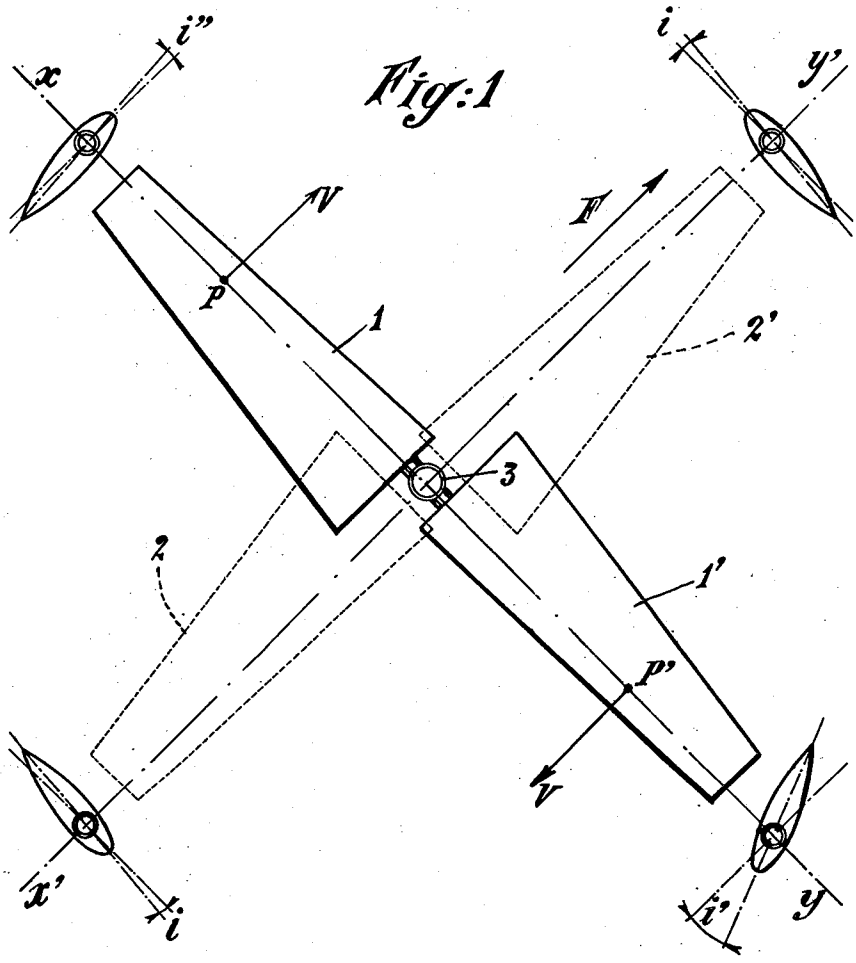
Feb. 26, 1952 L. BRÉGUET 2,587,104

APPARATUS OF THE GYROPLANE TYPE

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Fig. 1



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APPARATUS OF THE GYROPLANE TYPE

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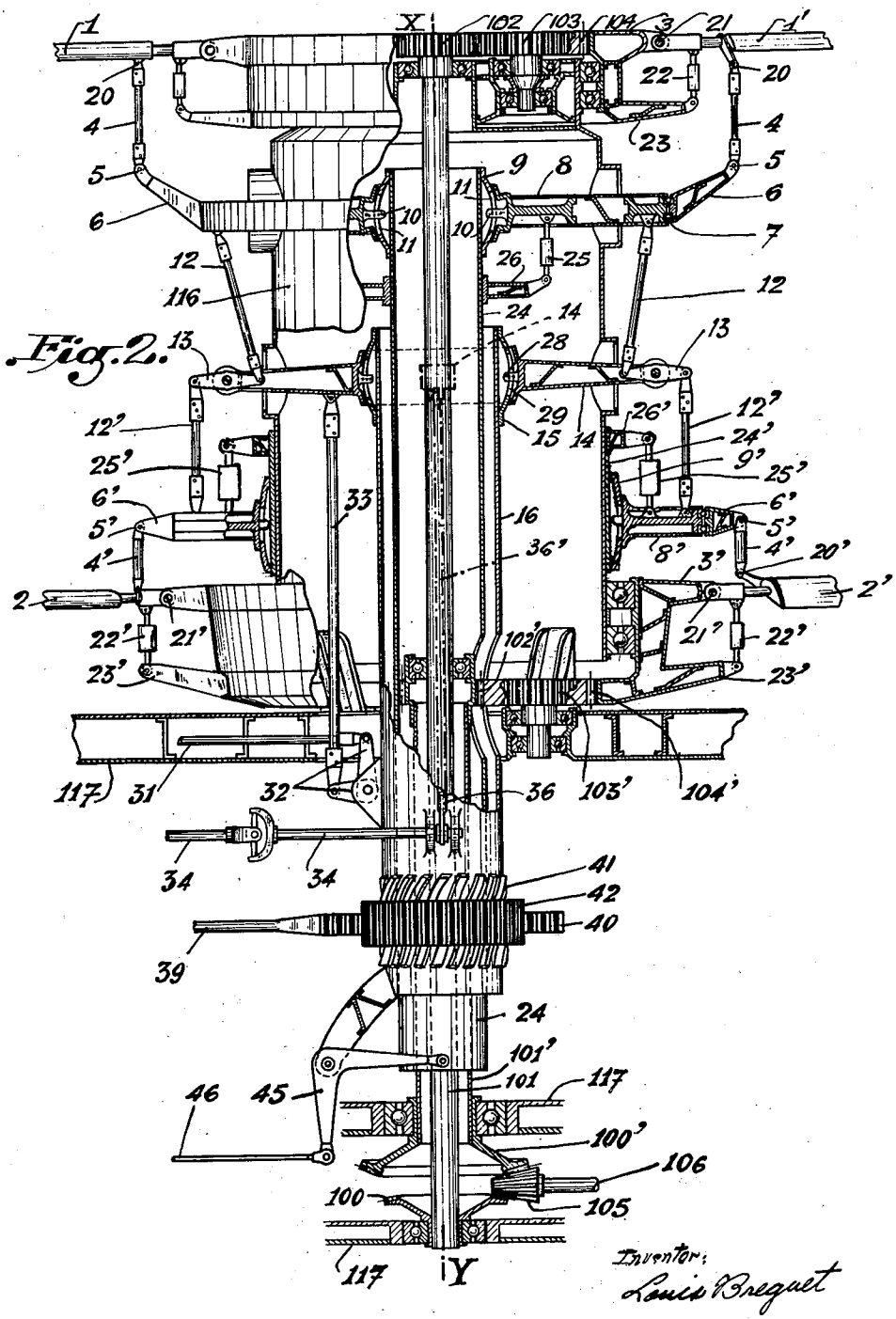


Fig. 2.

Inventor:
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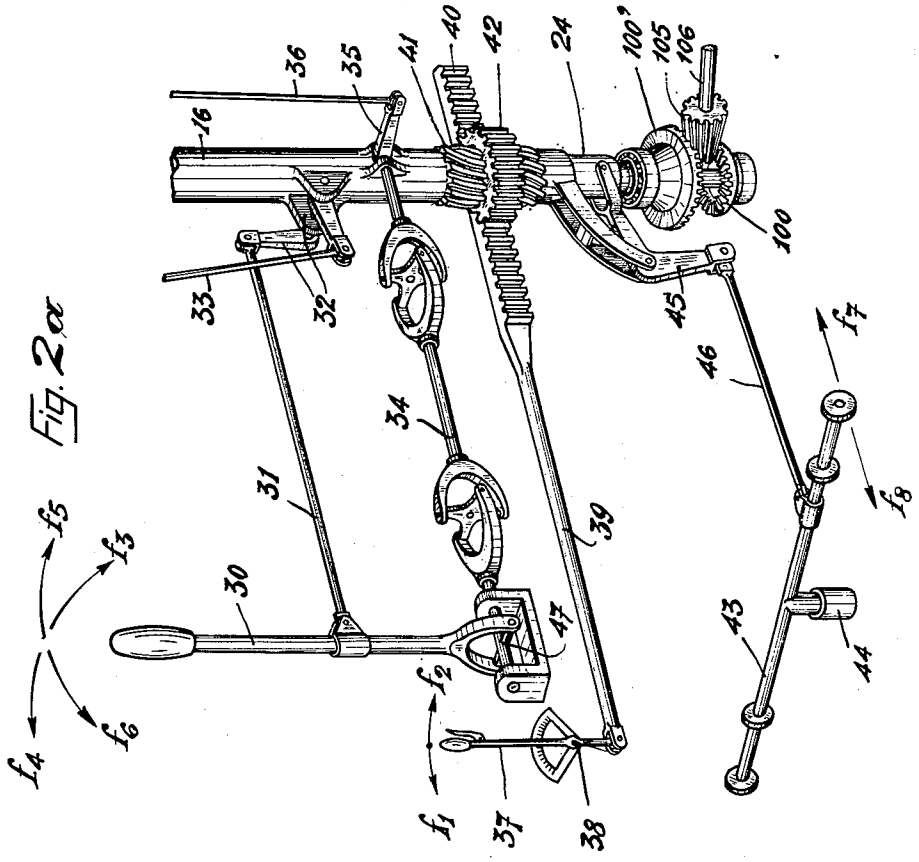
Watson, Cole, Grindle & Watson
Attys.

Feb. 26, 1952 L. BRÉGUET 2,587,104

APPARATUS OF THE GYROPLANE TYPE

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Fig. 2a



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APPARATUS OF THE GYROPLANE TYPE

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Fig. 3

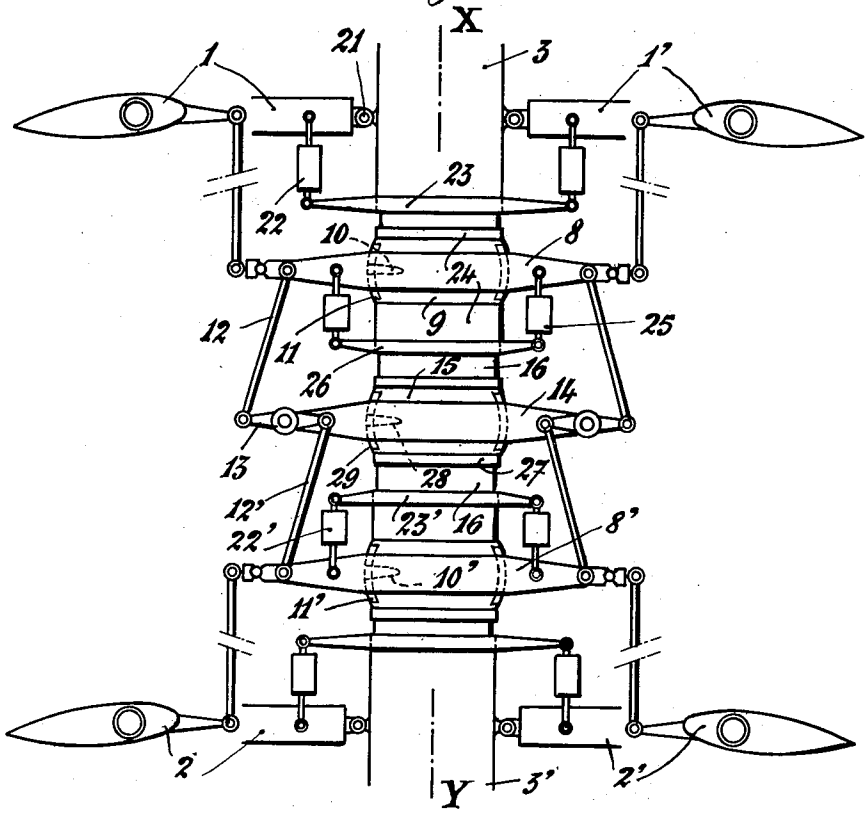
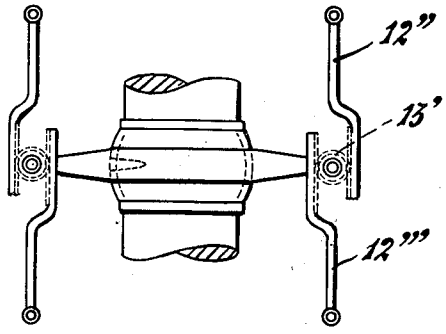


Fig. 4



INVENTOR

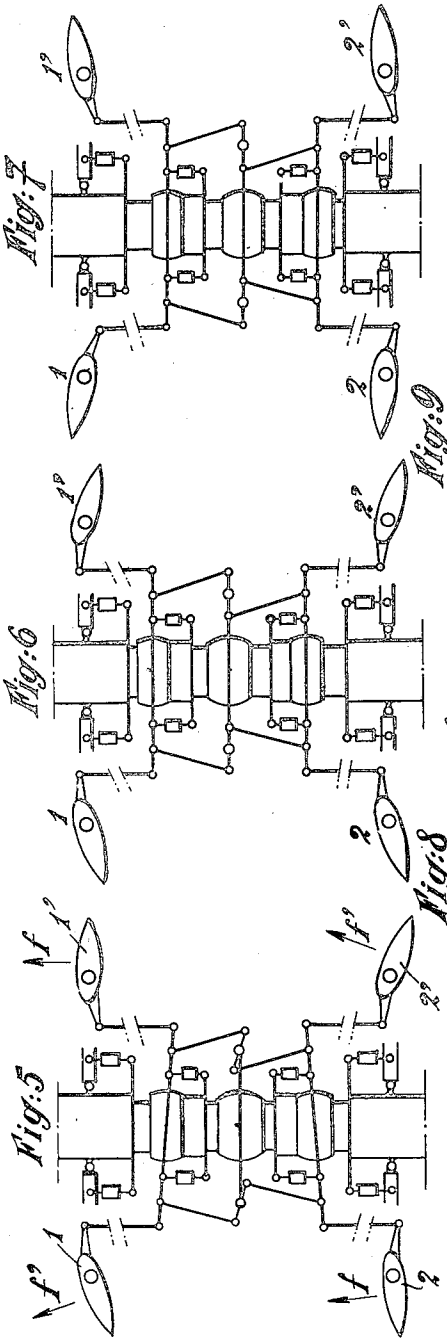
Louis Breguet

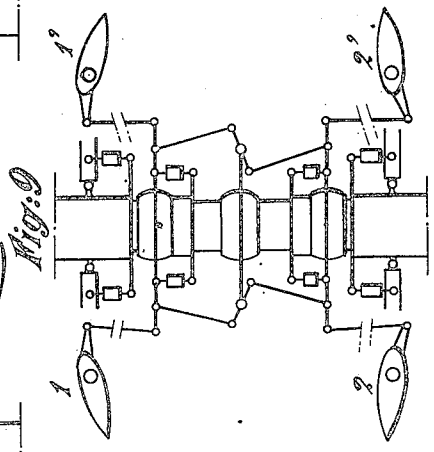
By Watson, Cole, Grindle & Watson

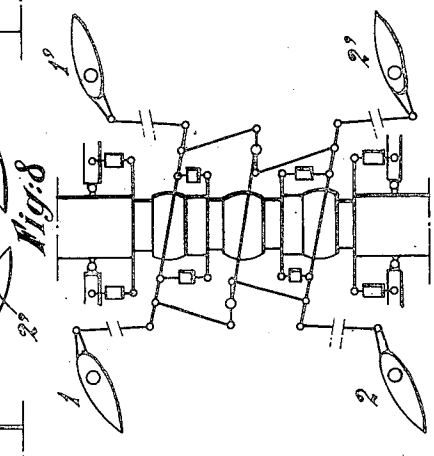
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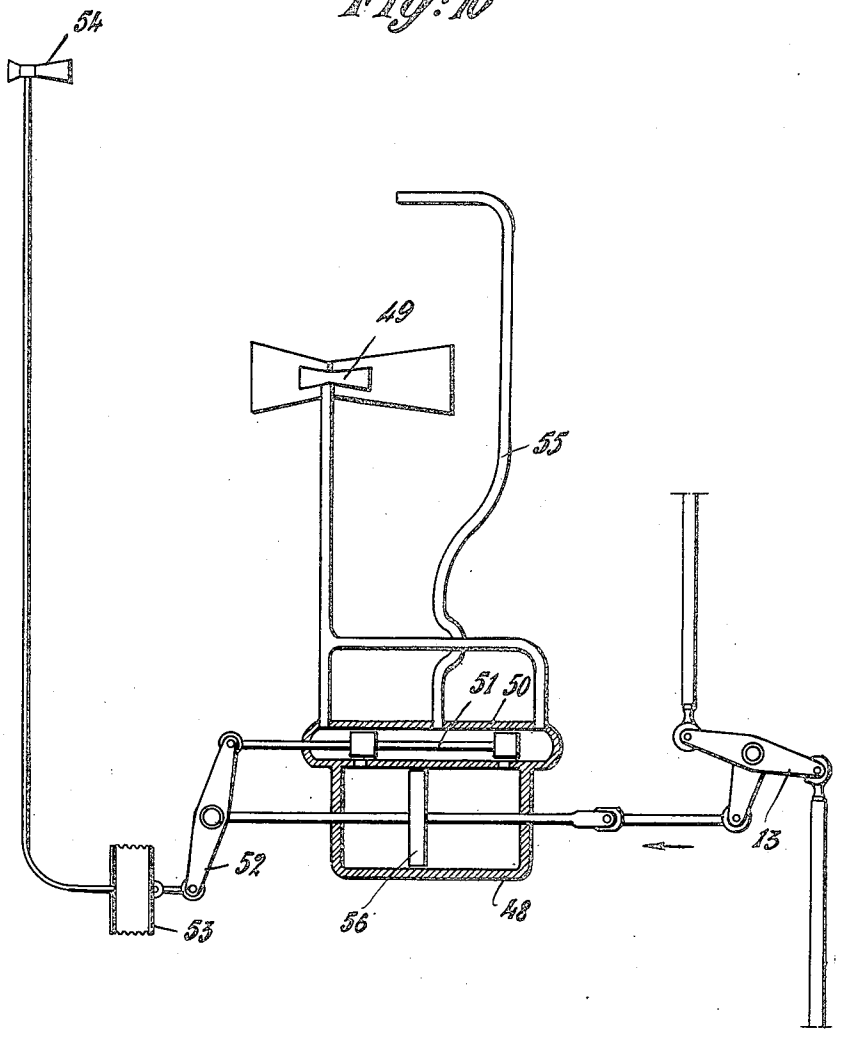
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Feb. 26, 1952 L. BRÉGUET 2,587,104

APPARATUS OF THE GYROPLANE TYPE

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Fig: 10



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UNITED STATES PATENT OFFICE

2,587,104

APPARATUS OF THE GYROPLANE TYPE

Louis Bréguet, Paris, France

Application August 13, 1946, Serial No. 690,321
In France September 30, 1941

Section 1, Public Law 690, August 8, 1946
Patent expires September 30, 1961

4 Claims. (Cl. 170—135.24)

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For ensuring the control of apparatuses with rotary sails of the gyroplane type both longitudinally and transversely and in order to provide for their equilibrium, it has already been proposed to use arrangements for increasing the angle of incidence of the blades when they pass in the meridian plane in which the pilot wishes to act while the angle of incidence of the diametrically opposed blades is simultaneously reduced.

These arrangements have an action equivalent to that obtained in Autogiros by inclining the hub of the propeller to which the blades are coupled through a free connection.

When in a gyroplane, the blades are freely pivoted to their hub in the usual manner, for instance through a cardan joint and the like means, the control of inclination and warping obtained through the above disclosed means lacks efficiency, accuracy and instantaneousness. This defect is chiefly ascribable to the vertical oscillations of the free blades as produced by the operation and to the buffeting generating objectionable secondary oscillations as produced when the gyroplane is progressing in a straight line or when the pilot acts on the control members, by reason of the rocking of the rotary plane of the arms and of the blades.

If in order to remove these drawbacks, the blades are rigidly connected with their hub, the righting torque produced by the variations in incidence may be considerable and its action almost instantaneous, but other defects may appear which are particularly serious when the gyroplane progresses translationally at considerable speeds, which results chiefly in an exaggerrated strain of the blades.

My invention has for its object an arrangement adapted to reduce the strain on the arms and blades in the gyroplane apparatuses including a rigid or semi-rigid connection for the blades, said arrangement being such that when the machine progresses translationally, there is produced an automatic reduction in the incidence of the blades under the action of the increased thrust and an increase of this incidence under the action of a reduced thrust.

The expression "semi-rigid connection of a blade" should be construed as meaning a connection which allows only a limited displacement of the blade in the plane defined by its axis and by the axis of rotation of the hub.

The improved arrangement is completed by a system ensuring a differential connection between the sails, or rotors, allowing in the case

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of two sails or rotors provided on the gyroplane in coaxial or non-coaxial relationship and adapted to rotate in opposite directions, a mutual balancing of the variations in the aerodynamic torque exerted on these two sails or rotors; there may be provided moreover an automatic compensated control acting through a general adjustment of all the blades of each rotor in accordance with the very translational speed of the gyroplane.

The following description given out with reference to the accompanying drawings by way of example and by no means in a limitative sense will allow my invention to be readily understood, the features appearing both in the drawings and in the specification forming obviously part of said invention.

Fig. 1 is an explanatory diagram showing in plan view two coaxial rotors rotating in opposite directions.

Fig. 2 is an elevational view, partly in section, of an embodiment of the invention.

Fig. 2*a* is a diagrammatic perspective view of the control members of a gyroplane fitted in accordance with my invention.

Fig. 3 is an elevational view of the differential connecting means in a particular position given thereto.

Fig. 4 illustrates a modification of said mechanism.

Figs. 5 to 9 are views similar to Fig. 3 but at a reduced scale, said diagrammatical views illustrating other positions of the connecting mechanism.

Fig. 10 shows diagrammatically in one of its forms of execution, the automatic control system.

In the arrangement shown in Fig. 1, it has been assumed that two opposite blades 1—1' are mounted, pivotally round their longitudinal axis *x*—*y*, on a hub 3 rotating clockwise round an axis perpendicular to the plane of the drawing and that these blades are given no degree of freedom with reference to the hub or may at the utmost move with a limited degree of freedom in the plane perpendicular to the plane of the figure, and passing through the axis *x*—*y*, said blades pivoting then round an axis perpendicular to said plane. Such a limited freedom of movement is given to the blades in order to avoid vibrations, but without allowing any flapping of said blades.

It has also been supposed that between the blades of the same rotor is provided a system for differential connection of the type described

in my prior U. S. Patent No. 1,919,089 and relating to a "Method and means for stabilizing, controlling and propelling a flying machine with rotary sails of the gyroplane type" said sails being power driven or rotating freely.

The mounting described in said prior patent provides through links connected with a rocking plate the balancing of the mean centrifugal and aerodynamic torques of two opposite blades of a same propeller or rotor or of two blades considered artificially as opposite in the case of an odd number of blades, so that the aerodynamic incidences i' and i'' of these blades may vary differentially until the torques balance one another.

With such a mounting, it is practically useless when the degree of freedom of the blades is limited, as stated, to resort to a rising and sinking movement of the blades as disclosed in my prior abovementioned patent for producing variations in incidence of the rotor during one revolution.

According to my present invention, there is provided a periodical modification of the incidences during one revolution whereby the pivoting of the blade round its longitudinal axis is rendered automatic under the action of an increase or reduction in the aerodynamic torque when the blade advances against a relative wind or recedes in said wind; this is provided by giving the blades a symmetrical section or outline, i.e. an outline for which the thrust center is invariable or else an autostable outline, i. e. an outline for which the center of thrust is displaced towards the front of the outline for increasing the thrust, the center of thrust being located to the rear of the longitudinal pivotal axis of the blade, which reduces the amplitude of the variations in incidence of each blade per revolution. The automatic pivoting thus obtained is practically instantaneous by reason of the small momentum of inertia of the blades round their longitudinal axis.

If it is supposed that this gyroplane assumes a translational movement in the direction of the arrow F at a speed v and that for instance the point P of the blade 1 advancing in the relative wind progresses by reason of the rotation of the rotor at a speed V higher than v, the aerodynamic torque at P as the blade passes in the plane perpendicular to v, as in the case illustrated, is proportional to the product of $(V+v)^2$ by the aerodynamic incidence; the corresponding torque at P' on the opposite blade 1' is proportional to the product of the aerodynamic incidence by $(V-v)^2$, as this latter blade recedes with reference to the relative wind. It is immediately apparent that by given different values to the angles of incidence i' and i'', it is possible to obtain a balancing of the mean aerodynamic torques and at the same time of the mean centrifugal torques of the blades 1 and 1' as stated; this is made possible by reason of the freedom of pivoting round the axis $x-y$ allowed for said blades.

In the case of symmetrical outlines, the thrusts which are proportional to the torques have a tendency to remain constant for each blade, which reduces the stresses to which said blades are submitted.

In the case of autostable outlines, i.e. of outlines of which the center of thrust advances when the incidences are reduced, said incidences will be reduced to a lesser extent than in the case of symmetrical outlines for blades advanc-

in the relative wind, which will allow within the limits authorized by the straining of the arms; thrusts which are more consistent with improved aerodynamic efficiencies.

In practice instead of a single couple of blades such as 1—1', it is preferable to use two thereof; the second pair shown in dotted lines at 2—2' in Fig. 1, moves in a direction opposite to the preceding pair; it is illustrated in the position for which the axis $x'-y'$ of the blades is parallel to the translational speed v, in which case the incidences i of the blades are the same.

It should be noticed that it is possible to provide in each rotor any desired number of blades angularly shifted by a same amount. However by way of simplification and in order to keep to the most frequent case, I will describe hereinafter the execution of my invention with rotors comprising only two diametrically opposed blades.

The above arrangement ensuring the cyclic arrangement of the incidences for each of the rotors mounted on the gyroplane will be advantageously completed in a gyroplane including two coaxial rotors rotating in opposite directions by an arrangement allowing the two primary rocking plates to assume opposite inclination.

The primary plates will be connected for this purpose by differential arrangements respecting their freedom of oscillation but allowing their simultaneous displacement or their angular relative shifting inside any meridian plane.

These automatic differential arrangements form one of the chief characteristics of the present invention. For allowing an easy control of a gyroplane, it is in fact necessary while allowing a free adjustment of the incidence as required for translational movement to obtain the possibility at every moment.

(*a*) of increasing the incidence of one blade while reducing that of the opposed blade as it passes through any given meridian plane. With two rotors rotating in opposite directions, the operation should preferably be performed on both propellers together, whereby it is possible for the pilot to produce any restoring torque as required for the warping or handling of the machine, indifferently when the translational speed is zero or for any value of the translational speed.

(*b*) of increasing or reducing in a general and permanent manner the incidences of all the blades for climbing or diving or for adjusting the pitch.

(*c*) of obtaining for two propellers rotating in opposite directions an incidence which is greater for one of the rotors than for the other, this forming in fact an easy manner of producing the giration or turning of the machine.

(*d*) lastly of automatically reducing the incidences of the blades when the throttle is being closed and consequently the driving of the rotor is reduced, the self rotation being performed with very small pitches.

Fig. 2 gives by way of example a general diagrammatic showing of a form of execution of this arrangement.

The general axis of revolution of the rotors is given out by X—Y. A so-called primary plate 8 is mounted centrally on a rotula 9 which allows it to rock in all directions, the center of this rotula being arranged on the axis X—Y. At the periphery of the plate 8 is arranged a ball bearing 7 the outer ring 6 of which is con-

nected through a connecting rod 4 with the blade 1 in the vicinity of its leading edge. The ends of the connecting rod 4 are pivotally secured through rotulas 5 and 20 to the ring 6 and to the blade 1 respectively. The other blade 1' of the rotor is coupled in a similar manner to the ring 6.

A similar connection is established between the blades 2 and 2' of the other rotor and a similar ring 6' is located at the periphery of another rocking plate 8'. The members corresponding to those illustrated with reference to the connection between the blade 1 and the plate 8 have received the same reference numbers accompanied by a dash.

I will refer hereinafter simultaneously to Fig. 2 and to the showing of Fig. 3 which has been modified diagrammatically as follows: in order to allow the incidences of the blades to appear more clearly, I have shown, above the inner end of the connecting rod 4, the connection of said rod with the corresponding blade cross-sectionally in a plane perpendicular to the axis of the blade; furthermore, I have shown at 3 and 3' the portions of the rotary shafts or hubs to which are connected the blades 1—1' and 2—2' respectively. As may be seen on Fig. 2, it is possible to figure in one's mind, these hubs are mounted for rotation in opposite directions on a stationary structure 116 borne by the frame 117 of the gyroplane having X—Y for an axis said hubs are driven by known means comprising for instance a bevel gear 100, a central shaft 101, pinions 102, 103 and 104 for hub 3 and a bevel gear 100', a hollow shaft 101' surrounding shaft 101, pinions 102', 103' and 104' for hub 3', bevel gears 100 and 100' being driven by a common bevel pinion 105 secured to a motor shaft 106. Finally I have shown by way of example a link 21 with an axis perpendicular to the plane of the drawing through the agency of which each blade is adapted to pivot in a plane defined by its axis x—y and the axis X—Y, the corresponding movements being braked and limited by elastic dampers 22 inserted between the blade and a collar 23 rigid with the hub 3; the same arrangement has been adopted for the other blades.

The plate 8 is rigid with a sleeve 24 adapted to slide with respect to the structure 116 and it carries a stud 10 engaging a meridian slot 11 in the rotula 9; thus the plate is adapted to assume any angular position without being allowed any relative rotation. The system of a rotula and locking means preventing rotation may be replaced by any equivalent means such for instance as a cardan joint. Elastic dampers 25 are inserted between the plate 8 and a collar 26 rigid with the sleeve 24 for braking and limiting the movements of said plate.

The same arrangement is adopted for the primary plate 8' and the corresponding members receive the same reference numbers accompanied by dashes.

Between the primary plates 8—8' is arranged a central plate 14 mounted on a rotula 15; the latter is rigid with a column 16. As in the case of the primary plates a stud 28 rigid with said plate 14 engages a meridian slot 29 in the rotula 15 and prevents any undesired rotation of said plate; in this case again a cardan joint may replace the system of the rotula and of the device for locking the plate against rotation. On Fig. 3, the hubs 3 and 3' and sleeves 24 and 24' have been diagrammatically shown as slidably mounted on column 16, whereas the rotula 15 has been

supposed to be rigid with a sleeve 27 secured to said column 16.

The primary plates 8—8' and the central plate 14 are interconnected through connecting rods 12—12', two connecting rods 12—12' being pivotally secured to a swing-bar 13 pivotally secured to the plate 14; it is possible to provide for instance four sets of connecting rods at 90° from one another or else three sets at 120°. By way of a modification (Fig. 4), it is possible to replace the swing-bars 13 by toothed wheels 13' meshing with racks provided at the ends of the rods 12''—12''' playing the same part as the corresponding rods 12—12'.

Reverting now more particularly to Fig. 2, it will be appreciated in order to make the showing clearer and the understanding easier that the column 16 is hollow and that it may rise and sink without rotating round the axis X—Y.

In the cockpit of the gyroplane are provided (Fig. 2a) two levers and a rudder bar which are within reach of the pilot for executing the different control operations. The lever 30 is mounted on a cardan joint at 47 and controls through a transmission illustrated under the form of a rod 31, a bell crank 32 and a rod 33, the angular setting of the central plate 14 which is caused to pivot round an axis perpendicular to the plane defined by the axis X—Y and the longitudinal axis of the gyroplane; this same lever 30 controls through a cardan shaft 34, an arm 35 and a rod 36 the angular setting of the central plate 14 by pivoting round a second axis perpendicular to the preceding axis.

The second control lever 37 is pivotally secured at 38 and provides through a rod 39 the end of which forms a rack 40 the rising and sinking movement of the column 16; to this end the column shows helical teeth 41 meshing with a pinion 42 provided with a corresponding tapping and with an outer series of teeth meshing with the rack 40.

The rudder bar 43 is pivotally secured at 44 and through the agency of a bell crank 45 and of a rod 46 it controls the rising and sinking movements of the primary plate 8.

The operation of the above described members and the manner of controlling the gyroplane thus equipped will be now disclosed, reference being made; more particularly to Fig. 2 considered in succession in combination with each of Figs. 5 to 9.

It will be first noticed that when the control levers 30—37 and the rudder-bar 43 occupy fixed positions and the primary plates 8—8' are capable of rocking in opposite directions round their rotulas 9—9' through the agency of the connecting rods 12—12' and of the swing-bars 13, this produces during flight the automatic and cyclic adjustment of the incidences; the incidence of the blades advancing against the relative wind is reduced while that of the blades receding in said wind increases. By reason of the differential equilibrium between the actions exerted on the primary rocking plates 8—8', no reaction is exerted on the central plate 14 and thereby no reaction is exerted either on the control levers and rudder bar.

Fig. 3 shows the plates 8—8' and 14 in their mean position perpendicular to the column 16, the conditions being then those of rest or of stationary flight for the gyroplane. In Fig. 5 which corresponds to Fig. 3 for the position of the levers and rudder-bar is shown clearly the inclination

in opposite directions of the plates 8—8' under the conditions defined in the preceding paragraph, the thrust on the blades 1 and 1' and on the blades 2 and 2' compensating one another.

Fig. 6 corresponds to the case where the pilot has caused the control lever 37 to rock in the direction of the arrow *f1* so as to produce a rise of the central plate 14 and therewith of the two primary plates 8—8'; in this case, the incidence of all the blades has increased which corresponds to rising position. If conversely, (Fig. 7) the pilot causes the lever 37 to pivot in the direction of the arrow *f2* the incidences of all the blades are reduced; the position obtained corresponds therefore to downward flight.

If the pilot rocks the control lever 30 in the direction of the arrow *f3* for instance, the blades are submitted on the left hand side to an increase in incidence (Fig. 8) and to a reduction in incidence on the right hand side, when they pass through the plane containing the axis X—Y and perpendicular to the longitudinal axis of the gyroplane. If the inclination is provided in the opposite direction *f4* the incidence increases on the right hand side and is reduced on the left hand side. A similar disclosure is applicable if the lever is inclined either in the direction of the arrow *f5* or in the direction of the arrow *f6* and generally speaking in any direction. This provides thus for warping action.

In the case where the pilot pushes the rudder bar 43 in the direction of the arrow *f7* this raises the plate 8 and as the plate 14 remains stationary, the plate 8' is lowered. The incidences of the upper rotor 1—1' increases and those of the lower rotor 2—2' are reduced (Fig. 9). If the pilot urges the rudder-bar in the opposite direction, given out by the arrow *f8* the opposite action is obtained. This produces thus a giratory torque in either desired direction.

In brief, the conditions of operation of my improved apparatus are as follows:

(*a*) in the automatic cyclic adjustment of the incidences, the two primary plates rock in opposed directions on their rotulas. The swing-bars assume a periodical inclination while their centers remain motionless on the central plate.

By reason of the differential balancing of the actions exerted on the two primary oscillating plates, no reaction is exerted on the central plate and therefore on the pilot's hand.

(*b*) If the central plate is inclined in any azimuthal direction, this modifies the mean positions of the two primary plates. According to the direction of inclination, of said plate, the incidence of the blades is increased or reduced in the two rotors, when they pass through the azimuthal direction considered. This produces thus a torque which rightens the apparatus in a direction which may be selected as desired.

(*c*) It is possible by making the cylindrical support carrying the rotulas of the plates slide upwardly to increase in a general and permanent manner the incidences of all the blades. These incidences are reduced by displacing the cylindrical support downwardly.

(*d*) by spacing away from one another the rotulas of the primary plates I increase in a permanent manner the incidence of the upper rotor, while they are reduced for the lower rotor. The reverse action is obtained by moving towards one another the rotulas of the two primary plates. This produces thus a giratory torque in one direction or the other.

It is apparent from the preceding disclosure that by reason of the arrangement disclosed, the pilot may execute all desired operations.

In practice, it is of interest to complete the above described mechanism by an automatic control arrangement which in case of a reduction of the speed of the engine and consequently of a reduction or cancellation of the driving torque acting on the rotors, reduces the incidences of the blades. It is sufficient therefore that the arrangement considered, controlled directly or indirectly by the motor may be connected to the plates 8—8' in a manner such as will modify their spacing. The adjustment should preferably be such that if the engines are slowed down, the rotors assume of their own a pitch near zero without the pilot having to interfere.

This automatic control arrangement may be centrifugal or hydraulic and its pressure in this case should depend on the torque of the engine or else it may be constituted by a system controlled by the depression at the admission into the engine.

Lastly, the arrangements of the control members may be advantageously completed by an arrangement controlled by the very speed of translation of the apparatus forming a speed compensation system operating automatically on the incidences of the blades.

This arrangement may be executed as illustrated in Fig. 10. It includes a driving piston 56 controlling through connecting rods the different swing bars 13 of which only one is shown for illustrating the control means; said piston 56 is adapted to move inside the cylinder 48; a Venturi tube 49 is connected with the distributor 50, the double piston 51 in which is connected with the swing-bar 52 which is also connected with the piston 56 and with a manometric capsule 53; said manometric capsule is submitted to the depression produced at the restricted part of a Venturi sleeve 54 arranged in the relative wind. As the distributor 50 is balanced through its being submitted to the depression from 49 at both ends and to normal atmospheric pressure in its center through the pipe 55, the capsule 53 easily produces the displacements of the piston 51 therein. Of course the control through a Venturi tube and a capsule may be replaced by any other suitable control means such as gliding and perpendicular surfaces, a Pitot tube, blade anemometers and the like, or else it is possible to act otherwise on the swing bars 13, for instance directly or through the agency of an auxiliary motor different from that described such as a fluid operated auxiliary motor, a hydraulic auxiliary motor and the like. It is also possible to act no longer on the swing bars, but on one of the primary plates 8 or 8'.

Obviously many detail modifications may be brought to the apparatuses which have been described without widening thereby the scope of the invention.

What I claim is:

1. In a gyroplane or the like flying machine of the kind having two rotors rotating coaxially in opposite directions and carried by a non-rotating column, the blades of said rotor being allowed of taking variable incidences and of affecting at the utmost limited flapping displacements, the combination of two primary toggle plates non-rotatably supported from said column, two ring members rotatably mounted around said toggle plates respectively, two sets of connecting rods, the rods of one set being connected each to a blade of one of the rotors and

to one of said ring members whereas the rods of the other set are connected each to a blade of the other rotor and to the other of said ring members, a balancing third toggle plate non-rotatably supported from said column and differential means supported by said third toggle plate and connecting together said primary plates.

2. In a gyroplane or the like flying machine of the kind having two rotors rotating coaxially in opposite directions and carried by a non-rotating column, the blades of said rotor being allowed of taking variable incidences and of effecting at the utmost limited flying flapping displacements, the combination of two primary toggle plates non-rotatably supported from said column, two ring members rotatably mounted around said toggle plates respectively, two sets of connecting rods, the rods of one set being connected each to a blade of one of the rotors and to one of said ring members whereas the rods of the other set are connected each to a blade of the other rotor and to the other of said ring members, a balancing third toggle plate non-rotatably supported from said column, swing bars pivotally secured to said third plate, two sets of connecting rods, the rods of one set being pivotally connected each to one of the primary plates and to one end of one of said swing bars whereas the rods of the other set are connected each to the other primary plate and to the other end of one of said swing bars.

3. In a gyroplane or the like flying machine of the kind having two rotors rotating coaxially in opposite directions and carried by a non-rotating column, the blades of said rotor being allowed of taking variable incidences and of effecting at the utmost limited flapping displacements, the combination of two primary toggle plates non-rotatably supported from said column, two ring members rotatably mounted around said toggle plates respectively, two sets of connecting rods, the rods of one set being connected each to a blade of one of the rotors and to one of said ring members whereas the rods of the other set are connected each to a blade of the other rotor and to the other of said ring members, a balancing third toggle plate non-rotatably supported from said column, pinions pivotally secured to said third plate, two sets of rack members, each member of one set being pivotally secured at one of its ends to one of said primary plates and meshing with one of said pinions whereas each

member of the other set is pivotally secured to the second of said primary plates and meshes with one of said pinions.

4. In a gyroplane or the like flying machine of the kind having two rotors rotating coaxially in opposite directions and carried by a non-rotating column, the blades of said rotor being allowed of taking variable incidences and of effecting at the utmost limited flapping displacements, the combination of two primary toggle plates non-rotatably but slidably supported from said column, two ring members rotatably mounted around said toggle plates respectively, two sets of connecting rods, the rods of one set being connected each to a blade of one of the rotors and to one of said ring members whereas the rods of the other set are connected each to a blade of the other rotor and to the other of said ring members, a balancing third toggle plate non-rotatably supported from said column, differential means supported by said third toggle plate and connecting together said primary plates, a control linkage supported by said column and adapted to control the angular setting of said third toggle plate under the action of a control lever, means for adjusting the longitudinal position of the third toggle plate and thereby of the primary plates with respect to said rotors, a second lever for controlling said last-mentioned means, means supported by said column for controlling the relative spacing between said primary plates and said third plate and a rudder bar for controlling said last-mentioned means.

LOUIS BRÉGUET.

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