June 6, 1944. R. R. HAYS 2,350,962

IRROTATIONAL ROTOR

Original Filed Feb. 16, 1938

Fig. 1.

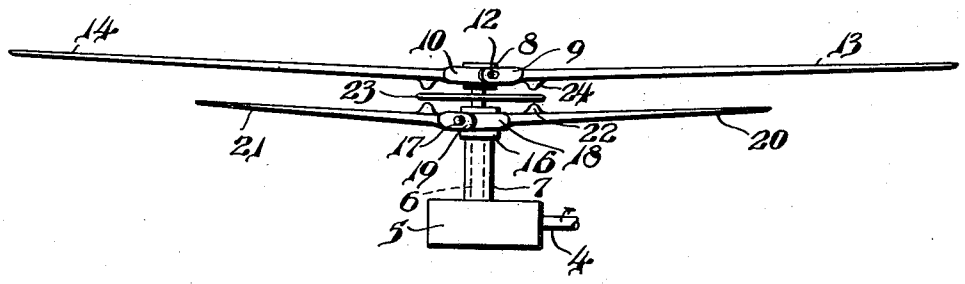
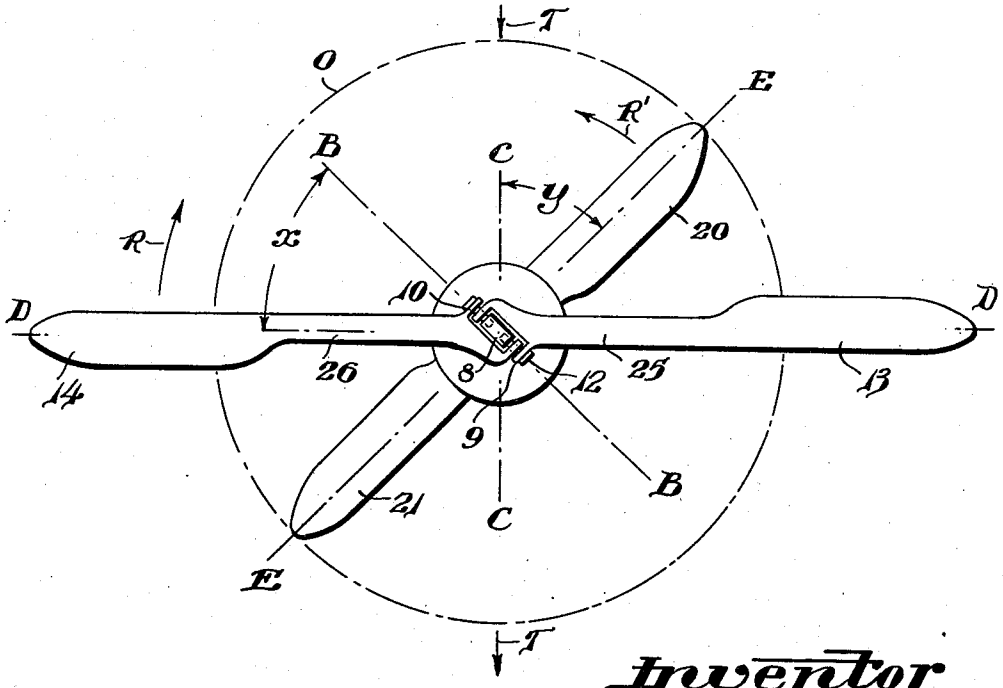


Fig. 2.



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IRROTATIONAL ROTOR

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Substituted for abandoned application Serial No. 190,817, February 16, 1938. This application July 12, 1943, Serial No. 494,424

7 Claims. (Cl. 244—17)

This invention relates to sustaining rotors for aircraft and more particularly to means for operating one rotor directly beneath another so that the effect from the standpoint of efficiency and control corresponds to that of a single rotor.

This application is a substitute for application Serial No. 190,817 filed Feb. 16, 1938.

In general, the present invention contemplates the adaptation of an irrotational mechanism to rotor design, the aim being an approach to the principle whereby the tangential speed of the blade elements remains constant irrespective of their distance from the center of the system. In keeping with this objective, it is a purpose of this invention to provide superimposed rotors of different sizes, operating in immediate proximity of one another at substantially the same tip speed ratios, and with the inner blade sections of the larger rotors reduced in plan form in the proximity of the swept area of the smaller rotors, so that the effect approaches that of multiple blade elements operating irrotationally in a single plane, the term irrotational being used in the sense defined by Walter S. Diehl's "Engineering Aerodynamics," Ronald Press Company, copyright 1928, pages 27 and 28. (Vortex theory.) "In this connection a vortex is a mathematical rather than a physical conception. The violent whirling motion in water, which is called a vortex, certainly has some rotation although it may be irrotational. It would be irrotational if the velocity varied inversely as the radius, and it is rotational to the extent that the velocities deviate from the inverse law."

In the further adaptation of this principle to the conventional rotor utilizing self aligning blades, it is a purpose of this invention to provide oblique hinge mountings for the individual blades in order that the maximum flapping of the individual rotors may coincide radially, regardless of whether the superimposed rotors turn in the same or opposite directions.

It is another object to provide blades of such relative weight, or the equivalent, on different rotors as to give similar flapping angles despite inflow velocity differences.

Still another object is the provision of a differential driving mechanism whereby the individual rotor elements are brought to similar tip speeds by reason of similar drags.

Another object is the provision of a movable plate between rotor elements, serving to prevent intersection of the blade paths of these elements in event of failure or faulty adjustment of any of the rotating parts.

Ancillary objects will become apparent from the following description read in conjunction with the accompanying drawing in which:

Figure 1 is a view in side elevation of one type of irrotational rotor, and

Figure 2 is a view in plan form of the same rotor.

Referring to the drawing:

A drive shaft 4, Fig. 1, operates a conventional differential and reduction gearing contained in the housing 5 and acts to turn the co-axial shafts 6 and 7 in opposite directions and with equal torques as described in Reports and Memoranda, No. 540, of the Advisory Committee for Aeronautics (British). A head member 8 on shaft 6, Fig. 2, carries aligned bolts 12 which form an axis B—B for the hinge hangers 9 and 10 of the blades 13 and 14 respectively of the larger rotor. Aligned bolts 17 carried by a head member 16 on the outer drive shaft 7 provide an axis C—C for the hinge hangers 18 and 19 of the blades 20 and 21 respectively of the smaller rotor.

The hinge axis B—B makes an acute angle X with the span axes D—D of the larger rotor blades, and the hinge axis C—C makes an acute angle Y with the span axes E—E of the smaller rotor blades. Projections 22 on the upper side of the blade butts on the smaller rotor, under conditions of extreme coning, contact the under face of a baffle plate 23 flexibly affixed to the drive shaft 6, and similar projections 24 on the under side of the blade butts of the larger rotor contact the upper face of the plate 23 at negative coning angles; the relative proportioning of the respective parts being such as to prevent intersection of blade paths of the two rotors at all times.

On the upper rotor the inner sections of the blades are reduced in plan form leaving streamlined spars 25 and 26 for a distance approximating the radius of the swept area O, Fig. 2, of the smaller rotor. Also, the lower rotor is constructed of lighter materials than the upper rotor so that under static flight conditions it has a greater coning angle than the upper rotor.

In operation, with the upper rotor turning in a direction R and the lower rotor turning in an opposed direction R' with an equal torque, it follows that either the relative blade areas or the pitch angles can be so varied that the R. P. M. of the smaller rotor will increase relative to the R. P. M. of the larger rotor until their drags tend to balance at a point giving similar tip speeds for both rotors.

In a general sense, such an arrangement is well known to the art. However, it has not been previously considered feasible to place oppositely turning rotors having self aligning blades in close proximity to one another by reason of the fact that it has been presumed that all articulative bladed rotors were similar to those in which the hinge axes lie at right angles to the span axes of the blades; in that during translation the high point of flapping of such blades does not lie in line with the airflow resultant to translation T, Fig. 2, but rather at a point as much as 45° of rotation past a point in line with the airflow T. Hence, if oppositely rotating rotors having this characteristic were placed in such proximity to each other as is an object of this invention, it is obvious that their blade paths would intersect at times of extreme flapping with disastrous results.

However, it has been found that by using self aligning blades mounted on an axis oblique to the span axis of the blade, thereby giving acute angles X and Y, Fig. 2, in plan form; or, by otherwise feathering the blades in an equivalent degree coincident with their flapping; the high point of flapping can be made to move counter rotationally by decreasing the value of these angles, and without loss of efficiency. Although counter rotational travel of the high point of flapping will vary slightly with blades having different characteristics, it was found experimentally that with average blades the high point of flapping would shift in line with the direction of translation at values of X and Y between 30° and 60° where the hinge axis laid substantially within the rotor's plane of rotation.

Thus it will be apparent that by using proper values of the angles X and Y, or by equivalent means, the high point of flapping of co-axial rotors can be made to coincide despite the fact that these rotors turn in opposite directions; and hence such rotors may be operated in such proximity to one another as to derive the advantages as regards efficiency and ease in control inherent to a single rotor without loss of those advantages inherent to super-imposed rotors having self aligning blades.

However, with starting and stopping, or by reason of faulty pitch setting of a blade, it is conceivable that the blade paths of the rotors might tend momentarily to intersect, in which case the baffle plate or disc 23, which normally tilts with the rotors' planes of rotation relative to the drive shaft 6, comes into effect by reason of the projections 22 and 24 riding on it to prevent such intersection of blade paths, as well as setting up a chattering which serves as a warning of this condition.

Another phase to be considered in attaining smooth and efficient operation of the rotors lies in the fact that the upper rotor gives the airstream encountered a downward component before it reaches the lower rotor; hence it is desirable that the lower rotor be of lighter construction than the upper in order to increase its individual tilting or flapping tendency in translation, thereby causing the planes of rotation of the two rotors to tend to remain parallel. And along this same line it will also be seen to be desirable to reduce the inner area of the upper rotor in order to avoid interference of the airflow to the lower rotor.

Obviously, both the theory of irrotational blade elements and the application of counter rotational travel of maximum flapping angles disclosed herein, is subject to wide variation and application without departure from the basic idea embodied in this particular rotor; therefore, what I claim is:

1. In aircraft having rotative sustaining surfaces, co-axial shafts, a hub on each of said shafts, self aligning rotor blades mounted on said hubs, a baffle plate between said hubs, and projections on said blades spaced to contact said baffle plate with departure from the normal path of said blades.

2. In aircraft having rotative sustaining surfaces, a drive shaft, a combination differential and reduction gearing driving co-axial shafts in opposite directions, a hub carried on the head of each of said co-axial drive shafts, hinge mountings on said hubs for self aligning rotor blades, the axes of said hinge mountings making acute angles in plan form with the span axes of said blades, a baffle plate positioned between the hubs and projections extending from the butts of the blades, said projections spaced to contact said baffle plate at times when the paths of said blades cease to be parallel.

3. In aircraft having superimposed, co-axial oppositely turning sustaining rotors with flapping articulated blades, means for feathering the individual blades including flapping axes oblique to the span axes of the blades, the weight ratios, and tip-speed ratios of the blades being of such relative values that the high point of the flapping of all blades occurs at a common predetermined position in azimuth, the superposed spacing of said rotors being less than the sum of the maximum downward deflection of the upper rotor blades and the maximum upward deflection of the lower rotor blades.

4. In aircraft having superimposed, concentric, sustaining rotors of different diameters and driven in opposite directions with equal torques, said rotors having flapping articulated blades of different plan form, means whereby the blades of said rotors are feathered coincident with flapping to a minimum pitch at their maximum flapping position, said position of maximum flapping occurring simultaneously on both rotors and in line with the direction of flight, and said rotors spaced a distance apart less than the sum of the maximum downward deflection of the upper rotor blades and the maximum upward deflection of the lower rotor blades.

5. In aircraft having a plurality of superposed concentric bladed sustaining rotors, means for driving said rotors in opposite directions with equal torques, said rotors having articulative blades mounted upon hub structures limiting their downward travel when not rotating, means for feathering said blades including flapping axes oblique to the blade span axes, the weight ratios, and tip-speed ratios of the blades being of such relative values that the high point of the flapping of each of said blades occurs at a position in line with the direction of flight and means including said feathering means whereby deviation of the high point of flapping of one rotor from this predetermined position is accompanied by a similar deviation of the high point of flapping of the same sign by the oppositely turning rotor.

6. In aircraft having rotative sustaining surfaces comprising a plurality of airfoil surfaces extending radially from a rotative hub structure, a plurality of said hub structures in superimposed concentric relationship, means for applying a differential driving torque to said hubs comprising co-axial drive shafts and differential gearing, a

plurality of flapping blades articulatively mounted upon said hubs to permit said blades to oscillate in a plane passing through the axes of rotation of the driving hubs and to automatically adjust themselves in the direction of the resultant of the centrifugal force combined with the aerodynamical thrust, said rotor blades also being rotatable about their longitudinal axes coincident with oscillation transverse to their mean plane of rotation, said coincidental feathering movement being in such relationship to the transverse oscillation of said blades as to position the maximum transverse oscillation of the individual blades at a common point in azimuth taken clockwise from the downwind position of said rotors, said rotor blades on one of said hubs being of lighter construction than the rotor blades on the other hub to compensate for aerodynamic interference between said rotor systems, the span of one of said rotor systems being smaller than the span of the adjacent system to provide an increased rotational speed on the smaller of said rotors by reason of the differential driving means, and the aspect ratio of the blades of the larger rotor system being greater than the aspect ratio of the blades of the smaller rotor system thereby limiting said increased rotational speed of the smaller rotor, said combination of elements providing aerodynamic spacing of the respective rotor systems whereby their planes of rotation tend to remain parallel during all phases of flight, the superposed spacing of said rotors being less than the sum of the maximum deflection of the upper rotor blades and the maximum upward deflection of the lower rotor blades, means effective upon failure of said aerodynamic spacing of said rotor systems to prevent intersection of the rotors respective planes of rotation including a baffle plate spaced to contact extensions of the individual blades.

7. In aircraft having superposed, co-axial, oppositely turning sustaining rotors with flapping articulated blades, means for feathering the individual blades including flapping axes oblique to the span axes of the blades, the weight ratios and tip-speed ratios of the blades being of such relative values that the high point of the flapping of all the blades occurs at a common predetermined position in azimuth whereby the path of the blades of the respective rotors tends to remain parallel during all phases of flight.

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