

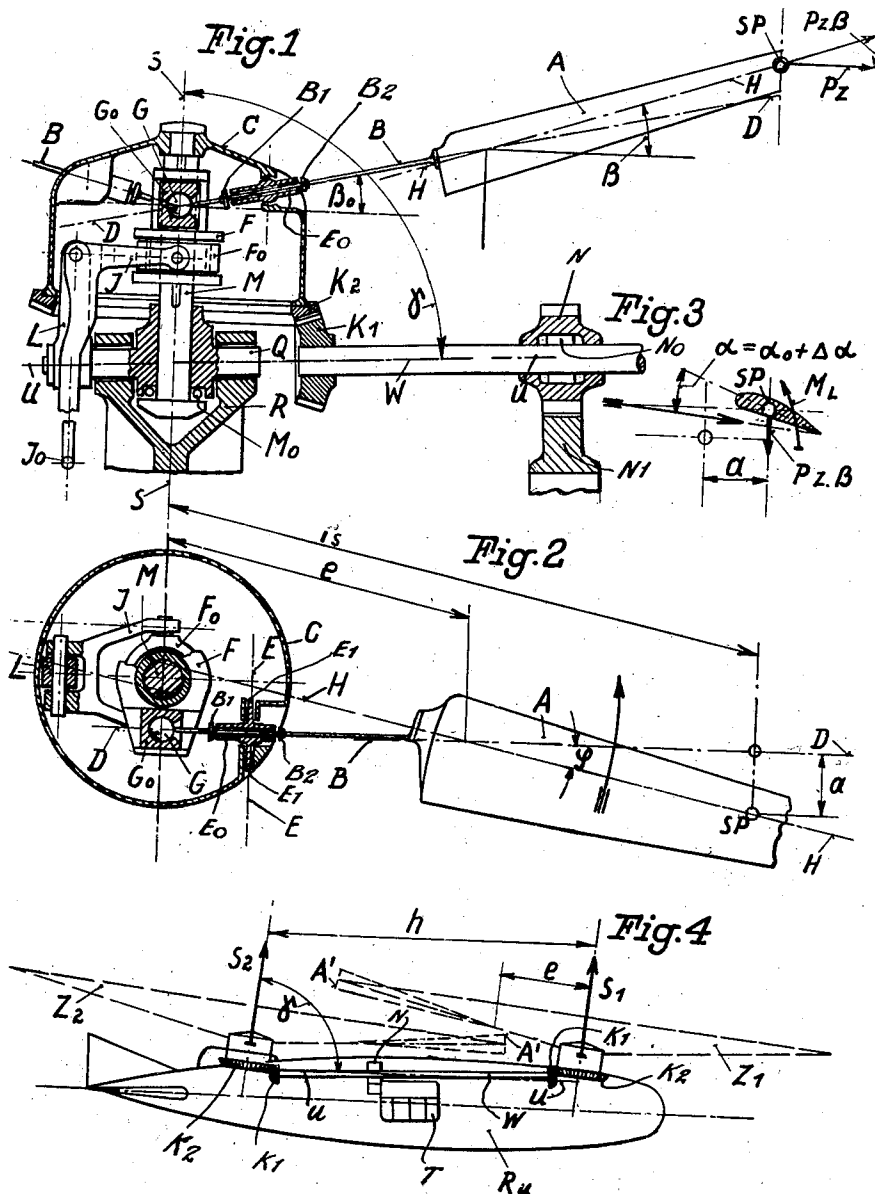
March 4, 1941.

A. RIEDL
HELICOPTER

2,233,747

Filed Jan. 3, 1939

2 Sheets-Sheet 1



Inventor:
A. Riedl
B. Robb Robb

March 4, 1941.

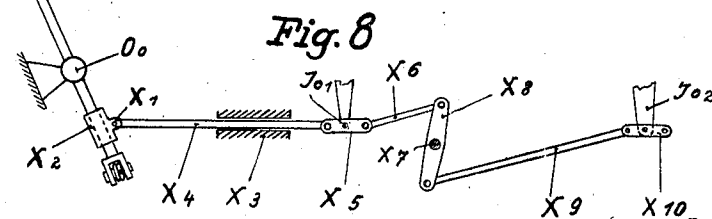
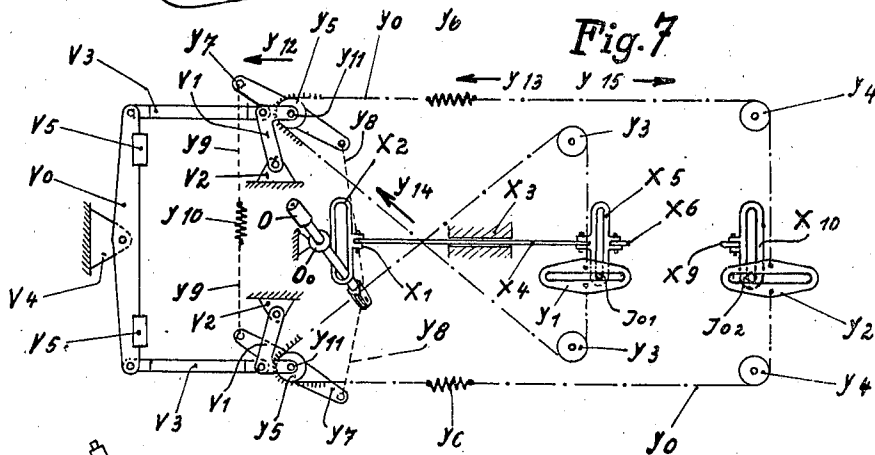
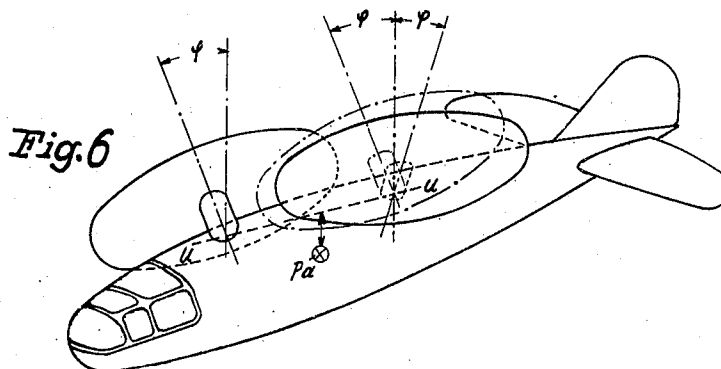
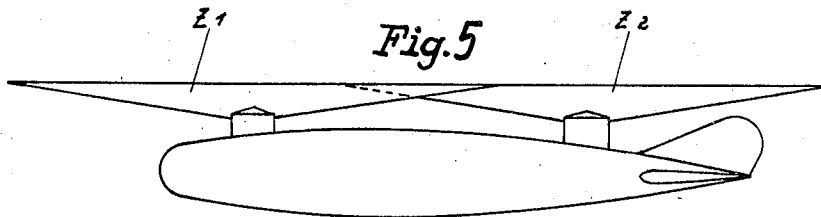
A. RIEDL

2,233,747

HELICOPTER

Filed Jan. 3, 1939

2 Sheets-Sheet 2



Inventor:
A. Riedl
By *Robb & Robb*
Attorneys

UNITED STATES PATENT OFFICE

2,233,747

HELICOPTER

Alois Riedl, Dresden, Germany, assignor to the firm Henschel Flugzeug-Werke Aktiengesellschaft, Schönefeld, Kreis Teltow, Germany

Application January 3, 1939, Serial No. 249,121
In Germany December 23, 1937

15 Claims. (Cl. 244—17)

This invention relates to rotary-wing aircraft. In order to keep down the induced resistance of travelling rotary-wing aircraft it is necessary to adapt the angle of incidence of the rotor blades to the conditions of air impact (velocity of impact and angle of attack) which vary greatly in the course of a revolution of the rotor, so as to obtain as constant blade lift as possible. Attempts have already been made, by the use of various kinds of articulated blades, to achieve such adapting of the angle of incidence of the blade to the fluctuating conditions of air impact, but the mass inertia of all the types of construction of this kind hitherto employed is so great that automatic adjustment of the blade incidence in dependence upon fluctuations in the velocity of air impact and in the effective angle of attack was only attainable with an inadmissible amount of lag. With the types of construction hitherto known it has not been possible to increase the characteristic vibration frequency n_c of the articulated blades vibrating under the influence of the mass and aerodynamic forces acting upon them to a figure substantially above the speed n of the rotor. The consequent mass inertia of the vibrating blade leads to a lag in the automatic adjustment, which lag may amount to almost a quarter of a turn of the rotor. However, deviations of this order of magnitude exceed the admissible limits since adaptation of the angle of incidence of the blade to the maximum and minimum air impact velocities relative to the transverse position is then no longer possible.

The types of construction that have hitherto become known mostly exhibit a pure flapping blade articulation in which the axis of articulation is at right angles to a longitudinal axis of the blade. Since with articulation of this kind the centre of gravity of the blade is as remote as possible from the axis of articulation, and alteration of the absolute pitch of the rotor blade is impossible, the resulting adaptability to fluctuating conditions of air impact, when $n_c = n$, is very slight and from the practical point of view unsatisfactory. Even in the case of blade articulation in which the axis of articulation is inclined to the blade axis, the hitherto attainable adaptability, when $n_c < 2n$ has remained, owing to ignorance of the most favourable conditions of articulation, far below the maximum obtainable.

The present invention concerns a form of blade articulation with the highest possible characteristic vibration frequency of the blades vibrating in response to mass and aerodynamic forces, as also a rotor arrangement which reduces the total

drag of the travelling rotary-wing aircraft to a minimum.

An embodiment of the invention is shown by way of example in the accompanying drawings, in which

Fig. 1 is a sectional elevation,

Fig. 2 a sectional plan of the blade articulation according to the invention with minimum mass inertia,

Fig. 3 is a cross-section of the blade,

Fig. 4 shows diagrammatically an aircraft equipped with the new type of rotor blade articulation,

Fig. 5 shows a helicopter with two rotors whose path comes interpenetrate,

Fig. 6 is a diagrammatic view of a helicopter with actuated vertical control and transverse control, and

Figs. 7 and 8 show a lay-out of the control mechanism.

The individual rotor blade A is so connected to the hub C with the aid of the carrying arm B, that the blade is capable of rotating about the axes D—D and E—E. With the aid of the arm B disposed in the axis D—D and of the ball joint G on the end of the arm B working in the sleeve F, the angle β_0 between the axis D—D and the horizontal is fixed for a certain condition of flight, so that the blade A is then only capable of rotating about the axis D—D. By comparison with other types of construction it is easily demonstrable that the simplest joint construction is obtained when the free pivot axis D—D is coincident with the real pivoting axis of the carrying arm B. The main axis of inertia H—H of the blade must for reasons of stability be so disposed relatively to the pivot axis D—D that these two axes intersect at a point short of the rotor axis of rotation S—S (Fig. 2). If e be the distance between this point of intersection and the rotor axis of rotation and φ the angle between the axes D—D, H—H then the inherent stability, due to this type of blade articulation, of a rotary-wing aircraft when poised stationarily (the most unfavourable condition) is proportional to the product of $e \times \varphi$. For this purpose φ must be opposed to the direction of rotation with respect to D—D.

Automatic adjustment of the effective (relative) blade pitch angle or angle of incidence α is in this case effected in dependence on the air impact conditions fluctuating in the course of a revolution of the rotor, in such a manner that even a slight change in the moment M_L produced by aerodynamic forces (referred to D—D) suffices

to rotate the blade A about the axis D—D until equilibrium is re-established between this moment M_L and the centrifugal moment

$$M_z = P_z \times \beta \times a$$

5 due to centrifugal force P_z . Figs. 2 and 3 show the centrifugal force component $P_z \times \beta$ acting in the centre of gravity SP of the blade at a distance of r_s from the rotor axis S—S, the distance between the centre of gravity of the blade and the pivot axis, (effective lever arm), being denoted by a . β is the angle which the blade axis H—H forms with the horizontal. Owing to the angle of inclination between the axes D—D and H—H necessary for reasons of stability, β varies during one revolution about β_0 as mean value.

As is easily demonstrable, automatic regulation of the blade pitch is most rapidly effected when the blade arrangement is such that the distance a between the centre of gravity of the blade and the pivot axis D—D is approximately equal to the inertia radius i of the blade irrespective of the angle ϕ and irrespective of the value of e .

As a measure of the thus obtainable sensitiveness and adaptability of the blade to the conditions of air impact varying greatly during travel there may be taken the ratio of its characteristic vibration frequency n_e to the speed n of the rotor. The characteristic vibration frequency n_e may be found from a consideration of the vibrating mass of the blade, which is subject to the aerodynamic forces varying with the vibration angle $\Delta\alpha$. If the distance a be taken as equal to the inertia radius i then for values of e which are smaller than

$$0.7 \times r_s \left(\phi < \frac{i}{0.3 \times r_s} \right)$$

the maximum sensitiveness obtainable may be expressed as follows:

$$\frac{n_e}{n} \approx \sqrt{\frac{\beta_0 \times r_s}{\alpha_0 \times 2.2}}$$

whereby β_0 is the angle of inclination of the axis D—D and α_0 the mean relative angle of incidence of the blade.

The following values may be taken by way of example as being typical of a normal blade:

$$\beta_0 = 16^\circ, \alpha_0 = 8^\circ, r_s = 25.i$$

50 With these values a sensitivity coefficient of

$$\frac{n_e}{n} = 5$$

can be obtained. This value is so favourable that an almost instantaneous responding of the blade pitch to any changes in the air impact conditions may be expected. On deviation from the condition of maximum blade sensitiveness $a \approx (0.9-1.1)$ there results a drop in the sensitivity coefficients to ~ 0.50 times their maximum value within the limits given by $a = (0.2-8)$. As is clear from Fig. 2 the values given for a are to be understood to be measurements taken at right angles to the axis D—D. These values may be taken as representing the limit of the practical usefulness of a blade articulation of this kind. The fixing of the angle β_0 for a certain condition of flight, as also the pronounced changes in the aerodynamic forces involved in one rotation of the blade A about the axis D—D ensure that the rotor blades follow the movements of the aircraft body in every direction of flight, so that it is also possible to carry out aerobatic manoeuvres with aircraft equipped with rotors of this type.

In the event of sudden failure of the drive, a blade which has such a high degree of sensitiveness will at once adjust itself to autorotation after a small drop in rotor speed in a very short time and without the pilot's intervention, owing to the action of the aerodynamic forces which are then paramount. It is thus sufficient to provide a free-wheeling clutch of known type between the drive and the rotor to render possible safe gliding when the engine fails.

The drive of the hub C provided with two or more blades A is effected by the shaft W which is connected to the driving gear wheel N_1 through the intermediary of a free wheel clutch. This latter consists of a clutch gear wheel N and the friction rollers N_0 located between the wheel N and the shaft W. The shaft W carries a bevel wheel K_1 which meshes with a bevel wheel K_2 rigidly connected to the hub C. According to Fig. 4 a shaft W provided with a bevel wheel K_1 at each end is driven by the engine T through the intermediary of a free wheel clutch N. It drives two rotors in opposite directions. The hub C is rotatably connected, by means of the spindle M and bearing M_0 , to a cross-head Q which in its turn is rotatably mounted in the bearing bracket R mounted on the body of the aircraft. In this case the drive is not impaired if the axis of the driving shaft W coincides with the pivot axis U—U of the cross-head Q. On the spindle M is fitted a sliding sleeve F which is locked against rotation in a known manner (e. g. by means of a tongue and groove) and which, with the aid of the sliding block G_0 , holds captive the ball journals G on the ends of the blade arms B. The sleeve F is connected by means of a sleeve ring F_0 to a control lever J which is pivotally supported by means of a bracket L on the cross-head Q adapted to swivel about the axis U—U. The other end J_0 of this lever J may be arranged to be moved in two dimensions in a known manner by means of control mechanism. The rotation of the arm B about the axis E—E is attained by supporting the bearing E_0 of the blade arm B by pivot pins E_1 in the hub C. To prevent axial displacement of the blade arm, collars B_1 and B_2 are fitted on the blade arm B in front of and behind the bearing E_0 . As the distance between the ball journal G and the axis E—E is fixed, the block G_0 is slidably mounted on the sleeve F, see Fig. 2. According to the diagram of assembly shown in Fig. 4 displacement of the lever J_0 longitudinally of the aircraft body R_a has the effect of moving the sleeve F in an axial direction and thus of altering the mean blade pitch β_0 by rotating the blade about the axis E—E. The mean blade lift $P_z \times \beta_0$ and the force exerted by the rotor are thereby also altered to the same extent. If the lever J_0 be moved transversely of the length of the aircraft body the setting of the sleeve remains unchanged while through the intermediary of L and Q the hub C is tilted laterally about the axis U—U and a corresponding lateral component of the rotor force is thereby generated. In order to utilise the controllability of the rotor force as to magnitude and direction obtainable with the aid of the blade suspension according to the invention, for the purpose of controlling the aircraft as a whole, the basic type of rotary-wing aircraft according to the invention involves the use of a pair of lifting rotors mounted on separate axles and rotated in opposite directions, these rotors being normally mounted one behind the other in view of the elongated shape of an aircraft fuselage.

Fig. 4 illustrates this arrangement. The lever arm h formed by the clearance between the two rotor axes renders it possible with the aid of the rotor forces S_1 and S_2 , which are controllable as to magnitude and direction, to produce all the governing moments required for steering and controlling the aircraft irrespective of the momentary condition of flight. In this case the normal elevation control can be effected by simultaneous displacement of the rotor sleeves F in opposite directions. The speed of travel may be regulated by varying the ratio between the rotor forces S_1 and S_2 to one another by an intermediate setting of the sleeves F of both rotors, whereby the angle of inclination γ of the two rotor axes to the direction of flight is varied. Lateral tilting of both rotors in opposite directions about the axis $U-U$ enables the normal lateral (rudder) control to be obtained. Tilting of both rotors in one and the same direction gives the normal aileron control, provided the axes $U-U$ be disposed directly over the centre of gravity of the aircraft. The rotors arranged in pairs should rotate in opposite directions so as to cancel the gyroscopic effects which otherwise would interfere with controlling of the aircraft, and to render hovering possible without reaction torque.

The rotors Z_1 and Z_2 of the helicopter illustrated in Fig. 5 are synchronously driven, for example by a common driving mechanism as shown in Fig. 4.

In Fig. 6 the position of the path cone of the rotors Z_1 and Z_2 are shown in full lines when the joy stick is swung out to starboard. The axis of rotation of the front rotor Z_1 is inclined out of the middle position towards the starboard side and the axis of rotation of the rear rotor Z_2 towards the larboard side by an angle ϕ . If lateral control is given, the axes of rotation of the two rotors lean towards the side in question so that the front rotor assumes the same position as in the case of swung out vertical rudder and the path cone of the rear rotor assumes the position shown in dotted lines. If the transverse and vertical controls are actuated at the same time the cone paths of the rotors assume these positions according to the interpenetrating control adjustments. The centre of gravity of the aircraft situated below the axis $U-U$ is designated by P_a .

Figs. 7 and 8 give an idea of a control arrangement which serves for controlling the rotors Z_1 , Z_2 and is equipped with the operating arrangements such as joy stick and vertical control pedals usual in aircraft with rigid wings.

In the case of the control illustrated, the joy stick O is mounted movable in all directions in the usual manner in a joint O_o . The drawings show the vertical control in central position, the lateral control towards the starboard side and the horizontal control to downward flight. The change in height of the aircraft is attained by regulating the speed of the rotors.

The horizontal rudder is actuated, for example when the aircraft is descending, by pressing the joy stick O forwards. The control rod X_1 connected by a joint X_1 to a link X_2 and axially guided in a bearing X_3 is pushed back with the also articulated link X_4 , which serves as bearing for the pin J_{o1} of the control lever J of the front rotor Z_1 . By this rearward displacement the sleeve F of the front rotor is shifted upward. The path cone of the rotating rotor blades A is therefore flatter and the lift produced

by this rotor is correspondingly less. The link X_5 is connected by a connecting rod X_6 (Fig. 8) to the reversing lever X_3 mounted on joints X_7 and the connecting rod X_8 to the link X_{10} destined to guide the journal J_{o2} of the rear rotor Z_2 . The lever J of the rear rotor Z_2 therefore presses the sleeve F of this rotor downwards when the joy stick O is moved forward with the result that the rotary path of the blades A of the rotor Z_2 is more steeply inclined and consequently the lifting force is increased.

The transverse and vertical control is so equipped that it moves aside the journals J_{o1} and J_{o2} of the control lever J with the aid of an endless control rope Y_o . By laterally actuating the joy stick O or by actuating the vertical rudder pedal V_5 a rope Y_o is moved in which guide bars Y_1 and Y_2 are provided for the journals J_{o1} and J_{o2} . The rope Y_o is stretched over two pairs of rope pulleys Y_3 and Y_4 each arranged laterally of the control lever journals J_{o1} , J_{o2} and over two sprocket wheels Y_5 . The portion of the rope bearing against the sprocket wheels Y_5 is constructed as a chain in order to ensure its reliable actuation by the two sprocket wheels Y_5 operated by the joy stick O . For compensating slight alterations in length during the operation of the control and to maintain a constant tension, springs Y_6 are fitted in the rope Y_o . During the lateral movement of the joy stick the sprocket wheels Y_5 are turned laterally by means of the levers Y_7 and ropes Y_8 and Y_9 connecting these levers to one another and to the joy stick O . A spring Y_{10} is fitted in the rope Y_9 for compensating alterations in length during the action. The journals Y_{11} of the sprocket wheels Y_5 are mounted in levers V_1 which in turn are oscillatable about a stationary bearing V_2 . The oscillatable levers V_1 are connected by connecting rods V_3 to the rocker V_o which carries the vertical rudder pedals V_5 and is supported in a stationary bearing V_4 .

If the pilot desires to give lateral control he depresses the corresponding pedal for example the one at the top of Fig. 7, that is that on the starboard side, and thus causes the lever V_1 on this side to swing forward with the sprocket wheel carried by this lever, whereas the other sprocket wheel swings rearwards. By the movement of the sprocket wheel in the direction of the arrow Y_{12} the portions of the rope Y_o resting thereon are pulled in the directions Y_{13} and Y_{14} .

The result of this is that the link Y_1 guiding the journal J_{o1} is pulled in the larboard direction and the axis $S-S$ of the rotor Z_1 is inclined towards the starboard about the cross-head Q . Similarly, the link Y_2 with the journal J_{o2} moves in starboard direction with the result that the axis $S-S$ of the rotor Z_2 leans to larboard.

When the joy stick O swings out for the lateral control the sprockets Y_5 rotate so that the control rope Y_o is moved in a direction for example that indicated by the arrows Y_{15} and Y_{14} . The links Y_1 , Y_2 and consequently the journals J_{o1} , J_{o2} of the control lever J are moved in the same direction so that the control lever J and consequently the axes of rotation $S-S$ of the rotors Z_1 , Z_2 lean in the same direction. The above described form of construction of the rope Y_o and of the rope pulleys and sprocket wheels carrying this rope enables a simple simultaneous operation of the lateral and vertical control.

The forces imparted to the rod system or the joy stick during the control by engine torque and other influences can be taken up in known manner by compensating springs, compensating weights or other means arranged within the control or on the joy stick. The control of the aircraft may also be effected by any other mechanism fulfilling the same purpose.

From the arrangement of rotors (Fig. 4) disposed one behind the other in the normal condition of travel there is achieved a great aerodynamic advantage which has not hitherto been consciously recognised and which may be explained as follows:

With one rotor alone, however perfect the automatic regulation of the blade lift may be, ideally uniform distribution of the slipstream velocities over the disc area can never be achieved in the condition of travel, since the distribution of the lifting forces over the length of the blade is always subject to marked fluctuations in the course of each revolution even when the mean lift remains constant.

With the counter rotating tandem-rotor arrangement shown in Fig. 4, however, each particle of air coming within the sphere of influence of the travelling tandem-rotor rotary-wing aircraft according to the invention, is influenced once by a forward moving and by a backward moving blade and is so flung back that behind the tail rotor (S_2) a symmetrical and equalised distribution of the slipstream velocities is obtained. In this manner it becomes possible, with the aid of this tandem arrangement, by complementary action to eliminate the imperfections of the two rotors (S_1, S_2), the blades of which for reasons of adequate inherent stability can be adjusted only to approximately constant blade lift, and in an otherwise unobtainable degree to approximate to the aerodynamic ideal of constant slipstream velocity.

It is also conceivable to devise minimum slip multi-rotor rotary-wing type aircraft comprising a plurality of such pairs of rotors in tandem arrangement.

If it is desired to obtain as large a jet area as possible with any given dimensions of the aircraft body for purposes of vertical climbing, the two rotors (S_1, S_2) will be made to overlap as shown in Fig. 4, in which case the path cone Z_2 of the tail rotor (S_2) extends almost up to the hub of the forward rotor screw (S_1). The diameter of the rotor disc may in this case be greater than 1.5 times the distance h between the rotor axes. When both rotors are jointly driven, and provided the blades are arranged in suitably offset relation, the two path cones Z_1, Z_2 may interpenetrate. If however it is desired to drive each rotor separately it is necessary to adopt the arrangement of the path cones shown in Fig. 4, in which interpenetration of the two cones is avoided, even in the extreme setting positions A' of the blades limited by stops, this being achieved by arranging the two rotors in suitably offset relation to each other. An arrangement of this kind may also be advantageous in connection with two rotors having a common drive, e. g. when owing to fracture of the propeller shaft W the two rotors become disconnected from each other and pass into autorotation with different speeds.

I claim:

1. In a rotor of the articulated blade type for rotary-wing aircraft, a rotatable blade support carrying two or more blades, each blade being

capable of freely rotating about an inclined axis, said inclined axis forming with a plane normal to the rotor axis an angle which is variable to accord with varying conditions of flight, said inclined axis being inclined relative to the main axis of inertia of the blade, and said inclined axis and main axis of inertia intersecting between the center of gravity of the blade and the rotor axis, and the distance, measured in parallel projection to the rotor axis, of the center of gravity of the blade from the inclined axis being equal to between 0.2 and 8 times the length of the smallest inertia radius of the blade, which smallest inertia radius is equal to the square root of the ratio of the smallest mass inertia moment of the blade: blade weight.

2. Apparatus as claimed in claim 1, in combination with means for manually varying the angle of inclination of the blades.

3. A rotary-wing aircraft having at least two rotors of the articulated blade type as claimed in claim 1, said rotors being rotatable in opposite directions and arranged one behind the other in the normal direction of travel, and means for varying the angle of inclination of the blades of the respective rotors in opposite directions.

4. Apparatus as claimed in claim 1, wherein said rotor includes a rotatable axle, a hub fixed thereto for rotation therewith about a common axis, a sleeve axially shiftable on said axle and also rotatable therewith, and blade supporting arms each having a universal connection with said sleeve at its inner end and fulcrumed on the hub at a distance from its inner end.

5. Apparatus as claimed in claim 1, wherein said rotor includes a rotatable axle, a hub fixed thereto for rotation therewith about a common axis, a sleeve axially shiftable on said axle and also rotatable therewith, and blade supporting arms each having a universal connection with said sleeve at its inner end and fulcrumed on the hub at a distance from its inner end, the axis of each blade supporting arm coinciding with the pivotal axis of the blade.

6. Apparatus as claimed in claim 1, wherein said rotor includes a rotatable axle, a hub fixed thereto for rotation therewith about a common axis, a sleeve axially shiftable on said axle and also rotatable therewith, blade supporting arms each having a universal connection with said sleeve at its inner end and fulcrumed on the hub at a distance from its inner end, means for adjustably supporting said axle and hub so as to enable the axis of rotation thereof to be inclined to different positions of adjustment, and a control lever mounted for independent pivotal movement in two directions, said control lever being operatively connected with said sleeve and the support for the hub and axle so that pivotal movement of the control lever in one direction serves to vary the angle of inclination of the rotor blades, and pivotal movement of the control lever in the other direction serves to incline the common axis of rotation of the hub and axle.

7. Apparatus as claimed in claim 1, wherein said rotor includes a rotatable axle, a hub fixed thereto for rotation therewith about a common axis, a sleeve axially shiftable on said axle and also rotatable therewith, blade supporting arms each having a universal connection with said sleeve at its inner end and fulcrumed on the hub at a distance from its inner end, means for adjustably supporting said axle and hub so as to enable the axis of rotation thereof to be inclined to different positions of adjustment, and a con-

control lever mounted for conjoint pivotal movement in two directions, said control lever being operatively connected with said sleeve and the support for the hub and axle so that pivotal movement of the control lever in one direction serves to vary the angle of inclination of the rotor blades, and pivotal movement of the control lever in the other direction serves to incline the common axis of rotation of the hub and axle.

8. A rotary-wing aircraft having at least two rotors of the articulated blade type as claimed in claim 1, said rotors being arranged one behind the other in the normal direction of travel, and means for varying the angle of inclination of the blades of the respective rotors in opposite directions.

9. Apparatus as claimed in claim 1, wherein said rotor includes a rotatable axle, a hub fixed thereto for rotation therewith about a common axis, a sleeve axially shiftable on said axle and also rotatable therewith, said sleeve carrying sliding blocks corresponding to the number of rotor blades, each block being transversely displaceable relative to the axle aforesaid, and blade supporting arms each having a universal connection with said sleeve at its inner end and fulcrumed on the hub at a distance from its inner end, the inner end of each blade supporting arm being articulated to one of the sliding blocks on the sleeve.

10. Apparatus as claimed in claim 1, wherein said rotor includes a rotatable axle, a hub fixed thereto for rotation therewith about a common axis, a sleeve axially shiftable on said axle and also rotatable therewith, and blade supporting arms each having a universal connection with said sleeve at its inner end and fulcrumed on the hub at a distance from its inner end, said blade supporting arms being movable laterally at their inner ends past the rotatable axle of the hub of the rotor.

11. Apparatus as claimed in claim 1, wherein said rotor includes a rotatable axle, a hub fixed thereto for rotation therewith about a common axis, a sleeve axially shiftable on said axle and also rotatable therewith, blade supporting arms each having a universal connection with said sleeve at its inner end and fulcrumed on the hub at a distance from its inner end, and a driving shaft for the rotor, said rotatable axle being disposed in a rotatable and pivotal cross-head the pivotal axis of which coincides with the axis of the driving shaft of the rotor.

12. Apparatus as claimed in claim 1, wherein said rotor includes a rotatable axle, a hub fixed thereto for rotation therewith about a common axis, a sleeve axially shiftable on said axle and also rotatable therewith, blade supporting arms each having a universal connection with said sleeve at its inner end and fulcrumed on the hub at a distance from its inner end, a driving shaft for the rotor, said rotatable axle being disposed in a rotatable and pivotal cross-head the pivotal axis of which coincides with the axis of the driving shaft of the rotor, and a control lever mounted for pivotal movement in two directions, said control lever being operatively connected with said sleeve so that pivotal movement of the control lever in one direction serves to vary the angle of the blade arms relative to the rotor axis, and pivotal movement of the control lever in the

other direction serves to move the hub with the blades about the pivotal axis of the cross-head.

13. Apparatus as claimed in claim 1, wherein said rotor includes a rotatable axle, a hub fixed thereto for rotation therewith about a common axis, a sleeve axially shiftable on said axle and also rotatable therewith, blade supporting arms each having a universal connection with said sleeve at its inner end and fulcrumed on the hub at a distance from the inner end, a driving shaft for the rotor, said rotatable axle being disposed in a rotatable and pivotal cross-head the pivotal axis of which coincides with the axis of the driving shaft of the rotor, a control lever mounted for pivotal movement in two directions, said control lever being operatively connected with said sleeve so that pivotal movement of the control lever in one direction serves to vary the angle of the blade arms relative to the rotor axis, and pivotal movement of the control lever in the other direction serves to move the hub with the blades about the pivotal axis of the cross-head, and control instrumentalities for obtaining independent strokes in two directions of the control lever.

14. Apparatus as claimed in claim 1, wherein said rotor includes a rotatable axle, a hub fixed thereto for rotation therewith about a common axis, a sleeve axially shiftable on said axle and also rotatable therewith, blade supporting arms each having a universal connection with said sleeve at its inner end and fulcrumed on the hub at a distance from its inner end, a driving shaft for the rotor, said rotatable axle being disposed in a rotatable and pivotal cross-head the pivotal axis of which coincides with the axis of the driving shaft of the rotor, and a control lever movable in two directions and operatively connected with the sleeve, said control lever being rotatably arranged on a bracket adapted to swivel about the pivotal axis of the cross-head so that pivotal movement of the control lever in one direction serves to vary the angle of the blade arms relative to the rotor axis, and pivotal movement of the control lever in the other direction serves to swing the hub with the blades about the pivotal axis of the cross-head.

15. Apparatus as claimed in claim 1, wherein said rotor includes a rotatable axle, a hub fixed thereto for rotation therewith about a common axis, a sleeve axially shiftable on said axle and also rotatable therewith, blade supporting arms each having a universal connection with said sleeve at its inner end and fulcrumed on the hub at a distance from its inner end, a driving shaft for the rotor, said rotatable axle being disposed in a rotatable and pivotal cross-head the pivotal axis of which coincides with the axis of the driving shaft of the rotor, a control lever movable in two directions and operatively connected with the sleeve, said control lever being rotatably arranged on a bracket pivotally disposed on the pivotal axis of the cross-head so that pivotal movement of the control lever in one direction serves to vary the angle of the blade arms relative to the rotor axis, and pivotal movement of the control lever in the other direction serves to swing the hub with the blades about the pivotal axis of the cross-head.