and that is generally perpendicular to the blade axis. As is well known, various configurations of airfoils have been designed and constructed for different kinds of aerial vehicles. The more commonly known vehicles that incorporate airfoils include: airplanes, helicopters, auto-gyros, rockets, and tilt-wing aircraft.

[0003] It has long been an objective in the design of manned aerial vehicles, to provide a vertical take-off and landing (VTOL) aircraft that is capable of performing within an extended operational flight envelope. Insofar as speed is concerned, such an aerial vehicle would preferably have a flight envelope that extends from hovering flight (i.e. zero velocity) to high-speed flight (e.g. greater than 250 knots). Further, it would be desirable for such a vehicle to have the capability of effectively, efficiently, and smoothly transitioning from one flight mode (e.g. hover, slow flight and high-speed flight) to another flight mode.

[0004] With certain limitations, helicopters and tilt wing aircraft are examples of aerial vehicles that have been designed with many of the above-mentioned objectives in mind. In this development and design process, however, other vehicle configurations have also been developed. As early as the 1930s, there was some experimentation with the so-called cycloidal propellers. Specifically, these propellers each incorporate several blades which move on respective cycloidal-type paths as they rotate about a common axis. Cycloidal propellers have the common characteristic that the respective longitudinal axis of each blade remains substantially parallel to a common axis of rotation as the propeller is rotated. In another aspect, however, cycloidal propellers can be rotated in either of two modes. One mode (curtate) is characterized by a blade movement wherein the chord line of the blade remains substantially tangential to the rotational path of the blade around the common axis. Another mode (prolate) is characterized by a blade movement wherein the chord line of the blade remains substantially parallel to the flight path of the vehicle as the blade is rotated around the common axis. In particular, a discussion of prolate flight is provided by U.S. Pat. No. 2,045,233 which issued in 1934 to Kirsten et al. for an invention entitled "Propeller for Aircraft." In contrast with the cycloidal modes of blade movement, if the blade is stabilized, so as not to rotate around the common axis, a third mode (fixed wing) is established. It happens that each of the above-mentioned flight modes has its advantages.

[0005] In light of the above, it is an object of the present invention to provide a system for moving an aerial vehicle which can propel and control the vehicle at hover and slow flight (curtate flight mode), at intermediate flight speeds (prolate flight mode), and in high-speed cruise (fixed wing mode). Another object of the present invention is to provide a system for moving an aerial vehicle that can effectively, efficiently, and smoothly transition between the curtate, prolate and fixed wing modes of flight. Yet another object of the present invention is to provide a system for moving an aerial vehicle which is simple to operate, relatively easy to manufacture, and comparatively cost effective.

SUMMARY OF THE INVENTION

[0006] The present invention is directed to a combined, cycloidal transmission and flight control system that operates to control and selectively propel an aerial vehicle along a flight path in either of three different operational flight modes. As described below in detail, these flight modes are: 1) curtate flight (hover and slow flight); 2) prolate flight (intermediate forward speeds); and 3) fixed wing flight (high speed forward flight).

[0007] Structurally, the system of the present invention requires a pair of rotatable hubs that are each individually mounted on opposite sides of the vehicle's fuselage. A plurality of equally, spaced-apart blade gears (e.g. three) are mounted near the periphery of each hub for rotation with the hub about a hub axis. Further, an airfoil blade is fixedly attached to each blade gear for movement with the blade gear. Thus, when the hub is rotated for flight in either the curtate or the prolate flight mode, each airfoil blade will travel on a blade path around the hub axis. In these two flight modes, the airfoils provide propulsion, as well as lift and control of the vehicle. On the other hand, when the hub is held stationary on the fuselage (a fixed wing flight mode), the airfoils' only function is to provide lift and control. Propulsion in the fixed wing flight mode is then provided either by a shrouded propeller on the empennage of the vehicle, or by some other propulsion means.

[0008] Each airfoil blade in the system of the present invention defines both a blade axis that extends the length of the blade, and a chord line that extends from the leading edge to the trailing edge of the airfoil blade. Operationally, a gear assembly moves each blade gear to individually control the angle of attack for each airfoil blade (i.e. the angle between the chord line of the airfoil and the relative wind). Specifically, this gear assembly is changeable to transition the system between its various flight modes. As indicated above, these modes are: the curtate flight mode (a first modality) wherein the chord line of the blade is maintained generally tangential to the blade path during the rotation of the hub; the prolate flight mode (a second modality) wherein the chord line of the blade is maintained generally parallel to the flight path of the vehicle as the blade rotates on its blade path; and the fixed wing flight mode (a third modality) wherein the chord line of the blade is maintained generally parallel to the flight path of the vehicle while the hub is held stationary on the vehicle.

[0009] In accordance with the present invention, control for each airfoil blade is provided by a dedicated gear assembly that collectively includes the blade gear mentioned above, a mid-gear, and a center gear. In their relationship to each other, the mid-gear is positioned between the blade gear and the center gear. Further, in each gear assembly there is a link that interconnects the center of the blade gear to the center of the mid-gear. Also, there is another link that interconnects the center of the mid-gear to the center of the center gear. Within this assembly, the blade gear and the mid-gear can be rotated about their respective axes in all of the three flight modes. For the prolate flight mode, however, although the blade gear and mid-gear can still rotate, rotation of the center gear is constrained.

[0010] As implied above, several (e.g. three) gear assemblies will be incorporated into each hub. The respective center gears will then establish a gear cluster in which all of the center gears rotate about a common center gear axis. An indexing of the respective center gears in the cluster, however, will be different in the curtate mode than it is in the prolate mode. Specifically, consider that as each center gear rotates about the center gear axis, it has a predetermined start point on the hub where its azimuthal angle (ϕ) is zero ($\phi=0°$). Then for a three gear assembly system, as the hub is rotated in the curtate mode there will need to be a 120° off-set between the azimuthal start points for each of the center gears (i.e. $\phi_1=0°$, $\phi_2=120°$, and $\phi_3=240°$). On the other hand, for the prolate mode, all of the center gears will need to be re-indexed with a common azimuthal start point (i.e. $\phi_1=\phi_2=\phi_3=0°$).

[0011] In operation, for both the curtate and prolate flight modes, the hubs on the vehicle are rotated around the hub axis by a drive shaft. Because the blade gears are mounted at or near the periphery of the hub, they are also driven along the blade path around the hub axis. When the center gears of the gear assemblies are allowed to rotate on the shaft, around their common center gear axis with off-set start points ($\phi_1=0°$, $\phi_2=120°$, and $\phi_3=240°$), the result of hub rotation is the curtate flight mode. On the other hand, when the center gears are held stationary on the shaft (i.e. the center gears do not rotate about the common center gear axis, with $\phi_1=\phi_2=\phi_3=0°$) the result of hub rotation is the prolate flight mode. Thus, in both the curtate and prolate flight modes, the rotating hub causes the airfoil blades to move with their respective blade gears on the blade path around the hub axis of rotation.

[0012] As indicated above, for the curtate flight mode (i.e. when the center gears have off-set start points) the chord line of the airfoil remains substantially tangential to the blade path. For propulsion and control purposes, cyclical variations of the respective angles of attack for each airfoil in the curtate mode are introduced by moving the cluster of center gears. Specifically, this movement is accomplished by moving the cluster of center gears omni-directionally in a plane such that the common center gear axis remains substantially parallel to the hub axis of rotation. A consequence of this is that cyclical changes in the respective angles of attack remain azimuthally uniform as the airfoil blades rotate about the hub axis.

[0013] For the prolate flight mode (i.e. when the center gears are constrained), although the airfoil blades still rotate with the blade gear around the hub axis, the chord line of the airfoil remains substantially tangential to the flight path of the vehicle. In this flight mode, the center gears are indexed so that all of the airfoils have a common azimuthal start point ($\phi_1=\phi_2=\phi_3=0°$) for their respective rotations about the hub axis. Again, however, cyclical changes in the respective angles of attack will remain azimuthally uniform as the airfoil blades rotate about the hub axis. Like the curtate flight mode, when the vehicle is in the prolate flight mode, propulsion and control of the vehicle is primarily obtained by cyclical variations in the respective angles of attack for each airfoil. Again, like the curtate mode, these variations are introduced by moving the center gears such that the common center gear axis remains substantially parallel to the hub axis of rotation.

[0014] As indicated above, for fixed wing flight, the hubs are stopped. Specifically, the hubs are stopped when hub rotation slows to below about 5 RPM, and they are stopped at a predetermined position. For example, when there are three airfoil blades per hub, the fixed wing configuration will preferably have two forward airfoil blades and one trailing blade. Specifically, one of the forward airfoils is stopped directly under the other, with the trailing airfoil blade generally behind and between the two forward airfoils. To accomplish this, both RPM and hub position can be measured electronically, and a solenoid latch can be activated to stabilize the hub when its correct position has been reached.

[0015] Control over the airfoil blades in the fixed wing flight mode can be accomplished in several ways. For one, the angle of attack for all of the airfoil blades can be uniformly changed in unison by rotating the center gear. For another, the angle of attack for only the trailing airfoil blade can be changed. This is done by moving the center gears fore and aft. Further, by moving the center gears with a component that is perpendicular to the fore and aft movement, the airfoil blades can be moved to act as spoilers.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] The novel features of this invention, as well as the invention itself, both as to its structure and its operation, will be best understood from the accompanying drawings, taken in conjunction with the accompanying description, in which similar reference characters refer to similar parts, and in which:

[0017] **FIG. 1** is a perspective view of an aerial vehicle employing the cycloidal propulsion system of the present invention;

[0018] **FIG. 2** is a cross-sectional view of an airfoil (blade) of the cycloidal propulsion system of the present invention as seen along the line **2-2** in **FIG. 1**, with representative aerodynamic forces acting on the airfoil superposed thereon;

[0019] **FIG. 3A** is a schematic view of the airfoils (blades) of the cycloidal propulsion system in a curtate mode of flight;

[0020] **FIG. 3B** is a schematic view of the airfoils (blades) of the cycloidal propulsion system in a prolate mode of flight;

[0021] **FIG. 4** is a cross-sectional view of a hub assembly for the system of the present invention as seen along the line **4-4** in **FIG. 1**;

[0022] **FIG. 5** is a schematic view of a gear assembly with attached airfoil;

[0023] **FIG. 6A** is an exploded representation of the center gear cluster of a hub assembly showing the interaction of center gears in the curtate flight mode;

[0024] **FIG. 6B** is an exploded representation of the center gear cluster of a hub assembly showing the interaction of center gears in the prolate flight mode;

[0025] **FIG. 7A** is a schematic representation of a rotation of a gear assembly through an angle θ in the curtate flight mode;

[0026] **FIG. 7B** is a schematic representation of a rotation of a gear assembly through an angle θ in the prolate flight mode;

[0027] **FIG. 8** is a schematic representation of a servo control system for controlling the cycloidal propulsion system of the present invention;

[0028] **FIG. 9A** is a representative view of airfoil angle of attack movements in response to translational movements of the center gear cluster;

[0029] **FIG. 9B** is a representative view of airfoil angle of attack movements in response to a rotational movement of the center gear cluster;

[0030] **FIG. 10** is an alternate embodiment of a gear assembly in accordance with the present invention; and

[0031] **FIG. 11** is a perspective view of the linkage used for the alternate embodiment of the gear assembly shown in **FIG. 10**.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0032] Referring initially to **FIG. 1**, an aerial vehicle that incorporates a cycloidal propulsion and control system in accordance with the present invention is shown and is generally designated **20**. As shown, the vehicle **20** has a fuselage **22** and an empennage **24**. A shroud **26** is shown mounted on the empennage **24** and a propeller **28** is surrounded by the shroud **26**. From **FIG. 1** it will be appreciated there is a hub assembly on each side of the fuselage **22** that includes a hub **30** and a plurality of blades **32**. As intended for the present invention, the plurality of blades **32** can be rotated with the hub **30** around the hub axis **34**. At this point, it is to be noted that for purposes of this disclosure, the blades **32***a*, **32***b* and **32***c* shown in **FIG. 1** are only exemplary because there may be either more or fewer blades **32** used in a hub assembly. Accordingly, discussions herein are often made with reference to only a single blade **32**. With this in mind, the referenced blade **32** may, in fact, be any one of the blades **32***a*, **32***b* or **32***c*. In any event, each blade **32** is an airfoil.

[0033] As indicated in **FIG. 1**, each blade **32** (e.g. blade **32***a*) has a blade axis **36** that extends generally in a direction from the root **38** of the blade **32** to its tip **40**. Using this structure as a base for reference, the aerodynamic properties of the blade **32** will be better appreciated with reference to **FIG. 2**. There it will be seen that each blade **32** defines a chord line **42** that extends from the leading edge **44** of the blade **32** to its trailing edge **46**, and that is generally perpendicular to the blade axis **36**. Depending on several factors, which include the respective design shapes of the upper surface **48** and the lower surface **50** of blade **32**, as well as the angle of attack (a) between the chord line **42** and the relative wind **52**, an aerodynamic force (F) will be generated on the blade **32** in accordance with well known aerodynamic principles. Specifically, as shown in **FIG. 2**, components of the force (F) will include lift (L) and drag (D), as well as a moment (M). For purposes of this disclosure, it is sufficient to appreciate that these forces are generated on the blade **32** in response to a relative wind **52**, and that these forces can be controlled by properly orienting the blade **32** with the relative wind **52**.

[0034] As mentioned above, the present invention envisions that blades **32** will be rotated by the hub **30** in either of two modes. These modes are the curtate mode and the prolate mode, and are respectively shown in **FIG. 3A** (curtate) and **FIG. 3B** (prolate). Specifically, it will be appreciated that as a blade **32** is rotated by the hub **30**, it will travel on a circular blade path **54** around the hub axis **34**. When rotated in the direction of arrow **56**, the blade **32** will sequentially pass through the locations on blade path **54** indicated by blade **32**, **32'** and **32"**. It is important to recognize that for rotation in the curtate mode **(FIG. 3A)**, at each blade location **32**, **32'** and **32"**, the orientation of the respective chord lines **42**, **42'** and **42"** will remain substantially tangential to the blade path **54**. On the other hand, for the prolate mode **(FIG. 3B)** the orientation of the respective chord lines **42**, **42'** and **42"** will remain substantially parallel to the direction of flight of the vehicle **20** (indicated by the arrow **58** in **FIG. 3B**). How this is accomplished for the present invention is best considered with initial reference to **FIG. 4**.

[0035] In **FIG. 4** it is to be appreciated that a hub gear **60** is fixedly attached to the hub **30**. Consequently, the rotation of a drive gear **62** by a drive shaft **64** will cause the hub **30** to rotate relative to the fuselage **22**. It will also be appreciated with reference to **FIG. 4** that the blade **32** is fixed to a blade shaft **66** and that, in turn, the blade shaft **66** is held on the hub **30** by a pivot mount **68**. As intended for the present invention, with this structure the blade **32** is driven along the blade path **54** by a rotation of the hub **30** while, at the same time, the blade **32** is free to independently rotate with the shaft **66** about the blade axis **36**. **FIG. 4** also shows that a blade gear **70** is attached to the blade shaft **66** for movement therewith.

[0036] By cross referencing **FIG. 4** with **FIG. 5** it will be seen that the blade gear **70** is a component of a gear assembly that is shown in **FIG. 5** and generally designated **72**. In detail, the gear assembly **72** includes the blade gear **70** as well as a mid-gear **74** and a center gear **76**. Further, the gear assembly **72** includes a link **78** that interconnects the center of rotation of blade gear **70** with the center of rotation of mid-gear **74**. Similarly, a link **80** interconnects the center of rotation of mid-gear **74** with the center of rotation of center gear **76**. At this point it is to be understood that, for the present invention, each hub **30** preferably includes three separate gear assemblies **72**. Accordingly, the respective center gears **76** of the gear assemblies **72** have been variously designated **76***a*, **76***b* and **76***c*.

[0037] In **FIG. 4**, for one embodiment of the present invention, it is shown that the center gear **76***a* is fixedly attached to a sleeve shaft **82**. The link **80**, however, which connects the respective centers of rotation of the mid-gear **74** and the center gear **76***a* is connected to an inner shaft **84**. As shown, the inner shaft **84** is coaxial with the sleeve shaft **82** and, accordingly, both the inner shaft **84** and sleeve shaft **82** will rotate about a same center gear axis **86**. Importantly, although the center gear axis **86** and the hub axis **34** remain parallel to each other, they are not necessarily collinear (i.e. coaxial). As disclosed in more detail below, relative off-set movements between the center gear axis **86** and the hub axis **34** provide control over the angle of attack (α) of the airfoil blade **32**.

[0038] Still referring to **FIG. 4**, an x-y pad **88** is shown which is mounted on the vehicle **20** so as to be moveable relative to the fuselage **22**. Further, a brake **90** is mounted on the x-y pad **88** that is used to selectively grip and hold the sleeve shaft **82** stationary relative to the x-y pad **88**. Additionally, there is a brake **92** that is mounted on the sleeve shaft **82** to selectively grip and hold the inner shaft **84** stationary relative to the sleeve shaft **82**. Thus, when the brake **92** is activated, and brake **90** is deactivated, sleeve shaft **82** will rotate together with the inner shaft **84** about the center gear axis **86**. In this configuration the center gear **76***a* and the other gears **70**, **74** in the gear assembly **72** are driven by a rotation of the hub **30** (curtate mode). On the other hand, when the brake **90** is activated and brake **92** is deactivated, the sleeve shaft **82** is held stationary relative to the x-y pad **88**. The inner shaft **84**, however, is able to rotate inside the sleeve shaft **82**. In this configuration the center gear **76***a* is not driven in rotation by the hub **30**. Instead, the mid-gear **74**, which is still being driven by hub **30**, rotates around the periphery of the center gear **76***a* (prolate mode). The effect that this has on other center gears **76** in a cluster (e.g. the cluster of center gears **76***a*, **76***b* and **76***c*) will perhaps be best appreciated with reference to **FIGS. 6A and 6B**.

[0039] Referring initially to **FIG. 6A**, it is noted that the center gears **76***a*, **76***b* and **76***c* collectively constitute a gear cluster. In **FIG. 6A**, this cluster is shown with the individual center gears **76** in an exploded relationship relative to each other. From this relationship it can be seen that the center gear **76***a* is formed with a pin **94***a*. As indicated, the pin **94***a* is affixed to the center gear **76***a* and extends therefrom for insertion into an azimuthal slot **96***b* that is formed into the center gear **76***b*. Similarly, the center gear **76***b* has a pin **94***b* that extends therefrom for insertion into an azimuthal slot **96***c* that is formed into center gear **76***c*. For a cluster of three center gears, the azimuthal slots **96***b* and **96***c* on center gears **76***b* and **76***c*, respectively, will each extend through an arc of 120° (i.e. $\phi_2=\phi_3=120°$). Thus, when the center gear **76***a* rotates about the center gear axis **86**, as indicated by the arrow **100**, a start point **98***b* on center gear **76***b* will follow the start point **98***a* on center gear **76***a* by the angle $\phi_2=120°$. Similarly, a start point **98***c* on center gear **76***c* will follow the start point **98***b* on center gear **76***b* by the angle $\phi_3=120°$. For referencing purposes, the indexing of the center gears **76***a*, **76***b* and **76***c* as shown in **FIG. 6A** pertains to the curtate flight mode.

[0040] Unlike the situation portrayed in **FIG. 6A**, the gear cluster shown in **FIG. 6B** is not being rotated. Specifically, this condition occurs when the brake **90** is activated to stop the rotation of center gear **76***a* relative to the x-y pad **88**. The other center gears in the cluster (i.e. center gears **76***b* and **76***c*), however, do not stop rotating with the center gear **76***a*. Instead, when the center gear **76***a* is stopped, the center gear **76***b* will continue to rotate through the angle ϕ_2 (e.g. 120°) until the interaction between pin **94***a* of center gear **76***a* and the azimuthal slot **96***b* in center gear **76***b* stops the center gear **76***b*. Center gear **76***c*, will then still continue to rotate through the angle ϕ_3 (e.g. another 120°) until the interaction between pin **94***b* of center gear **76***b* and the azimuthal slot **96***c* in center gear **76***c* stops the center gear **76***c*. At this point, as seen in **FIG. 6B**, the respective start points **98***a*, **98***b* and **98***c* of center gears **76***a*, **76***b* and **76***c* are in alignment. For referencing purposes, the indexing of the center gears **76***a*, **76***b* and **76***c* as shown in **FIG. 6B** pertains to the prolate flight mode.

[0041] The consequences of respectively indexing the representative clusters of center gears **76** shown in **FIGS. 6A and 6B** will, perhaps, be best appreciated by referencing **FIG. 6A** with **FIG. 7A** (curtate mode) and **FIG. 6B** with **FIG. 7B** (prolate mode). When making these references, consider that the center gear **76** shown in **FIGS. 7A and 7B** may be either center gear **76***a*, **76***b* or **76***c*. Also, consider that the position of airfoil blade **32**, as shown in both **FIGS. 7A and 7B**, indicates a rotation of the hub **30** through an angle θ, starting from a location wherein the airfoil blade **32** is positioned as shown in **FIG. 5**. With all of this in mind, first consider the curtate mode of flight (**FIG. 7A**) wherein the center gear **76** is driven by the hub **30** in rotation around the center gear axis **86**.

[0042] As seen in **FIG. 7A**, with a rotation of the hub **30** through an angle θ, the airfoil blade **32** is moved along an arc on the blade path **54** through the same angle θ. This movement causes the blade gear **70** to urge against the mid-gear **74**, which, in turn, urges against the center gear **76**. As this happens, the centers of the various gears **70**, **74** and **76** remain connected by the respective links **78** and **80**, and the center gear axis **86** is held substantially stationary relative to the blade path **54**. The result is that all of the gears **70**, **74** and **76** will rotate. Specifically, the blade gear **70** rotates in the direction of arrow **102**, the mid-gear **74** rotates in the direction of arrow **104**, and the center gear **76** rotates in the direction of arrow **106**. Because all of the gears **70**, **74** and **76** have substantially the same diameter, the consequence of this is that the chord line **42** of airfoil blade **32** remains substantially tangential to the blade path **54** (this is the curtate mode). On the other hand, when the center gear **76** is held stationary for the prolate mode, only the blade gear **70** and mid-gear **74** will rotate in response to a rotation of the hub **30**. Specifically, as shown in **FIG. 7B** the blade gear **70** will rotate in the direction of arrow **108**, and mid-gear **74** will rotate in the direction of arrow **110**. The consequence in this case is that the respective rotations of the gear **70** and **74** off-set or cancel each other. Thus, during movement of the airfoil blade **32** along the blade path **54**, the chord line **42** of the blade **32** remains substantially parallel to the flight path of the vehicle **20**, indicated by the arrow **58**.

[0043] An important fact for consideration in the blade motions discussed above is the location of the start points **98** for the various center gears **76** as the airfoil blades **32** travel around the hub axis **34** on blade path **54**. In the curtate mode (**FIG. 6A** and **FIG. 7A**) the start points **98***b* and **98***c* of center gears **76***b* and **76***c*, respectively, follow the start point **98***a* of center gear **76***a* by 1200 and 2400. Within this relationship, the chord lines **42** of the respective blades **32***a-c* remain substantially tangential to the blade path **54** at all locations on the blade path **54**. In the prolate mode, however (**FIG. 6B** and **FIG. 7B**), the center gears **76***a-c* are re-indexed so that all of the gears **76** are effectively aligned to have a common start point **98**. Within this relationship, the chord lines **42** of the respective blades **32***a-c* have a same orientation at each same point on the blade path **54**. Specifically, as intended for the present invention, this same orientation at each same point maintains the chord line **42** of the respective airfoil blades **32** substantially parallel to the flight path of the vehicle **20**.

[**0044**] Control over the respective angles of attack (α) for the airfoil blades **32** in the curtate and prolate flight modes is accomplished by collectively moving the cluster of center gears **76** in translation. Specifically, this translation is accomplished by moving the center gear axis **86** in a radial direction from the hub axis **34**, while the center gear axis **86** remains substantially parallel to the hub axis **34**. In particular, the translational movement of the cluster of center gears **76** is accomplished by moving the x-y pad **88**. In **FIG. 8** it will be seen that to do this, a frame **112** is mounted on the fuselage **22** and a servo **114**, which is also mounted on the fuselage **22**, is connected between the fuselage **22** and the frame **112** to move the frame **112** in a back-and-forth motion in the x-direction (indicated by the arrows **116**). Another, independently operated servo **118** is mounted directly on the x-y pad **88** and it is connected with the frame **112** to move the frame **112** in a back-and-forth motion on the x-y pad **88** in the y-direction (indicated by the arrows **120**). As intended for the present invention, movement of the x-y pad **88** in its x-y plane on the fuselage **22** can be accomplished omni-directionally through distances from the hub axis **34** that may be as much as one half of the diameter of the center gears **76**. The omni-directional capability of this movement can then be employed to cyclically vary the angle of attack (a) for individual airfoil blades **32**. Specifically, this control will generate forces on the airfoil blades **32** in a manner that will control the speed and direction of flight of vehicle **20** in either the curtate or prolate modes. In the fixed wing mode, however, control is obtained by selectively introducing combinations of translational and rotational movements of the cluster of center gears **76**.

[**0045**] For control over the vehicle **20** in the fixed wing flight mode, refer to **FIG. 9A** and **FIG. 9B**. Specifically, as indicated above, the vehicle **20** is propelled in the fixed wing flight mode by the shrouded propeller **28** on the empennage **24**. Accordingly, rotation of the hub **30** is not required. Therefore, as the RPM of hub **30** falls below about 5 RPM, the drive shaft **64** is disengaged and the hub **30** is locked to the fuselage **22** by a latch (not shown). Preferably, when the hub **30** is locked for the fixed wing mode, the airfoil blades **32** will be arranged relative to the direction of flight (arrow **58**), generally as shown in **FIG. 9A**. With this configuration, it is to be appreciated that a translational movement of the center gear axis **86** in directions substantially parallel to the chord lines **42***a-c* will move the airfoil blade **32***c*. Specifically, by moving the center gear axis **86** in the forward direction, indicated by arrow **122**, the airfoil blade **32***c* will move in the direction of arrow **124***c*. On the other hand, an aft movement of the center gear axis **86** in the direction indicated by arrow **126** results in the movement of airfoil blade **32***c* in the direction of arrow **128***c*. It is also to be appreciated that pure rotational movements of the cluster of center gears **76** will result in movements of all of the airfoil blades **32***a-c*. Specifically, a rotation of the center gears **76** in the direction of arrow **130** will result in a movement of the airfoil blades **32***a-c* in the direction of arrows **124***a-c*, and a rotation of the center gears **76** in the direction of arrow **132** will result in a movement of the airfoil blades **32***a-c* in the direction of arrows **128***a-c*. As another possible control configuration for the airfoil blades **32***a-c* in the fixed wing mode, **FIG. 9B** indicates that a movement of the center gear axis **86** in the direction of arrow **134** will result in respective movements of the airfoil blades **32***a* and **32***b* in the directions of arrow **136***a* and **136***b*. Thus, the airfoils **32***a* and **32***b* can provide a braking action for the vehicle **20** that is opposite to its direction of travel (indicated by arrow **58**).

[**0046**] For an alternate embodiment of the gear assembly discussed above, reference is made to both **FIG. 10** and **FIG. 11**. There it will be seen that the dimensions of the gear assembly (i.e. gears **70**, **74** and **76**) have been reduced. In this case the center gear **76** and mid-gear **74** are interconnected with a bevel blade gear **70'** that travels on a modified blade path **54'**. An extension arm **138** is provided with a bevel gear **140** at one end which interacts with the bevel blade gear **70'**. At the other end of extension arm **138** there is another bevel gear **142** that interacts with a second bevel blade gear **144**. The airfoil blade **32** is affixed to this second bevel blade gear **144** and, through the actions of bevel gears **140** and **142**, the airfoil blade **32** is controlled by the center gears **76** substantially as disclosed above.

[**0047**] While the particular Cycloidal VTOL UAV as herein shown and disclosed in detail is fully capable of obtaining the objects and providing the advantages herein before stated, it is to be understood that it is merely illustrative of the presently preferred embodiments of the invention and that no limitations are intended to the details of construction or design herein shown other than as described in the appended claims.

What is claimed is:

1. A system for moving an aerial vehicle along a flight path, said system comprising:

a substantially disk-shaped hub mounted on the vehicle for rotation about a hub axis, with said hub lying in a plane substantially perpendicular to the hub axis;

an airfoil shaped blade positioned on said hub for rotation therewith, wherein said blade travels on a blade path around the hub axis during rotation of said hub, said blade defining a blade axis and a chord line;

a gear assembly changeable between a first modality (curtate flight) wherein the chord line of said blade is maintained generally tangential to the blade path during rotation of said hub, and a second modality (prolate flight) wherein the chord line of said blade is maintained generally parallel to the flight path of the vehicle during rotation of said hub; and

a means for rotating the chord line of said blade about said blade axis to alter the angle of attack of said blade and generate forces for moving the vehicle along the flight path.

2. A system as recited in claim 1 wherein said gear assembly comprises:

a blade gear, with said blade fixedly attached thereto, said blade gear being mounted on said hub for rotation around the blade axis and for rotation with said blade around the hub axis;

a center gear oriented on said hub for rotation around a center gear axis with the center gear axis substantially parallel to the hub axis; and

a mid-gear rotationally interconnecting said blade gear with said center gear.

3. A system as recited in claim 2 further comprising:

a first link having a first end and a second end with the first end thereof pivotally mounted on said blade gear and the second end thereof pivotally mounted on said mid-gear; and

a second link having a first end and a second end with the first end thereof pivotally mounted on said mid-gear and the second end thereof pivotally mounted on said center gear.

4. A system as recited in claim 3 wherein said chord line rotating means comprises a means for moving the center gear to vary a distance between the center gear axis and the blade axis.

5. A system as recited in claim 4 wherein said center gear has a diameter and the center gear axis is moveable within a radial range from the hub axis between a location wherein the center gear axis is coaxial with the hub axis and a location wherein the center gear axis is approximately at a one half center gear diameter from the hub axis.

6. A system as recited in claim 2 wherein the blade axis is substantially perpendicular to the chord line, and wherein the blade axis is substantially parallel to the hub axis during rotation of said blade on the blade path around the hub axis.

7. A system as recited in claim 2 further comprising a means for selectively holding said center gear stationary relative to said hub axis to establish said gearing means in the second modality.

8. A system as recited in claim 2 further comprising a means for holding said hub stationary relative to the vehicle to change said gear assembly into a third modality (fixed wing flight).

9. A system as recited in claim 8 wherein said chord line rotating means comprises a means for rotating said center gear while said gear assembly is in the third modality.

10. A system as recited in claim 2 wherein said blade, said blade gear, and said mid-gear, in combination, comprise a blade orientation unit and said system comprises:

a plurality of said blade orientation units; and

a plurality of center gears with each said center gear connected to a respective blade orientation unit.

11. A cycloidal propulsion and control system for moving an aerial vehicle along a flight path which comprises:

a first hub and a second hub, said first and second hubs being respectively mounted on the vehicle for rotation about a common hub axis;

a first plurality of elongated airfoil blades defining respective chord lines and mounted on said first hub substantially parallel to the hub axis for rotation about the hub axis;

a second plurality of elongated airfoil blades defining respective chord lines and mounted on said second hub substantially parallel to the hub axis for rotation about the hub axis; and

a means for individually and selectively varying an orientation for each chord line of each said airfoil blade for propelling and controlling the vehicle while the vehicle is on the flight path.

12. A system as recited in claim 11 wherein each rotating airfoil blade travels on a blade path around the hub axis and wherein said varying means comprises a gear assembly changeable between a first modality (curtate flight) wherein the chord line of said blade is maintained generally tangential to the blade path during rotation of said hub, and a second modality (prolate flight) wherein the chord line of said blade is maintained generally parallel to the flight path of the vehicle during rotation of said hub.

13. A system as recited in claim 12 wherein each airfoil blade defines a blade axis and wherein said gear assembly comprises:

a blade gear, with said airfoil blade fixedly attached thereto, said blade gear being mounted on said hub for rotation around the blade axis and for rotation with said blade around the hub axis;

a center gear oriented on said hub for rotation around a center gear axis with the center gear axis substantially parallel to the hub axis; and

a mid-gear rotationally interconnecting said blade gear with said center gear.

14. A system as recited in claim 13 wherein three gear assemblies are mounted on each said hub.

15. A system as recited in claim 14 wherein each center gear has a respective start point for establishing a same orientation for the chord line of each airfoil blade at a predetermined point on the blade path.

16. A system as recited in claim 15 wherein said respective start points of said three center gears are mutually off-set from each other by an arc of 120° (curtate mode).

17. A system as recited in claim 15 wherein said respective start points of said three center gears are substantially aligned with each other (prolate mode).

18. A method for moving an aerial vehicle along a flight path which comprises the steps of:

mounting a first plurality of elongated airfoil blades on a first hub, wherein each airfoil blade defines a chord line and is mounted on said first hub substantially parallel to a hub axis of rotation;

mounting a second plurality of elongated airfoil blades on a second hub, wherein each airfoil blade defines a chord line and is mounted on said second hub substantially parallel to the hub axis of rotation;

selectively rotating the first and second plurality of airfoil blades about the hub axis; and

individually and selectively varying an orientation for each chord line of each said airfoil blade for propelling and controlling the vehicle while the vehicle is on the flight path.

19. A method as recited in claim 18 wherein each rotating airfoil blade travels on a blade path around the hub axis and wherein said varying step involves changing between a first modality (curtate flight) wherein the chord line of said blade is maintained generally tangential to the blade path during rotation of said hub, and a second modality (prolate flight) wherein the chord line of said blade is maintained generally parallel to the flight path of the vehicle during rotation of said hub.

20. A method as recited in claim 19 further comprising the step of holding said hub stationary relative to the vehicle to change said gear assembly into a third modality (fixed wing flight).

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(54) TRI-CYCLOIDAL AIRSHIP

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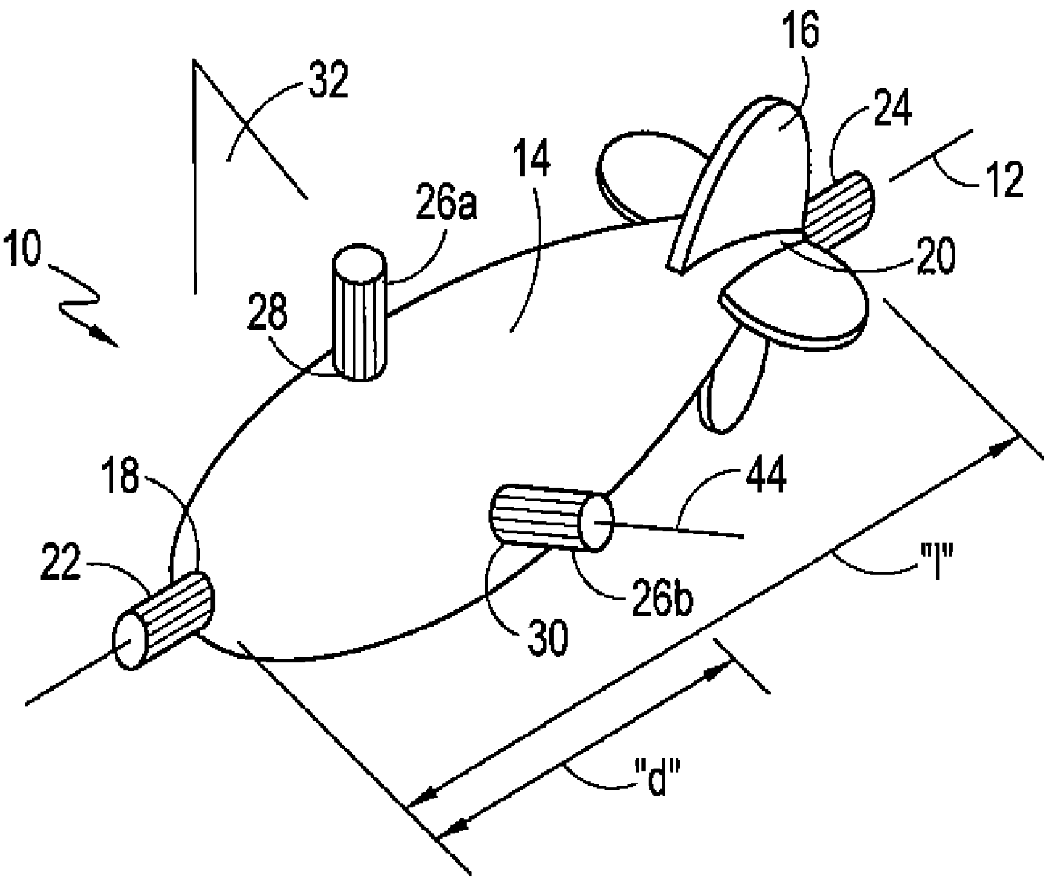
(57) ABSTRACT

An unmanned, lighter-than-air airship includes three omni-directional thrust generating units. One unit is mounted at the fore-end of the airship to generate thrust in a plane that is perpendicular to the longitudinal axis of the airship. This unit controls pitch and yaw movements of the airship. The other two units are mounted on the airship equidistant from the first unit, and are located in a same midships plane that is perpendicular to the longitudinal axis. These two units generate thrust vectors that control roll movements of the airship and provide propulsion for the airship.



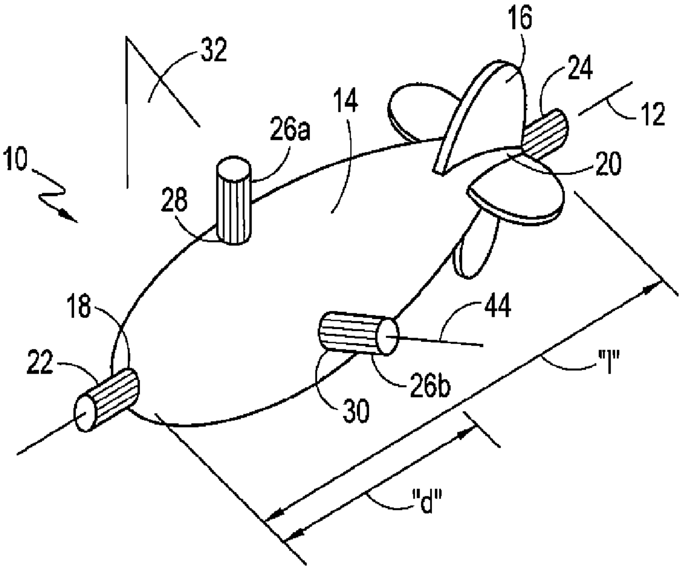


Fig. 1

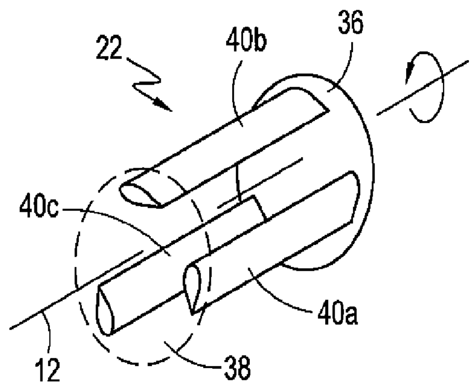


Fig. 2

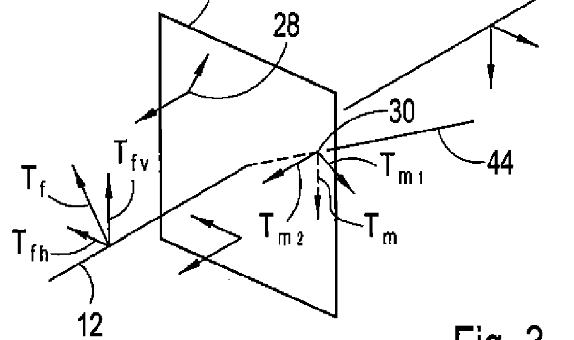


Fig. 3

TRI-CYCLOIDAL AIRSHIP

FIELD OF THE INVENTION

[0001] The present invention pertains generally to systems and methods for flying unmanned, lighter-than-air airships. More particularly, the present invention pertains to systems and methods for both propelling and controlling the flight of an airship. The present invention is particularly, but not exclusively useful as a system and method for operating omnidirectional, cycloidal units that generate thrust vectors which, in concert, propel an airship, as well as provide control in pitch, yaw and roll.

BACKGROUND OF THE INVENTION

[0002] Control over the propulsion and maneuver of an airborne vehicle, just like control over land or sea vehicles, requires an ability to selectively generate controllable forces on the vehicle. In the simple case where a hot air balloon is being used as an airborne vehicle, only the lifting force that is necessary to overcome the weight of the balloon can be generated and controlled. Thus, hot air balloons can not be effectively maneuvered. As a practical matter, however, most airborne vehicles need to be maneuverable. To do this, it is necessary to generate forces on the vehicle that will keep it airborne (i.e. lift) and propel it through the air (i.e. thrust). Additionally, it is necessary to generate forces that will establish and maintain a desired altitude for the airborne vehicle in pitch, yaw and roll, as it is being propelled through the air.

[0003] For the specific case of a lighter-than-air airship, the lifting force that keeps the airship airborne is a lighter-than-air gas (e.g. helium). In general, the gas that is to provide lift is somehow confined within the fuselage of the airship, much like a hot air balloon. For such a vehicle, however, the maneuver forces that provide control for thrust, pitch, yaw and roll must be provided by other means. Typically, these forces are provided by various combinations of propulsion units (e.g. engine driven propellers), and control surfaces (e.g. rudder, elevator and trim planes). When used in manned airships, where some degree of operational stability is essential for crew effectiveness, typical power plants and control surfaces are quite adequate. On the other hand, if the airship is unmanned, non-traditional power plants may be more effectively employed. This will be particularly so if the airship's fuselage is to be maneuvered and maintained in variously selected orientations for extended periods of time, which might otherwise cause extreme discomfort for an aircrew member.

[0004] Examples of applications for an unmanned airship include such uses as advertising and surveillance. For instance, it is apparent that about only one-third of an airship's fuselage surface can be effectively seen by an observer on the ground. On the other hand, an airship that can be maneuvered in roll through 120°, and thereafter selectively held stationary, could effectively present a sequence of three different advertisements to the same viewing audience. In another application, an airship that can be maneuvered to be geo-stationary for a selected period of time, and then conveniently moved to another geo-stationary location, could be useful for a variety of surveillance applications. In these, and all other cases, there are control considerations that need to be addressed. Importantly, in all of these cases, control is provided by the selective application of forces on the airship.

[0005] Power plants (i.e. propulsion units) for airborne vehicles are of many types and variations. In all instances, however, they are specifically employed to generate a thrust vector that has both a direction and a magnitude. One particular type of propulsion unit that is of specific interest here, is a so-called cycloidal propulsion unit. Such a unit is disclosed in detail in U.S. application Ser. No. 10/690,284 titled "Cycloidal VTOL UAV," which is assigned to the same assignee as the present invention and which is incorporated herein, in its entirety. The particularly interesting aspect of such a cycloidal propulsion unit is the fact that it can generate a thrust vector that is located in a definable plane. In particular, a cycloidal propulsion unit can generate a thrust vector of variable magnitude, and establish a direction for the thrust vector that is variable through 360° in the plane. Simply stated, a cycloidal propulsion unit can create a thrust vector that is controllable and variable in both magnitude and direction, in a given plane.

[0006] In light of the above, it is an object of the present invention to provide a lighter-than-air airship that incorporates cycloidal propulsion units for producing maneuver and control forces on the airship. Another object of the present invention is to provide an airship with the ability to execute 360° of roll, and maintain a selected orientation in roll for an extended period of time. Yet another object of the present invention is to provide an airship that can selectively move to, and then loiter at, a sequence of geo-stationary locations. Still another object of the present invention is to provide a lighter-than-air airship with cycloidal propulsion units that is relatively easy to manufacture, is simple to operate, and is comparatively cost effective.

SUMMARY OF THE INVENTION

[0007] An airship in accordance with the present invention includes a fuselage for holding a lighter-than-air gas that provides lift for the airship. Further, the fuselage has a fore-end and an aft-end, and it also defines a longitudinal axis that extends between the two ends. Maneuverability of the airship is provided by various thrust generators that are mounted on the fuselage to provide both propulsion and control for the airship. Specifically, due to their respective locations, and their orientations on the fuselage, these thrust generators are capable of providing propulsion, as well and control in pitch, yaw and roll for the airship. As intended for the present invention, all of the thrust generators are omnidirectional, cycloidal units.

[0008] For the present invention, one omnidirectional, cycloidal unit is mounted at the fore-end of the fuselage. This particular unit generates a thrust that is selectively directed in a thrust vector plane which is substantially perpendicular to the longitudinal axis of the airship. The specific purpose of this unit is to control both the pitch and yaw motions of the airship. Additionally, another such unit can be mounted at the aft-end of the fuselage for this same purpose. For the present invention, if both units are employed, they can be controlled either individually, or in concert with each other. Further, an empennage can be formed on the airship to aerodynamically assist in the pitch and yaw control of the airship.

[0009] In addition to the thrust generators disclosed above, the airship of the present invention also includes a plurality of omnidirectional, cycloidal units that are mounted on the fuselage and are located in a same, midships plane. In detail, the midships plane is perpendicular to the longitudinal axis of the airship, and it is located at a distance "d" from the fore-end of the airship. Further, with the distance between the fore-end and the aft-end of the airship being a distance "l", the distance "d" will preferably be less than half of "l" (d<l/2). Within this arrangement, each of the thrust generating units in the midships plane will generate a thrust vector that can be selectively directed in a respective thrust vector plane. Each of these thrust vector planes is substantially parallel to the longitudinal axis of the airship. Thus, they are able to provide both propulsion for the airship, and control for the roll motions for the airship.

[0010] In one embodiment of the present invention, there are two propulsion/control units in the midships plane. For this embodiment the thrust vector plane of the first propulsion/control unit is substantially parallel to the thrust vector plane of the second propulsion/control unit. In another embodiment of the present invention there are at least three, and possibly more, such propulsion/control units. For either embodiment, all of the propulsion/control units are mounted on the fuselage substantially equidistant from the longitudinal axis. Further, they are each substantially equidistant from each adjacent propulsion/control unit.

[0011] For purposes of the present invention, all of the omnidirectional, thrust-generating, control units are cycloidal and, preferably, they all operate in a curtate mode. Operational control of the units can be accomplished individually, or in concert with each other. This is so for control units that are positioned on the longitudinal axis of the airship (pitch and yaw control), and for the propulsion/control units that are positioned in the midships plane (propulsion and roll control).

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] The novel features of this invention, as well as the invention itself, both as to its structure and its operation, will be best understood from the accompanying drawings, taken in conjunction with the accompanying description, in which similar reference characters refer to similar parts, and in which:

[0013] FIG. **1** is a perspective view of an airship in accordance with the present invention;

[0014] FIG. **2** is a perspective view of a cycloidal propulsion unit for the airship of the present invention with portions thereof shown in phantom for clarity; and

[0015] FIG. **3** is a representative illustration of a relationship between thrust vectors of propulsion units, and their respective orientations, as used for propelling and maneuvering an airship in accordance with the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0016] Referring initially to FIG. **1**, an airship in accordance with the present invention is shown, and is generally designated **10**. As shown, the airship **10** defines a longitudinal axis **12** and includes a fuselage **14** with an empennage **16**. More specifically, the longitudinal axis **12** extends between a fore-end **18** of the airship **10**, and its aft-end **20**. As intended for the present invention, the airship **10** is a lighter-than-air vehicle. Therefore the fuselage **14** is filled with a lighter-than-air gas, such as Helium. In many respects, the airship **10** is much like any other so-called "blimp." The primary difference between the airship **10** and other lighter-than-air vehicles, however, is in its systems for propulsion and control.

[0017] For purposes of propelling and controlling the airship **10**, FIG. **1** shows that the airship **10** includes a propulsion unit **22** that is mounted at the fore-end **18** of the airship **10**. Also, FIG. **1** shows that there is a propulsion unit **24** mounted at the aft-end **20** of the airship **10**, and that there is a plurality of propulsion units **26** mounted on the fuselage **14**. In detail, FIG. **1** shows that a propulsion unit **26***a* is mounted at a point **28** on the fuselage **14**, and that a propulsion unit **26***b* is mounted at a point **30** on the fuselage **14**. It is to be appreciated, however, that there may be additional propulsion units **26** for the airship **10** and that the propulsion units **26***a,b* are, therefore, only exemplary. Regardless of how many propulsion units **26** are used, they will all be, preferably, mounted in a same midships plane **32** (note: only a portion of the midships plane **32** is indicated in FIG. **1**). As for the relationship of the midships plane **32** to the airship **10** (see FIG. **1**), it is located somewhere between the fore-end **18** and the aft-end **20**, and it is substantially perpendicular to the longitudinal axis **12** of the airship **10**. Further, for a distance "l" between the fore-end **18** and the aft-end **20**, the midships plane **32** will be located on the axis **12**, at a distance "d" from the fore-end **18**. Preferably, "d" is less than half the distance "l" (d<l/2).

[0018] For purposes of this disclosure, the propulsion unit **22**, shown in FIG. **2**, is only exemplary. Indeed, for the airship **10** of the present invention, the other propulsion units **24** and **26** are all substantially identical to the propulsion unit **22**. In particular, all of these propulsion units are omnidirectional, and they all function in a cycloidal mode. Structurally, as shown in FIG. **2**, the propulsion unit **22** includes a hub **36** and a hub **38** that are oriented to rotate about a same axis (e.g. axis **12**). Further, they jointly support a plurality of airfoil blades **40***a,b,c* between them. Thus, as the hubs **36** and **38** are rotated to move the airfoil blades **40***a,b,c* around the axis **12**; and as the airfoil blades **40***a,b,c* are controlled to generate variable forces as they rotate around the axis **12**; the propulsion unit **22** will generate a thrust vector (T). Importantly, the thrust vector (T) will always be directed in a thrust vector plane that is substantially perpendicular to the axis **12**. The actual direction of the thrust vector (T) in the thrust vector plane, however, will depend on the cycloidal input that is given to the airfoil blades **40***a,b,c*. In this operation, the propulsion unit **22** will move the airfoil blades **40***a,b,c* in a curtate mode that is described in greater detail in U.S. application Ser. No. 10/690,284 mentioned above.

[0019] For the airship **10**, insofar as their individual operation is concerned, the propulsion units **22**, **24** and **26** are all substantially identical. They are, however, mounted at different locations on the fuselage **14**. With this in mind, first consider the propulsion unit **22** (see FIG. **2**) with reference to FIG. **3**. With this consideration it is to be seen that the propulsion unit **22** can be operated to create a thrust vector T_f that is directed in a plane perpendicular to the longitudinal axis **12** of the airship **10**. Importantly, the thrust vector T_f will have both a vertical component T_{fv} and a horizontal component T_{fh}. Depending on the magnitude and the direction of T_f in the plane perpendicular to the axis **12**, the vertical component T_{fv} can be varied to control pitch for the airship **10**. Similarly, the horizontal component T_{fh} that can be varied to control the yaw motion of the airship **10**. As mentioned above, it is to be appreciated that a propulsion unit **24** at the aft-end **20** can be added to supplement the control aspects provided by the propulsion unit **22**. Now consider the propulsion unit **26***b* that is located in the midships plane **32**. By cross-referencing FIG. **3** with FIG. **1**, it will be seen that the propulsion unit **26***b* can be operated to create a thrust vector T_m that is perpendicular to its axis **44**. Also, it is seen that this thrust vector T_m is directed in a plane that is parallel to the axis **12**. Thus, depending on its magnitude and direction, this thrust vector T_m can be generated to have an azimuthal component T_{m1} and an axial component T_{m2}. Accordingly, for control purposes, the azimuthal component T_{m1} can be varied to control roll for the airship **10**. On the other hand, the axial component T_{m2} can be varied to provide propulsion for the airship **10**. As shown in the drawings, other propulsion units **26** can be positioned in the midships plane **32** and similarly operated to control roll and provide propulsion.

[**0020**] In an overview for the operation of the airship **10**, the propulsion unit **22** generates a thrust vector that lies in a thrust vector plane perpendicular to the longitudinal axis **12** of the airship **10**. Specifically, depending on its magnitude and direction, this thrust vector, T_f is used to control pitch and yaw motions of the airship **10**. If desired, a propulsion unit **24** can be added and used with the propulsion unit **22** for this same purpose. In an alternate embodiment, the propulsion unit **24** can possibly be used alone, as an alternative to the propulsion unit **22**. In any case, along with the propulsion units **24**/**26**, a desired number (i.e. a plurality) of propulsion units **26** are mounted on the airship **10** in the midships plane **32**. Specifically, these propulsion units **26** are used to generate thrust vectors that lie in respective thrust vector planes that are parallel to the longitudinal axis **12** of the airship **10**. These thrust vectors (provided by propulsion units **26**) have azimuthal components that control roll of the airship **10**, and axial components that provide propulsion for the airship **10**.

[**0021**] While the particular Tri-Cycloidal Airship as herein shown and disclosed in detail is fully capable of obtaining the objects and providing the advantages herein before stated, it is to be understood that it is merely illustrative of the presently preferred embodiments of the invention and that no limitations are intended to the details of construction or design herein shown other than as described in the appended claims.

What is claimed is:

1. An airship which comprises:

a fuselage having a fore-end and an aft-end, and defining a longitudinal axis extending therebetween;

at least one control unit mounted on said fuselage for generating thrust directed in a thrust vector plane substantially perpendicular to the longitudinal axis to control pitch and yaw motions of said airship; and

a plurality of propulsion/control units mounted on said fuselage, with each said propulsion/control unit generating thrust directed in a respective thrust vector plane substantially parallel to the longitudinal axis to provide propulsion and roll control motions for said airship.

2. An airship as recited in claim 1 comprising a plurality of said control units, with a first said control unit mounted at the fore-end of said airship and a second said control unit mount at the aft-end of said airship.

3. An airship as recited in claim 2 further comprising means for operating said first control unit in concert with said second control unit.

4. An airship as recited in claim 2 further comprising a means for operating said first control unit independently from said second control unit.

5. An airship as recited in claim 1 comprising a first propulsion/control unit and a second propulsion/control unit, wherein the thrust vector plane of said first propulsion/control unit is substantially parallel to the thrust vector plane of said second propulsion/control unit.

6. An airship as recited in claim 1 comprising three said propulsion/control units, wherein all said propulsion/control units are mounted on said fuselage substantially equidistant from the longitudinal axis and are located in a same midships plane, wherein the midships plane of said propulsion/control units is substantially perpendicular to the longitudinal axis and each propulsion/control unit is substantially equidistant from each other said propulsion/control unit.

7. An airship as recited in claim 1 further comprising a means for concerted operation of said at least one control unit and said plurality of propulsion/control units.

8. An airship as recited in claim 1 wherein said at least one control unit and said plurality of propulsion/control units are cycloidal and operate in a curtate mode.

9. An airship as recited in claim 1 wherein said airship is lighter-than-air.

10. A propulsion and control system for an unmanned airship which comprises:

a first omnidirectional cycloidal unit for generating and directing thrust in a first thrust vector plane to control pitch and yaw movements of the airship;

a second omnidirectional cycloidal unit for generating and directing thrust in a second thrust vector plane; and

a third omnidirectional cycloidal unit for generating and directing thrust in a third thrust vector plane, wherein both said second unit and said third unit are equidistant from said first unit and are located in a midships plane, with the midships plane at a predetermined distance "d" from said first unit, and wherein both said second unit and said third unit operate in concert with each other to provide propulsion and roll control for said airship.

11. A system as recited in claim 10 further comprising:

a fuselage having a fore-end and an aft-end, and defining a longitudinal axis extending therebetween, wherein said first omnidirectional cycloidal unit is mounted at the fore-end of said fuselage; and

a fourth omnidirectional cycloidal unit mounted at the aft-end of said fuselage.

12. A system as recited in claim 11 wherein said first unit and said fourth unit are located on the longitudinal axis with a distance "l" therebetween, and further wherein the distance "d" is less than half the distance "l" (d<l/2).

13. A system as recited in claim 11 further comprising an additional omnidirectional cycloidal unit located in the midships plane to provide propulsion and roll control for said airship.

14. A system as recited in claim 10 further comprising a means for concerted operation of said first, second and third units.

15. A system as recited in claim 10 wherein said first, second and third units are cycloidal and operate in a curtate mode.

16. A system as recited in claim 10 wherein said airship is lighter-than-air.

17. A method for propelling and controlling an airship which comprises the steps of:

generating at least three thrust vectors wherein each thrust vector lies in a respective thrust vector plane with a first thrust vector plane substantially perpendicular to both a second thrust vector plane and a third thrust vector plane; and

concertedly controlling a magnitude and a direction for each thrust vector, wherein control in the first thrust vector plane control pitch and yaw movements of the airship and control in the second and third thrust vector planes control propulsion and roll movements of the airship.

18. A method as recited in claim 17 wherein the thrust vectors are generated by omnidirectional cycloidal units.

19. A method as recited in claim 18 wherein the omnidirectional cycloidal units are operated in a curtate mode.

20. A method as recited in claim 17 wherein the airship is unmanned and is lighter-than-air.

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