July 13, 1937. R. R. HAYS 2,086,802

HINGE DIFFERENTIAL FOR ROTATIVE WING AIRCRAFT

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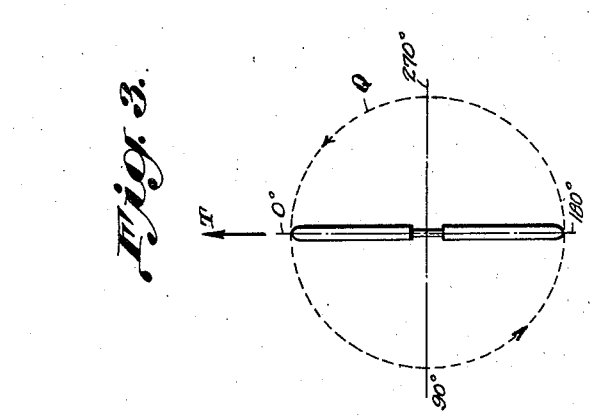

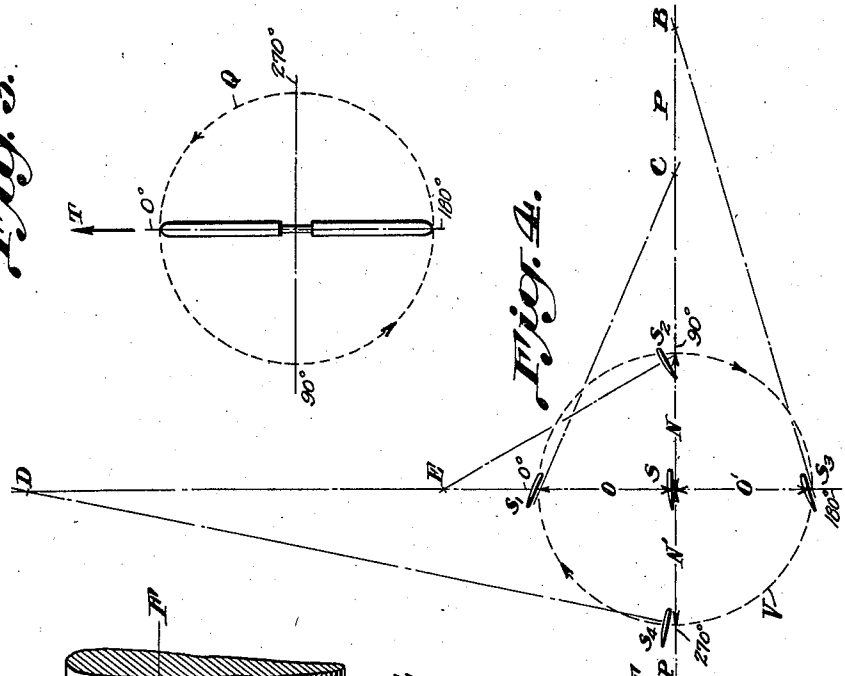

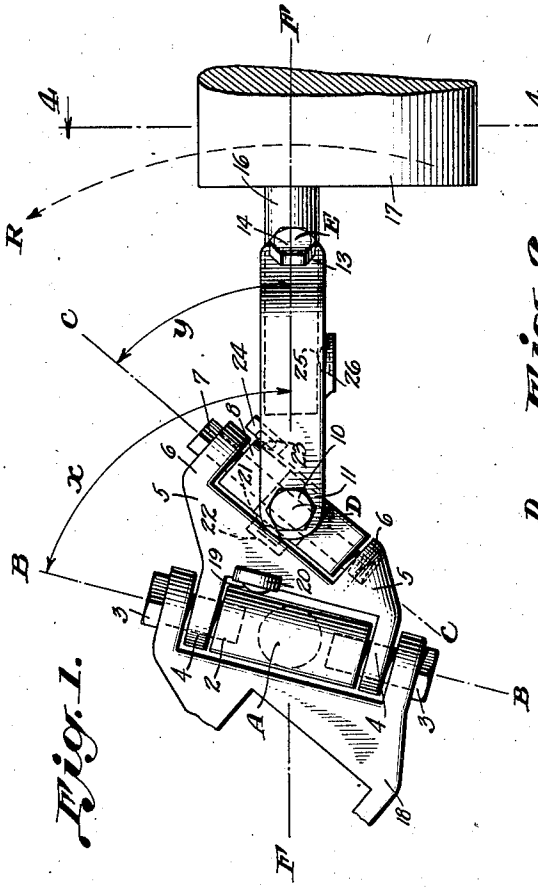

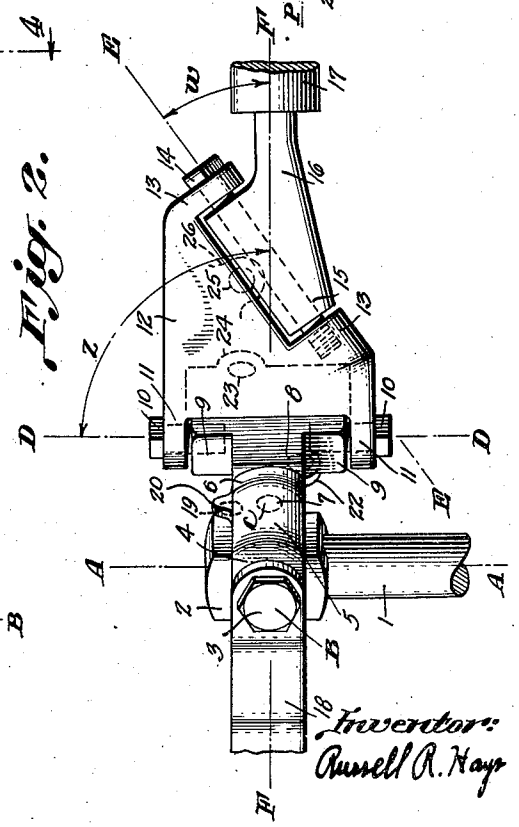

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HINGE DIFFERENTIAL FOR ROTATIVE WING AIRCRAFT

Russell R. Hays, Wellsville, Kans.

Application June 22, 1936, Serial No. 86,473

11 Claims. (Cl. 244—17)

This invention relates to aircraft having sustaining rotors and more particularly to a hinge mounting for the individual blades of such rotors, being a continuation in part of my co-pending application, Serial Number 84,923, filed June 12, 1936.

An object of this invention is broadly the provision of a pitch differential mechanism, automatically operative on a sustaining rotor in translation to produce a minimum pitch of the blades at forward moments of rotation, and a maximum pitch at moments when they are retreating relative to the direction of travel, these moments of maximum and minimum pitch occurring within substantially 90 degrees of each other during rotation of the blades about the rotor axis.

Another object is the provision of a mechanism in which the drag as transmitted by the blades of a rotor having articulative blades, will tend to remain constant at all moments of rotation, and in keeping with this objective the tip of each blade will tend to describe a circle in a plane at right angles to the mean radial position of the blade during each revolution.

Yet another object is the provision of a hinge mounting for articulative blades in which swinging movement within the plane of rotation of the blade occurs about an axis lying in a vertical plane containing the longitudinal axis of the blade, the blade axis making an acute angle with this hinge axis.

Still another object is the provision of a hinge mounting having dual articulation and appropriate stops for effecting a wider range of pitch variation as a result of swinging movement of the blade within its plane of rotation, than can be effected by a single hinge mounting, being an adaptation to a vertical plane of the horizontal hinge mounting described in my co-pending application Serial Number 84,923.

Another object is the provision of a hinge mounting for such a blade providing dual articulation as a result of swinging of the blade both transversely and within its plane of rotation, such articulation occurring simultaneously about two different axes during every 90 degrees of rotation of the blade about the main rotor axis.

All of which is with the object of increasing the efficiency and smoothness of operation of the rotor, as will become more apparent in reading the following description in conjunction with the accompanying drawing in which:

Figure 1 is a view in plan form of one such blade mounting providing a pitch differentiation such as is embodied in this invention.

Figure 2 is a side elevational view of the same hinge mechanism.

Figure 3 is a diagrammatic view in plan form of a sustaining rotor showing the position of the blade tips in degrees of rotation relative to the direction of travel, and

Figure 4 is a somewhat diagrammatic sectional view taken along the line 4—4 of Fig. 1 showing the relative degrees of articulation and the resultant pitch variation occurring through rotary swinging movement of the blade.

Referring to Figs. 1 and 2, a main shaft 1 containing the rotor axis A—A, has a head member 2 solidly affixed to it and carrying the aligned bolts 3—3 in its ends which form a horizontal axis B—B for the hangers 4—4 of the hinge member 5, the outer side of which carries the hangers 6—6 in which is solidly affixed the bolt 7 comprising an axis C—C on which is journaled the horizontal projections 8—8 of the vertical hinge member 9—9 in the ends of which are mounted aligned vertical bolts 10—10 forming a vertical axis D—D for the hinge hangers 11—11 of the hinge member 12, the outer end of which carries the hinge hangers 13—13 in which is secured the bolt 14 forming an axis E—E on which is journaled the hanger 15 of the hinge section 16, the outer end of this section being rigidly secured to the butt of the blade 17 in such a manner as to give a pitch setting of the blade in keeping with accepted practice.

The longitudinal axis F—F of the blade 17 intersects the axes E—E, D—D, C—C, B—B, and A—A in its mean coning position and mean radial position, at which time the face 19 of the stop 20 which is a part of the hinge member 5, contacts the head member 2 thereby limiting the upward pivoting of the hinge member 5 about the axis B—B at this point, and in a similar manner the face 21 of the stop 22 at the outer and under side of the hinge member 5 contacts the hinge member 9—9 to stop downward pivoting of the hinge member 9—9 about the axis C—C at this point. The face 23 of the stop 24 on the hinge member 12 contacts the projection 8 of the hinge member 9—9 stopping forward pivoting of the hinge member 12 about the axis D—D at this point, and the face 25 of stop 26 at the outer and rearward side of the hinge member 12 contacts the hinge member 16 at the same time stopping rearward pivoting of the hinge member 16 about the axis E—E.

In operation, the advantages of this method of articulatively mounting the blades become more apparent from consideration of the pitch

requirements resultant to translation with a sustaining rotor. The dissymmetry of airflow occurring at cross-wind moments of rotation is generally recognized. However, the fact that the forwardly working blades deflect the airflow to an extent that often makes a negative pitch setting of the blade tip desirable at these moments and an increased pitch setting equally desirable at trailing moments of rotation, is not so well known. And where it has been recognized that a smaller or negative tip setting is desired on the forwardly working blade than on the advancing blade, no mechanism has hitherto been available which would provide such a pitch setting without imposing either an excessive pitch setting at rearwardly working moments of rotation, or else too small a pitch setting on the retreating blade when the proper pitch setting was given to the advancing blade.

This defect has its source in the fact that the feathering mechanisms now in use vary their pitch at opposite moments of rotation by the same degree. In other words, an increase in pitch of the blade at one side by a given amount results in an equal decrease in pitch of the same blade 180 degrees of rotation about the rotor axis later. Whereas, what is desired is a minimum pitch at forward working moments of the blade and a maximum pitch 90 degrees of rotation later at retreating moments of rotation.

With this objective in mind, certain mechanical movements are utilized in achieving such pitch variation that are more significant than a brief examination of the structure shown would presuppose. The first of these is that in a universally mounted articulative blade system, and more particularly in conjunction with feathering, dissymmetry of airflow with a resultant dissymmetry in the lift and drag on the individual blades, sets up a harmonic oscillation of the blade, not merely transversely but also within the plane of rotation, the result being that the tip of the blade describes one clockwise circle, Fig. 4, or near circle to every complete rotation of the blade about the main rotor axis in the direction shown in Fig. 3.

Thus the fundamentals of the pitch differential disclosed comprise from a mechanical standpoint, a rotating member, movement of which at any moment of rotation during translation, produces movement of or about at least two axes, one of which is relatively fixed in its position to the main rotor axis A—A. This basic principle, of a rotating member acting in conjunction with another member or members mounted upon a plurality of pivotal axes, one of which is relatively fixed, to produce the desired feathering action in a rotor of this type, is the essence of this disclosure; and the fact, that in this instance a simplified combination of hinge members and stops acting in conjunction with a universally articulated blade achieves this result with a high degree of simplicity, does not preclude the application of the same basic idea to rotors of other types, more specifically those having feathering but not articulative blades.

With this in mind the operation of the hinge mounting is more easily analyzed by first considering the pitch variation achieved by transverse swinging of the blade, then within the plane of rotation, and finally of the two in combination with rotation of the blade tip. In the first instance, the change of pitch resultant to transverse swinging is discussed at length in my copending application Serial Number 84,923.

Referring to Fig. 4, the blade section S, in moving about the circular path V, is seen to move transversely a distance O above the plane of rotation P—P at which time, due to the stop **20**, Figs. 1 and 2, preventing upward pivoting of the hinge member **5**, the blade pivots about the axis C—C with a decrease in pitch proportional to the angle Y, whereas with downward movement through the distance O' below the plane P—P, the pivoting is about the axis B—B, and since the angle X made by the axis B—B with the blade axis F—F is greater than the angle Y, a smaller decrease in pitch occurs during downward swinging movement of the blade than during upward swinging movement.

In an analogous manner swinging of the blade within its plane of rotation takes place about the axes D—D and E—E. Forward pivoting of the hinge member **12** being prevented by the stop **24**, the blade pivots about the axis E—E during its forward travel N with an increase in pitch directly proportional to the angle W; whereas, with rearward travel through the distance N', rotation occurs about the axis D—D with a decrease in pitch proportional to the angle Z which in this instance is 90 degrees, and hence no feathering results.

The degree of swinging within the plane P—P being determined by the distance of the axes D—D and E—E from the rotor axis A—A, it follows that for any specific blade such values of the angles X, Y, Z, and W can be used, as in this instance; where the vertical angle W is smaller than the larger horizontal angle X, and the larger vertical hinge angle Z is greater than the smaller horizontal hinge angle Y, so that with approximately equal values of the distances N and O, it is readily apparent that the minimum pitch of the blade occurs at S_1, Fig. 4, or at such moments as the blade is forwardly rotating at the point 0 degrees of Fig. 3, whereas the maximum pitch occurs at S_2 or at retreating moments of rotation at the point 90 degrees of Fig. 3.

The fact that increasing oscillation of the blade tip with a consequent increase in the radius of the circular path V, is accompanied by an equal degree of pitch variation is apparent from the fact that all pitch variation starts the common point at S in the center of the circle V.

What is not so apparent is that the drag of the blades as transmitted to the rotor center should remain constant at all phases of the blade's rotation about the circular path V. This condition resides in the interaction between the circular paths V and Q. Thus since the highest and lowest travel of the blade to the mean plane of rotation P—P occurs at S_1 and S_3 at which moments of rotation the blades are aligned with the direction of travel T, the oscillation takes the form of a rearward pitching moment at this phase of rotation, the drag at the rotor center being equal to the sine of the angle made by the blades with the plane P—P times the lift.

And in a similar manner, the extremes of swinging movement S_2 and S_4 within the plane of rotation P—P, occur at cross-wind moments of rotation of the rotor. Thus, since the lift and drag are transmitted to the rotor center through the medium of centrifugal forces resultant to disalignment of articulative blades, it follows that the drag transmitted to the rotor center at these moments is equal to the sine of the angle made by the blade with its mean radial position times the centrifugal forces working on the blade, and thus since the angles of disalignment in both

vertical and horizontal planes tend to be constant by reason of the distances O and N being constant, and since the mass and velocity of the blade is constant in all instances, the drag acting at the center of the rotor tends to remain constant.

The advantages, to be gained in efficiency and smoothness of operation through such a constant drag and by reason of such pitch variation, being self evident, what I claim is:

1. In an aircraft having a rotative hub and sustaining blades mounted thereon, a hinge mounting for the individual blades on said hub comprising a plurality of pivotal axes offset relative to the system's center and angularly disposed relative to the system's plane of rotation and to each other, one of said axes being more offset than the other, and stops limiting the pivotal movement of the outer of these axes about the inner axis.

2. In an aircraft having a bladed sustaining rotor, a hub, a hinge mounting for the individual blades on said hub comprising a plurality of pivotal axes lying within a substantially vertical plane and making an acute angle with each other, and a plurality of pivotal axes lying substantially within a horizontal plane and making an acute angle with each other.

3. In an aircraft having a bladed sustaining rotor, a hub, a hinge mounting on said hub for the individual blades comprising a plurality of pivotal axes lying within a substantially vertical plane and making an acute angle with each other, and at least one of said axes making an acute angle with the longitudinal axis of the blade; and a plurality of pivotal axes lying substantially within a horizontal plane and making an acute angle with each other and with the longitudinal axis of the blade forwardly to the direction of the blade's rotation about the rotor axis.

4. In an aircraft having a bladed sustaining rotor, a hub, a hinge mounting on said hub for the individual blades comprising a series of hinge members connected by pivotal axes to form a plurality of hinges, a stop mounted on one member of one hinge for limiting relative movement of the member of said hinge about the hinge pivot in one direction and a stop on one member of another of said hinges for limiting relative movement of the members of said hinge about the hinge pivot in the opposite direction, and said pivotal axes making angles with the longitudinal axis of the blade of such relative magnitude as to vary the pitch of the blade operative about said pivotal axes resultant to articulative rotary movement by such a degree as to provide a maximum and minimum pitch setting during substantially 90 degrees of rotation of the blade about the rotor axis.

5. In an aircraft having a bladed sustaining rotor, a hub, a hinge mounting on said hub for the individual blades comprising a series of hinge members connected by pivotal axes to form a plurality of hinges operative about their respective axes in response to rotary articulative movement of the blade, said pivotal axes substantially intersecting the longitudinal axis of the blade with one of said axes in a vertical plane making a smaller angle with the blade axis than that made by any of the other axes, and another axis in the vertical plane making a greater angle with said blade axis than the smaller of the angles made by said pivotal axes lying in a horizontal plane with said blade axis, and stops actively associated with the hinge member alternately limiting pivotal movement of said hinge members by such a degree as to provide a minimum pitch setting of the blade during such phases as it is rotating forwardly to the rotor's direction of travel, and a maximum pitch setting at such phases as it is retreating relative to the rotor's direction of travel.

6. In an aircraft having a bladed sustaining rotor, a hub, a universal mounting on said hub for the individual blades comprising a series of hinge members having a plurality of pivotal axes lying in at least two planes, stops alternating pivotal movement of the members of said universal mounting about their respective pivotal axes in response to radial rotation of the blade about its mean radial position whereby each pivotal axis co-acts with each pivotal axis in the other plane to vary the pitch of the blade during some phase of each complete revolution of the blade about the main rotor axis.

7. In an aircraft having a bladed sustaining rotor, a hub, a universal mounting on said hub for the individual blades comprising a series of hinge members the pivotal axes of which make acute angles with each other in at least two planes, means alternating movement of said hinge members about said pivotal axes, and said pivotal axes making such angles with the longitudinal axis of the blade as to urge the blade tip into a circular path, during radial swinging movement resultant to airflow dissymmetry, of such a character that the drag forces transmitted to the rotor center tend to remain constant.

8. In an aircraft having a sustaining rotor, a hub, universally mounted blades on said hub, said universal mounting including a plurality of hinge members joined by pivotal axes, and means alternately producing movement by a different degree of said hinge members about said pivotal axes in response to movement of the blade from its mean radial position whereby the pitch of each blade is varied asymmetrically at opposed phases of rotation.

9. In a rotor, a hub, blades, means for securing said blades to said hub so that their pitch may be varied, means for predetermining the mean pitch variation of the blades of the rotor at different phases of rotation by asymmetrically varying the pitch of the blades at different phases of each rotation of the rotor.

10. In a bladed rotor subject to a flow of fluid therethrough and non-parallel to the axis of rotation of the rotor, means for varying the pitch of the blades of said rotor, means for equalizing the drag of the blades of said rotor including means for positively varying the mean pitch angle of the rotor at different phases of each rotation.

11. In a bladed rotor having at least one pair of oppositely extending substantially radial blades, said rotor being subject to a flow of fluid therethrough and non-parallel to the axis of rotation of the rotor, means for equalizing the lift on said oppositely extending blades by asymmetrically varying their pitch at varying phases of rotation, thereby positively varying the mean pitch of the rotor blades at corresponding phases of rotation.

RUSSELL R. HAYS.

DISCLAIMER

2,086,802.—*Russell R. Hays*, Wellsville, Kans. HINGE DIFFERENTIAL FOR ROTATIVE WING AIRCRAFT. Patent dated July 13, 1937. Disclaimer filed December 18, 1944, by the patentee.

Hereby enters this disclaimer to claim 1 in said specification.

[*Official Gazette January 30, 1945.*]