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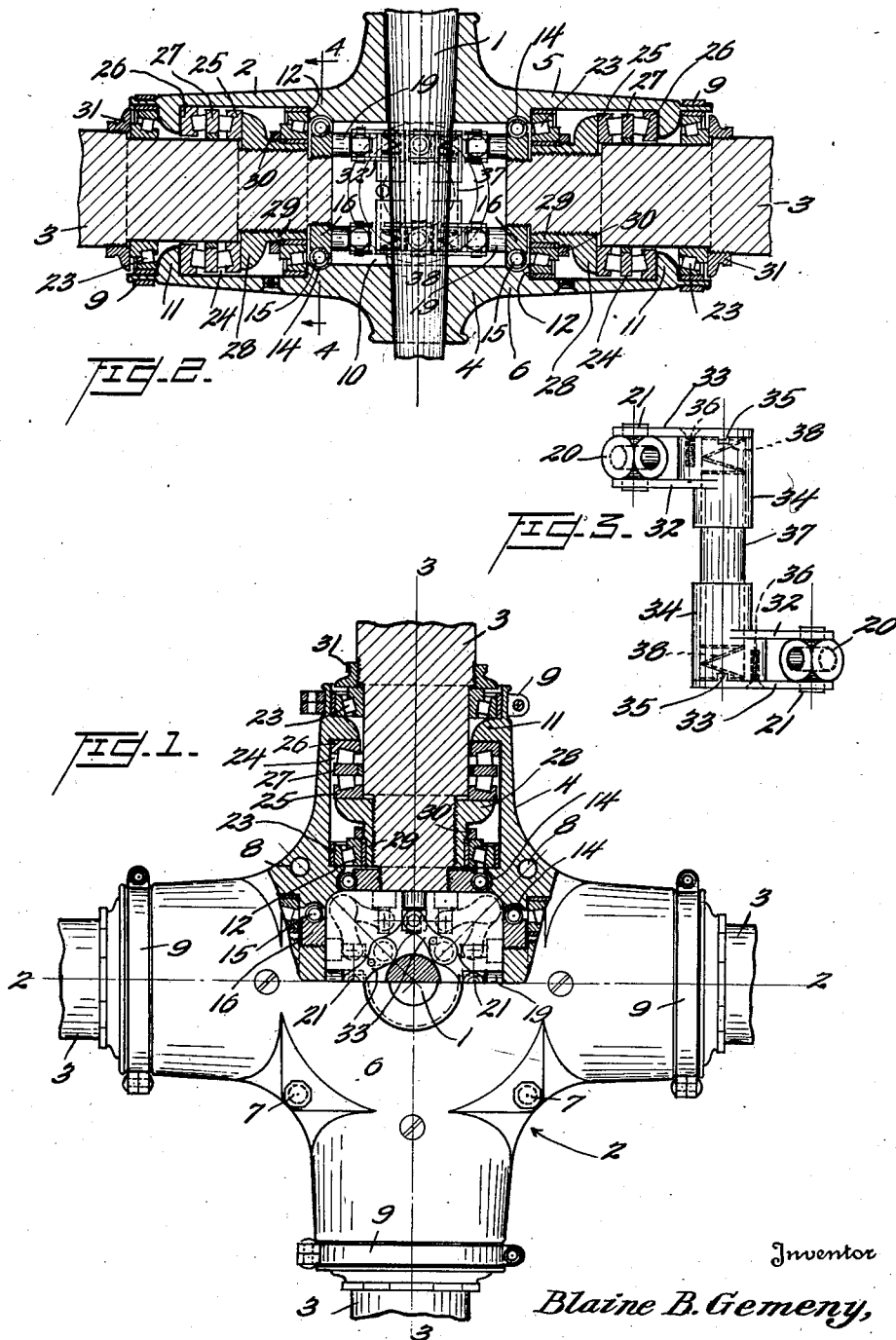
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2,233,364

VARIABLE PITCH PROPELLER

Original Filed Jan. 20, 1936

2 Sheets-Sheet 1



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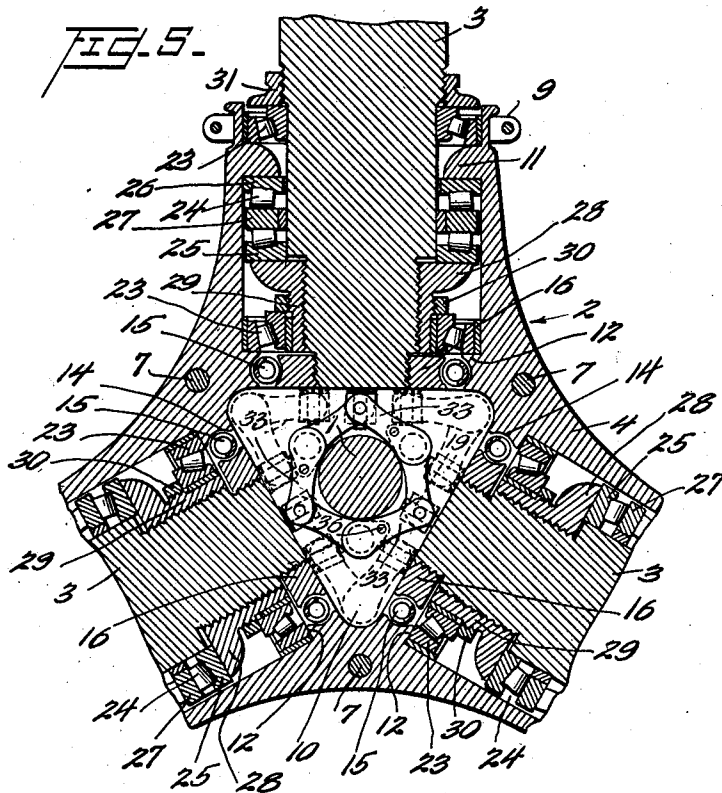
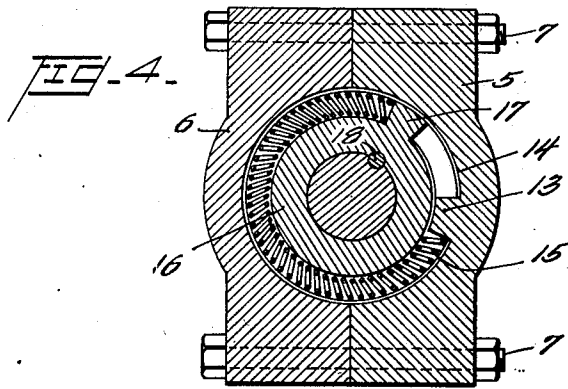
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VARIABLE PITCH PROPELLER

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Application January 20, 1936, Serial No. 59,967

Renewed July 20, 1940

10 Claims. (Cl. 170-162)

The invention relates to improvements in automatic variable-pitch propellers, and more particularly to a propeller for air craft and one in which the pitch is automatically self adjusted under load and operating conditions, and one in which the weight has not been materially increased over that of a standard fixed propeller.

Decided advantages may be gained by the use of variable pitch propellers but, in structures heretofore produced, such advantages have been largely offset by the necessarily increased weight, complicated operating means such as gearing and fluid pressure devices to obtain the variable pitch characteristics, and by the extreme high cost of production. Furthermore, nearly all of the variable pitch propellers hitherto produced depend on the pilot or operator for their variable pitch control.

This application is in part a continuation of my co-pending application Serial No. 711,245, filed February 14, 1934 issued as Patent No. 2,030,903, which relates to an automatic variable pitch propeller and defines such a structure wherein the centrifugal forces otherwise tending to turn the blades during operation of the propeller are balanced out and the air forces acting on the propeller blades during their operation are utilized and controlled to automatically vary the pitch of the propeller to obtain an efficient angle of attack in direct accordance with engine speed; speed of the plane and wind velocities.

It is one of the objects of this invention to provide an automatic variable pitch multiple blade propeller having more than two blades wherein all of the blades are synchronized in their control, and in which the centrifugal forces tending to turn the blades in the hub during operation of the propeller are balanced out so that the angle of attack may be automatically varied in direct response to air forces acting on the blades while the propeller is in operation.

In the co-pending application, above identified, there is described a propeller structure with a plurality of propeller blades having the center of the air forces acting thereon during operation of the propeller so disposed with respect to the center of gravity of the blade sections as to cause a turning movement of the blades in the hub of the propeller and resilient means controlling the movement of the blades under such air force, together with movable weights interconnected with the blade shanks to synchronize the blades and balance out centrifugal forces acting thereon during operation of the propeller. It is one of the objects of this invention to provide pro-

pellers having more than two blades with similar means for balancing out centrifugal forces and with means for automatically varying the pitch of the propeller in accordance with the air forces acting on the blades.

Automatic variation of the pitch of a propeller cannot be satisfactorily obtained by utilizing the centrifugal forces acting on the blades to produce the variation. The centrifugal forces depend only on the speed of rotation of the propeller, whereas the air forces acting on the blades thereof depend on engine speed, speed of the plane and wind velocities. In carrying out the objects of this invention, the centrifugal forces, otherwise tending to turn the blades in the hub, are balanced out at all positions of the blades by properly balanced weights interconnected with the hub ends of the blades and resilient means associated with the hub ends of blades control turning movements of the blades in accordance with air forces acting on the blades during operation of the propeller.

The invention will become apparent to those skilled in the art from the detailed description hereinafter set forth in which reference is made to the accompanying drawings wherein like reference numerals represent the same elements throughout the several figures of the drawings.

In the drawings:

Fig. 1 is a view of a four blade propeller embodying the invention showing the structure partly in elevation and partly in central longitudinal section with the movable position of control elements indicated thereon by dotted lines.

Fig. 2 is a central longitudinal section taken on lines 2-2 or 3-3 of Fig. 1.

Fig. 3 is an elevation of one of the weighted connections intermediate adjacent propeller blades with concealed parts indicated thereon by dotted lines.

Fig. 4 is a transverse sectional view taken on line 4-4 of Fig. 2.

Fig. 5 is a view corresponding to Fig. 1, showing a three blade propeller structure.

Referring to Figs. 1 and 2, the numeral 1 indicates a conventional engine shaft on which the propeller 2 is mounted. The propeller consists of the blades 3 whose roots extend into the hub 4. The hub is of the split housing type consisting of two counterpart portions or halves 5 and 6, which are arranged to be squeezed tightly around the blade shanks and bearings within the hub. The squeezing or clamping engagement is accomplished by through bolts 7 which pass through registering bolt holes 8 drilled through

the counterpart portions and by clamping rings 9 at the ends of the housing. The counterpart portions are duplicates, machined along meeting faces to insure proper registry and cooperation with each other. The half portions are machined to provide a central transversely extending bore to receive the engine shaft in mounting the propeller. The hub members are provided with an enlarged central recess 10 to accommodate for movement therein movable counterweights connected between the adjacent shanks of the propeller blades for balancing the centrifugal force exerted on the blades and presently to be described. Extending inwardly thereof, each of the counterpart portions of the housing is provided adjacent the outer ends with integral semi-circular flanges or bearing retaining members 11. These flanges or members are surfaced on opposite sides to receive and support bearings included in the hub assembly and serve to define, in conjunction with similarly surfaced, outwardly facing shoulders 12, recesses in which the bearings are received. Adjacent to the outwardly facing shoulders 12, the hub housing portions are provided with an inwardly extending lug 13, and either side thereof with concave recesses 14 adapted to form, in conjunction with means on the blade shanks, a housing for a helical spring 15.

The blades 3 have their shanks provided with a series of reduced or stepped portions extending within the hub for cooperation with bearing and control members therein. The innermost stepped portions of the shanks are threaded to receive thereon, in adjustable relationship, lever control members in the form of crank collars 16 which have concave recesses in their outer periphery extending therearound from opposite sides of lugs 17. The concave recesses are arranged to register with the recesses 14 in the hub sections and form therewith housings for the springs 15 which are interposed, respectively, between the lugs 13 on the hub housing and the lugs 17 on the collars. The lugs 13 and 17 are in overlapping relationship and cooperate as steps in limiting turning of the blade shanks in a clockwise direction as viewed in Fig. 4 of the drawings. The springs 15, interposed between the lugs on the hub and crank collars, normally tend to turn the blade shanks in a clockwise direction but allow turning of the shanks in a counterclockwise direction under forces tending to compress the springs.

The crank collars 16 are adjusted with respect to the hub housing by screw threaded adjustment along the reduced shanks of the blades, and are held in adjusted positions by means of keys 18 engaging keyways in the blade shanks and the collars—see Fig. 4. This precludes any movement of the collars with respect to the blades after proper adjustment has been made.

The control members 16 are provided at diametrically opposed points with stub shafts 19 extending into the central recess in the hub housing. These stub shafts 19 afford supports and mounting means for weight mechanism for balancing the centrifugal forces tending to cause a turning movement of the blades in the hub when the propeller is rotated. This mechanism comprises a plurality of identical weight lever arm assemblies each of which are connected between a stub shaft on one blade control element and another stub shaft on the control element for an adjacent blade. Referring in particular to Fig. 3, each weight lever assembly consists of

two collars 20 having integral therewith on opposite sides, stub shafts 21 rotatably supporting weight lever arms 32 and 33 apertured and fitted over the collar stub shafts. The weight lever arms 32 are each provided at their free ends with a cylindrical housing 34 open at each end. Weight lever arms 33 are each in the form of a flat plate, abutting and closing one end of the cylindrical housing of the other weight lever arm and having two oppositely disposed laterally extending lugs 35 that engage within matched recesses in the ends of the cylindrical housing portion of cooperating arm 32. Screws 36, or any other suitable detachable fastening means, may be employed to maintain the two engaging lever arms in the assembled position described. A floating weight in the form of a pin 37 telescopically and slidably engages within adjacent cylindrical housings, with its ends each in abutting relationship with a coil spring 38 within one of the cylindrical housings. By this construction, it will be noted that the weight lever arms may rotate and have sliding movement on the ends of the pin 37 and the springs 38 will tend to hold the pin at equal distances from the closed ends of the cylindrical housings. The weight lever arms extend in relatively opposite directions from each control element so that the longitudinal axis of the pin connecting lever arms from adjacent control elements lies substantially in a plane bisecting the angle defined by prolonged longitudinal axis lines through adjacent propeller shanks.

The entire weight mechanism connecting the several control elements on the shanks of the propeller blades acts as a unit to counterbalance the centrifugal forces acting on the blades when the propeller is operated. The arrangement is such that when the propeller blades turn in the hub, the stub shafts 19 on the control elements may move in two directions over a circular path, whereas the main body of the counterweight, of which the floating pin and housing is the principal part, moves in a straight line. When the blades turn from a low pitch angle to a high pitch angle, the connected stub shafts 19 move closer together in two directions. The turning of the lever on the floating pins and the stub shaft 19 permits this movement in one direction and the sliding of the lever arms on the floating pins permits the movement in the second direction. The showing of the weight mechanism assembly of Fig. 3 is in open position, whereas in a closed position the space between the cylindrical housings is substantially closed. When the propeller is not being operated, the weights assume a position wherein the engine shaft may serve as a stop. The arms and counterweights being pivoted on the stub shafts of the control elements, and adjacent levers being pivotally and slidably associated in their connection with the counterweights, these will move together in synchronism outwardly from the axis of the engine shaft when the propeller is operated, thereby increasing the leverage applied to the control elements in counterbalancing centrifugal forces acting on the blades.

The weights are so selected and arranged with relation to a particular propeller design as to result in accurate counterbalancing, at any position of the blades, the centrifugal forces that otherwise cause the blades to turn in the hub. There are two controllable factors in providing for accurate counterweight balance. One is the weight of the arms and the counterweight itself,

and the other is the distance from the center of the hub to the center of the stub shaft on the control element or collar which determines the leverage and throw or the extreme open position of the weights. The full open position of the counterweights corresponds to the full open position of the blade angle so that the centrifugal force acting on each blade is in exact relation to the blade angle at all times. The counterweights are so arranged as to offer no obstruction to the engine shaft at any time. It will be understood that the size and diameter of the collar 16 will be determined by the leverage required for the counterweights and the exact shape of the hub recess will be governed by the necessary clearance to provide for travel of the counterweights. As the diameter of the collar or control element is increased, the greater is the leverage of the counterweights, permitting finer tuning of the counterweight action. Also, the collars act as part of the housings for the springs and are determining factors in the design of the spring if the springs are located in the position as shown for purpose of illustration.

The relative distances of the center of the air pressure on a blade and the center of gravity of the blade sections from the leading edge of the blade are so arranged that the air forces acting on the blades during operation of the propeller may be utilized to produce a turning movement of the blades in one direction in the hub of the propeller. In this arrangement, the center of the air pressure acting on a blade is always displaced laterally a predetermined distance from the center of gravity of a blade section, always at one side of the gravity center, but this distance is so small that the leverage of the air force causing a turning of the blade in the hub is also small. Therefore, the spring force required to regulate the effect of the air force will be relatively small and does not require springs of excessive dimensions. These springs may be accurately designed for the ranges of control necessary in different propeller structures. Adjustments of spring length and tension can be obtained by introducing adjusting means between the springs and the lugs in many different ways well known to the art.

The springs tend to hold the blades in an extreme open position or a maximum blade angle until the propeller is rotated and the air pressure thereon is sufficient to turn the blades to a smaller blade angle and to offer a positive resistance to the air forces closing the blade angle to less than the calculated angle of attack at normal cruising speed of the engine. In cooperation with the spring control, it will be noted that the movement of a blade in one direction is limited by engagement of the lugs, as previously described and in the opposite direction by engagement of the counterweights with the engine shaft.

The bearings for each of the propeller blades consist of two radial thrust anti-friction roller bearings 23 and an axial thrust anti-friction roller bearing 24 at each end of the hub housing. The axial thrust roller bearings are positioned within the hub housing in engagement with the inwardly directed bearing retaining flange 11. This bearing consists of the two outer roller race plates 25 and 26 and the single intermediate roller plate 27 interposed between the rollers. The bearing assembly is adjusted to position against the retaining flange by means of a collar 28 which has a screw-threaded relationship with one of the reduced or stepped portions of the

blade shanks. The collar 28 serves as an adjusting member for the main thrust bearing and has a reduced portion 29 screw-threaded in part and extending within the inner member of one of the radial thrust bearings positioned against the outwardly facing shoulder 12. An adjusting means 30 has threaded engagement with the reduced portion 29 of the main adjusting collar 28 to provide for clamping engagement of the inner radial thrust bearing against the outwardly facing shoulder 12 on the hub portion. The other radial thrust bearing is positioned within the outer end of the hub against the inwardly directed bearing retaining flange 11, where it is held in position of adjustment by an internally threaded collar 31 engaging a threaded portion on the shank of the propeller blade. The bearing assemblies are duplicated at each end of the hub and the above description suffices for each assembly. With the arrangement described, it will be noted that very tight adjustments of the bearings can be obtained and yet have all of the main centrifugal force acting on each blade effectively applied to a single axial thrust bearing. The radial thrust bearings take all of the torque and may be positioned as tightly as possible against their seats on the hub housing by the adjusting collars, yet when in operation, the centrifugal force, which amounts to many thousand pounds for each propeller blade, is applied to the axial thrust bearing, it will tend to relieve the radial thrust bearings from their original tight adjustment sufficiently to enable the centrifugal thrust to be taken solely by the axial thrust bearings.

As previously pointed out, one of the important features of this invention is the utilization of the air pressure to decrease the angle of attack to the position of maximum efficiency. This is done by employing blades so designed that the distance of the center of gravity of the blade sections from the leading edge and the distance of the center of air pressure on the blades are so related that the air forces will tend to produce a turning movement of the blade in opposition to the spring pressures acting on the blade shanks. This feature of design of the blade is set forth in detail in the copending application, above identified, and it suffices for this description to define the blades as those having the center of gravity and the center of the air forces thereon as described above.

The invention contemplates the use of blade structures whereon the center of air pressure is always to occur at a greater distance from the leading edge than the center of gravity to obtain desired control over the air forces. The center of air pressure occurring below the center of gravity of the blade section would cause the blade to turn in the hub so as to reduce the angle of attack, which is the desired action. However, to control the amount of reduction of this angle of attack, the springs 15 previously described act to hold the blade at an angle of attack predetermined by the propeller designer for normal cruising and full throttle speeds of the engine. It will be obvious from the foregoing description, that the springs operating on the blade shanks within the hub perform their function in conjunction with the air force to adjust the blades to the ideal angle of attack at normal and full throttle speeds of the engine, regardless of the speed of the plane or the velocity of the wind up to the limit of the maximum blade angle, so that the fluctuations of wind velocity are automatically compensated for. In taking off, div-

ing, climbing, or in acrobatics, the blades will automatically adjust themselves to the ideal angle of attack at normal and full throttle speeds, or, in other words, the thrust of the propeller will be maximum in relation to the speed power coefficient for maximum efficiency throughout the entire range of use in such operation.

The center of air force being below and back of the center of gravity of the blade sections, in the operation of the propeller above described, the air force is utilized to decrease the angle of attack under control of the springs tending to hold the blade in the extreme open position or maximum blade angle. The type and design of spring employed will be determined by the conditions dealt with in each case of structure variation, but in all cases the result will be that described in connection with the illustrated embodiment of the invention. The centrifugal forces acting on the propeller blades tend to turn the blades in the hub, this action being counterbalanced by the free swinging weights of the governor. The governor and the springs, together with the utilization of the air force by suitably designed propeller blades, result in a self-adjusting variable pitch propeller free from gearing and other pitch varying agencies, and further results in a propeller having a minimum number of parts so that assembly and adjustment thereof is a simple matter.

In the modified form in Figure 5, showing application of the invention to a three blade propeller, the central recess in the hub is substantially triangular in shape. The general structure, however, including that for the weight governor connections, is substantially the same in detail except for size as previously described for the four blade propeller. It will be understood that the size and weight of the lever arms and floating weight pins will be determined by the designer in accordance with characteristics of the propeller design.

While the invention is hereinabove described in connection with the preferred embodiment, it is to be understood that the words which have been used are words of description rather than of limitation and that changes within the purview of the appended claims may be made without departing from the true scope and spirit of the invention in all of its aspects

I claim:

1. In a variable pitch propeller, the combination of, a hub, a plurality of propeller blades spaced less than 180° apart rotatably mounted coplanar in said hub and having crank members fixed to their inner ends, collars on the crank members diametrically opposed with relation to the longitudinal axis of a blade, a movable weight lever arm pivotally mounted on each of said collars, a movable weight member slidably and pivotally supported between a lever arm extending from one crank member and a lever arm from an adjacent crank member, said movable weight and lever arm assemblies being relatively movable with respect to the crank members to counterbalance centrifugal forces acting on the propeller.

2. In a multiple blade variable pitch propeller having a metal hub and a plurality of blades spaced less than 180° apart having their shanks mounted for turning movement in the hub, an annular crank member attached to each blade shank, each crank member having diametrically opposed laterally extending lever mounting members thereon, a weight lever arm pivotally mount-

ed at one end on each of said lever mounting members and having a cylindrical housing at its free end, weight members slidably mounted in and between a pair of cylindrical housings on lever arms extending from adjacent crank collars whereby all of the weight lever arms are connected in pairs by a plurality of weight members, said lever arms having sliding and rotative engagement with said weight members to permit free movement of the weights to oppose centrifugal forces tending to turn the blade in the hub when the propeller is rotated.

3. In a multiple blade variable pitch propeller having a metal hub and a plurality of blades having their shanks mounted for turning movement in the hub, an annular crank member attached to each blade shank, each crank member having diametrically opposed laterally extending lever mounting members thereon, spring means interposed between the hub and each crank member tending to turn the crank member in one direction, a weight lever arm pivotally mounted at one end on each of said lever mounting members and having a cylindrical housing at its free end, a weight member having cylindrical portions slidably mounted in and between a pair of cylindrical housings on lever arms extending from crank members of adjacent blades whereby all of the weight lever arms are connected in pairs by a plurality of weight members, said lever arms having sliding and rotative engagement with said weight members to permit free movement of the weights to oppose centrifugal forces tending to turn the blade in the hub when the propeller is rotated.

4. In a multiple blade variable pitch propeller having a metal hub and a plurality of blades having their shanks mounted for turning movement in the hub, an annular crank member attached to each blade shank and mounted in a plane which intersects mounting planes of crank members on adjacent blades, each crank member having diametrically opposed laterally extending stub shafts thereon, a weight lever arm pivotally mounted at one end on each of said stub shafts and having a cylindrical housing with one end open at its free end, a weight member having cylindrical portions slidably mounted in and between a pair of cylindrical housings on lever arms extending from crank members of adjacent blades whereby all of the weight lever arms are connected in pairs by a plurality of weight members, said lever arms having sliding and rotative engagement with said weight members to permit free movement of the weights to oppose centrifugal forces tending to turn the blade in the hub when the propeller is rotated.

5. In a variable pitch propeller, the combination of a hub, a plurality of blades rotatably mounted in said hub and having crank members fixed to their inner ends, said crank members each having stub shafts diametrically opposed with relation to the longitudinal axis of the associated blade, a collar support rotatable on each of said stub shafts, a movable weight lever arm pivotally mounted on each collar support, a movable weight member slidably and rotatably supported between a lever arm extending from one crank member and a lever arm from an adjacent crank member, said movable weight and lever arm assemblies being relatively movable with respect to the crank members to counterbalance centrifugal forces tending to turn the blades in the hub when the propeller is rotated.

6. In a variable pitch propeller, the combina-

tion of a hub, a plurality of blades rotatably mounted in said hub and having crank members fixed to their inner ends, resilient means opposing movement of the crank members in one direction, each of said crank members having stub shafts diametrically opposed with relation to the longitudinal axis of an associated blade, a support member rotatable on each of said stub shafts, a movable weight lever arm pivotally mounted on each of said support members, a movable weight member slidably and rotatably supported between a lever arm extending from one crank member and a lever arm from an adjacent crank member, spring means between each weight and its supporting lever arms tending to centralize the weight between the supporting lever arms, said movable weight and lever arm assemblies being relatively movable with respect to the crank members to counterbalance centrifugal forces tending to turn the blades in the hub when the propeller is rotated.

7. In an automatic variable pitch propeller having a hub and at least three equally spaced radiating blades mounted for turning movement on their axes, means connecting the blades for automatically balancing out centrifugal forces acting on the blades during rotation of the propeller, and means for automatically controlling the pitch of the blades in accordance with the air forces acting thereon during operation of the propeller, said first mentioned means including crank levers on the blades and a series of weight lever arms and radially movable weight members connecting adjacent inner ends of the propelled blades through said crank levers, said weight lever arms having pivotal and sliding connection with the weight members and connections with said crank members providing pivotal movement in two directions.

8. An automatic variable pitch propeller comprising a hub, three at least equally spaced radiating blades with coplanar axes mounted for turning movement on the hub, crank members fixed to the inner ends of the blades, a plurality

of weights and movable lever arms supporting said weights, said lever arms and weights connecting in series the crank members on the inner ends of the blades to automatically counterbalance centrifugal forces tending to turn the blades in the hub during rotation of the propeller, and connecting means between the crank members and weight lever arms at diametrically opposed points on said crank members providing universal movement of the arms with respect to the crank levers.

9. A variable pitch propeller comprising a hub, three or more equally spaced radiating blades mounted for turning movement in the hub, means for varying the angles of the blades in relation to air forces on the blades during rotation of the propeller, means including movable weight lever arms and radially movable weight members connecting each blade with the next adjacent blade on opposite sides thereof to provide a series connection of all of the blades to automatically balance centrifugal forces tending to turn the blades in the hub during rotation of the propeller, and connections between said weight lever arms and blades providing universal movement of the arms.

10. In a variable pitch propeller, the combination with a motor shaft, a hub mounted on said shaft, three or more equally spaced radiating propeller blades rotatably mounted in said hub and each blade having a crank member fixed on the inner end thereof, a series of movable weighted connections enclosed within the hub for connecting the crank members in series from diametrically opposite points thereon, means pivotally connected with the cranks and pivotally associated with the weighted connections to provide outward radial movement of the connection between said blades, said weighted connections serving to counterbalance centrifugal forces tending to turn the blades when the propeller is rotated.

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