March 3, 1942. E. H. GODFREY 2,275,361

ADJUSTABLE PITCH PROPELLER

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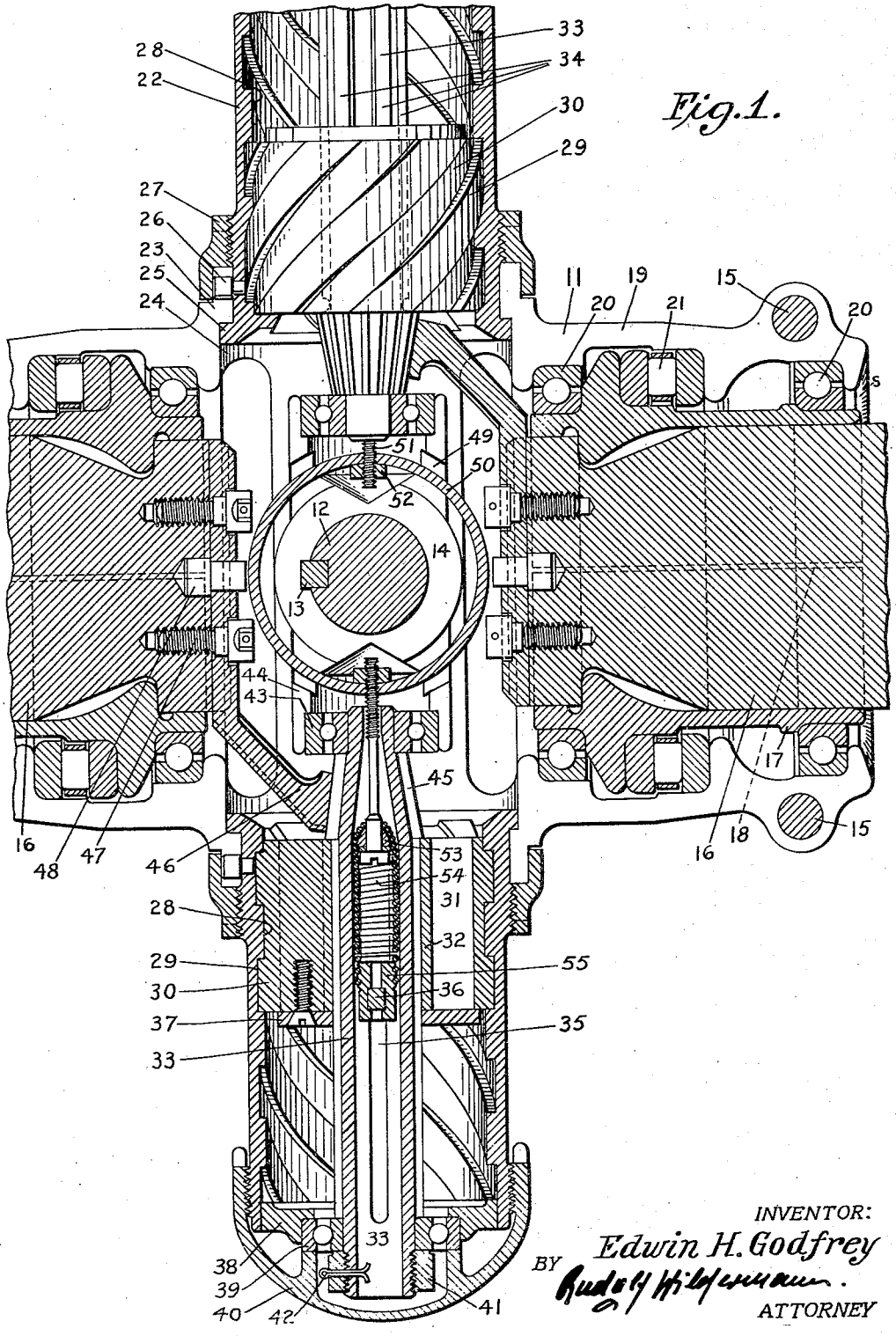


Fig. 1.

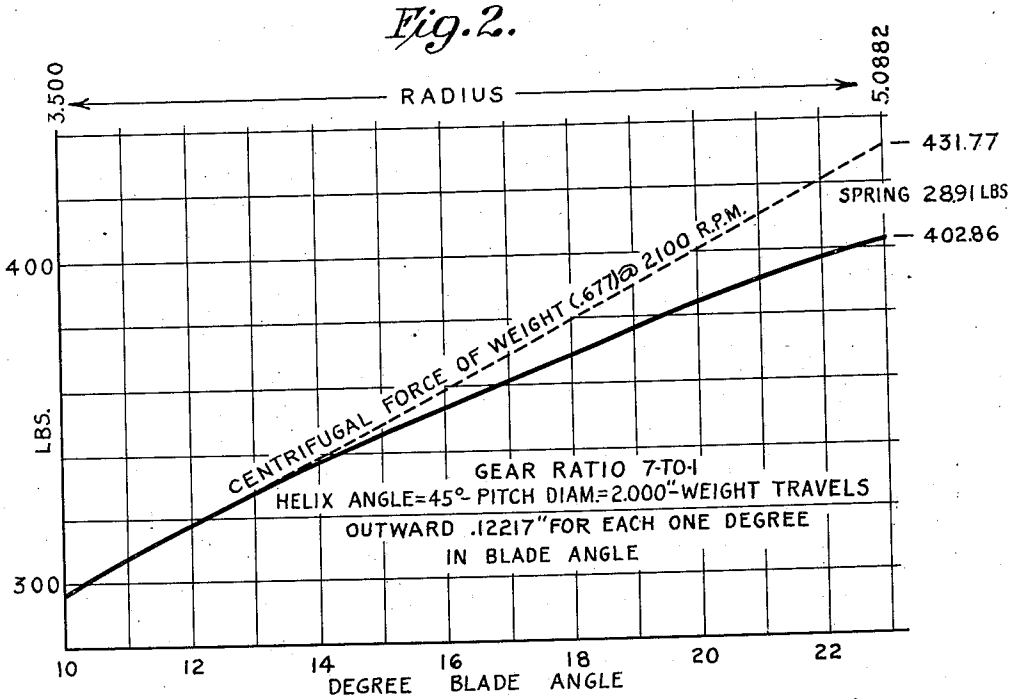
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ADJUSTABLE PITCH PROPELLER

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Fig. 2.



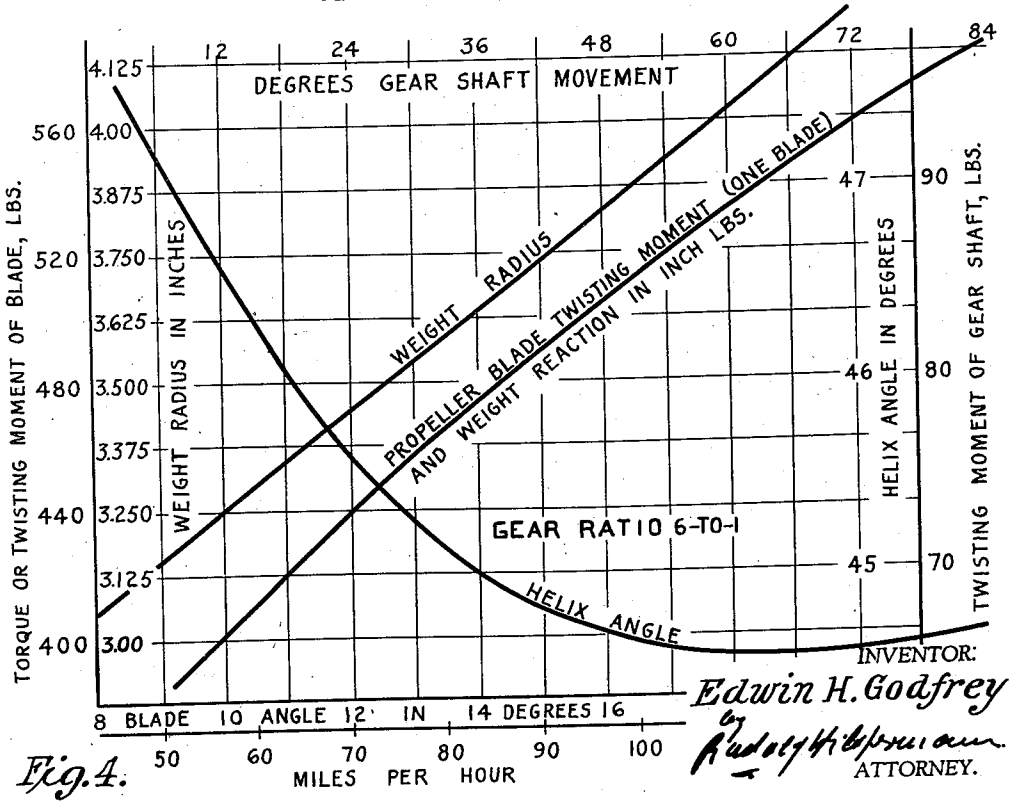


Fig. 4.

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ADJUSTABLE PITCH PROPELLER

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Fig. 7.

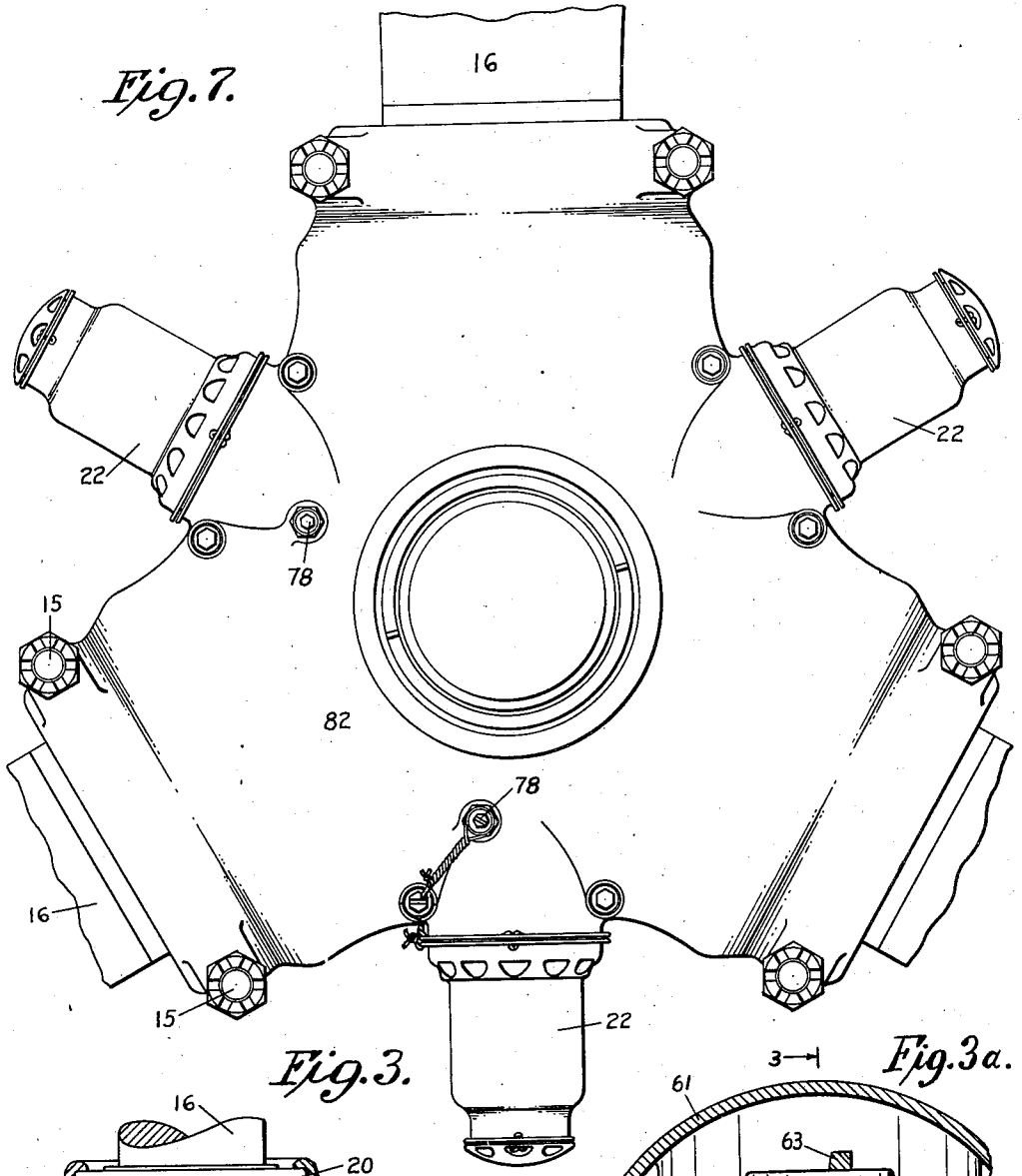


Fig. 3.

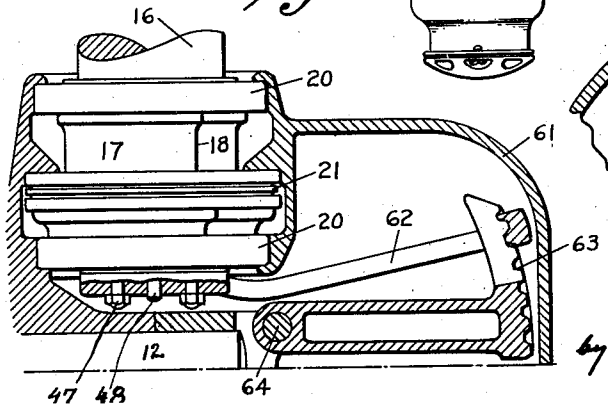
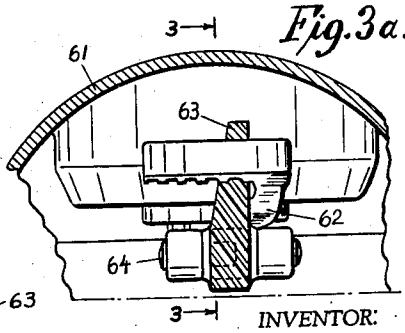


Fig. 3a.



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Fig. 5.

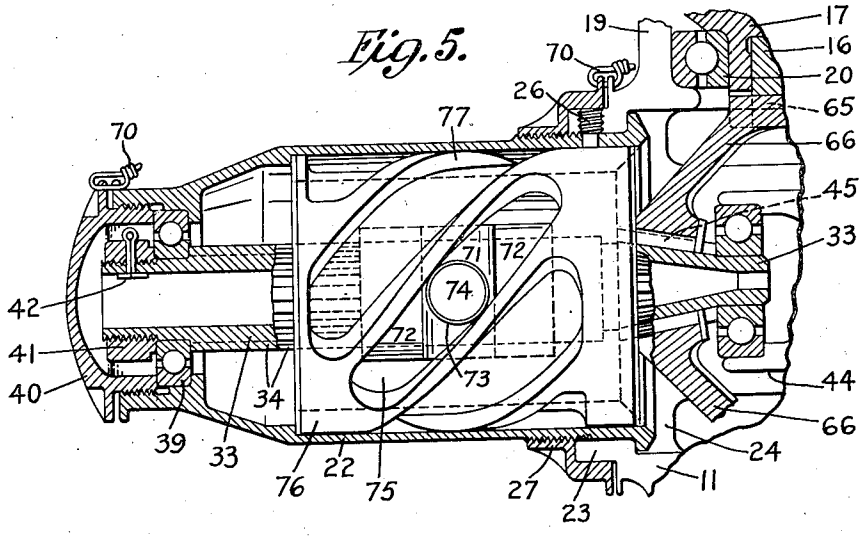
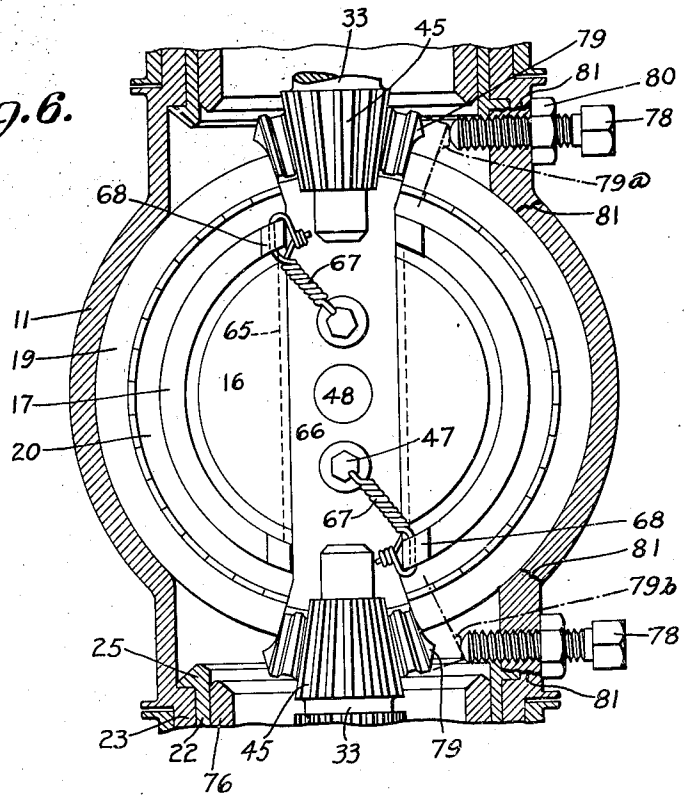


Fig. 6.



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Patented Mar. 3, 1942

2,275,361

UNITED STATES PATENT OFFICE

2,275,361

ADJUSTABLE PITCH PROPELLER

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Application March 6, 1937, Serial No. 129,487

10 Claims. (Cl. 170—162)

This invention concerns the automatic control of variable pitch propellers.

A variable pitch propeller of a suitable design is best adapted—in connection with the craft it is mounted on—to perform a predetermined work at a certain pitch or angular setting of the blades. Correspondingly the blades of the said propeller, when angularly set at a higher or lower pitch will in each instance be best adapted to perform a certain work, which is larger or smaller, respectively.

To the work best performed at a certain pitch of a blade corresponds a fixed torque exerted by said blade around its axis of adjustability or variability of pitch. We may counteract that torque by an exactly measured equal reaction. At every other pitch of the blade we have a different torque corresponding to the ideal load—usually at a related speed of rotation of the propeller; and in each instance we may counteract the torque by a predetermined reaction.

It is the object of this invention to provide a simple, sensitive yet rugged mechanism which automatically provides at each different angular setting or pitch of a propeller blade a predetermined reaction exactly equal to and preferably counterbalancing the torque caused at that setting or pitch, when the propeller performs the work for which the said setting or pitch is best adapted.

When and if I obtain the said object, and presuming that the blade is journalled so that the torque increases with an increase of the angle of the pitch, then the working load, and therefore the torque, always tends to return the blade to a lower pitch, and I provide an ideal automatic control of the pitch of the blade of a variable or adjustable propeller, as follows:

As long as the propeller performs the work for which its pitch or setting at that time is best adapted, the reaction completely balances the torque, so that the pitch or setting remains unchanged. But when the propeller is called upon to perform work in excess of the work for which its pitch or setting at that time is best adapted, then the reaction is insufficient to balance the increased torque, the blade will be rotated by the increased torque, until a pitch or setting is reached, at which the reaction counteracts the torque, and the new pitch or setting is best adapted for the work now being performed by the propeller. An opposite adjustment of the pitch under converse conditions is of course readily understood by those familiar with this art.

Now the said torque and the angle of the setting or pitch are not directly correlated, i. e. one is not a simple function of the other. But in the ordinary performance of a craft, say an aeroplane, the preferred pitch at which the propeller best performs relates to a certain speed of rotation of the propeller. I have carried out exhaustive tests and computations in connection with a number of variable propellers of present-day design, and I have determined that there exists an almost straight ratio between the angle of the preferred pitch and the radius extending from the axis of the propeller to the center of gravity of a weight, when the said radius is adjusted so that the centrifugal force of said weight, at a propeller speed corresponding to the said pitch, is equal to the torque corresponding to the said pitch and therefore also to the desired reaction.

This invention concerns more particularly, in combination with a variable pitch propeller, centrifugal means and a transmission interconnecting the blade of said propeller and said centrifugal means, so that the reaction produced by the centrifugal means is exactly equal to the above referred to torque.

It will be understood from the foregoing, that in accordance with the experiments I have carried out with standard variable propellers, the radial path of a centrifugally moving weight and the angle of the blade are not exactly correlated. But within the meaning of this invention the design of a propeller might be so revised that at a straight-line relationship between the radius of the centrifugal weight and the pitch angle of the propeller blade the centrifugal force just balances the torque. But I also realize, that it is undesirable to impose collateral restrictions upon the propeller construction, which encumber it, even might cause inefficiency. Therefore I also give consideration to a compensation of the said discrepancy, in one or the other of the following ways:

(A) The reaction may be adjusted by variations of weight, e. g. by varying the weight exerting the centrifugal force.

(B) The actual path of the centrifugal weight may be adjusted, so that its radial path is in straight-line ratio with the pitch angle, when the centrifugal force produces the desired reaction.

(C) Adjustment in the transmission by irregular gearing, cam action for instance.

Various additional objects, which attach to these and other modifications of this invention will be better understood from the description of

exemplary executions of the invention, as illustrated in the drawings, where—

Fig. 1 represents an example for item A, in a cross section normal to the propeller shaft.

Fig. 2 is a chart comparing torque, as it changes with the pitch angle, with centrifugal force changing with the radius, in connection with an arrangement like that of Fig. 1.

Fig. 3 is a quadrant of a cross-sectioned side view illustrating modification B, the line of cross-section being indicated by numeral 3 and arrows in Fig. 3*a*.

Fig. 3*a* is a corresponding part end view inside of the housing, the housing being sectioned away.

Fig. 4 is another chart, relating to an example falling under the scope of the following figures.

Fig. 5 is a sectional cross-sectioned view of the weight and transmission parts concerning a modification under item C.

Fig. 6 is a corresponding, sectioned view, looking in the housing onto the inner end of a blade. The actual sectioning is in the plane of the propeller axis, except at and near the stop screws. More particularly the section is offset to the back of the propeller shaft at the portion marked 6*1*—6*1*, so that the propeller shaft does not show in this view.

Fig. 7 is a front elevation of a variable pitch propeller with three blades centrifugally balanced according to this invention.

The propeller of Fig. 1 has a split housing, of which only the rear part *11* is shown. The detached front part substantially matches in elevation the rear part shown, and is to be assembled therewith by bolts *15* in a plane which substantially coincides with the plane of cross-section of Fig. 1.

Aside from a few parts, such as the key *13* which secures hub *14* arising from the back of the housing upon the propeller shaft *12*, the parts to the right and left of a vertical center line, through the axis of the propeller shaft, and above and below a horizontal center line through such an axis are substantially symmetrical, at least as far as the broken away parts of the extremities are concerned.

A pair of these extremities are the blades *16* which are encapsuled at their roots by rings *17* split at *18*. The rings *17* together with the blades *16* are journalled in the split bearing extensions *19* of the housing by way of roller bearing *21* and ball bearings *20*.

The capsules *22* of the centrifugal units extend from the housing rectangularly between the propeller blades. The capsules *22* extend through necks *23* provided upon opposite sides of the housing into a bore *24* upon the inside of the housing. Into that bore *24* of the housing fit flanges *25* at the ends of capsules *22*. Nuts *27* are engaged upon the outer circumferences of the capsules *22* and serve to clamp the capsules upon the necks *23*. Pins *26* angularly retain the capsules in the necks *23*. The insides *28* of the cylinders of the capsules *22* are helically rifled and the outer faces *29* of the centrifugal weights *30* are correspondingly fluted, so that rotation is imparted to the centrifugal weights *30* when they move centripetally and centrifugally in and out in said capsule *22*. The fluted outside *29* of each centrifugal weight *30* is connected by spokes *31* to the hub *32* of the weight. The inner bores of the hubs *32* are provided with a cross-sectionally irregular formation, for instance, an internal gear formation which in the manner of a feather key slidably but non-rotatably guides the weight *30* upon the centrifugal or gear shaft *33*. Shaft *33* is therefore provided with corresponding irregular formation, e. g. teeth *34*.

The hollow shafts *33* have longitudinal clearance slots *35*. Through these slots extend the square pins *36*, which are countersunk into the ends of the weights *30* and retained upon said ends by cover plates *37*. The purpose of the pins *36* will be explained later.

In the outer end of the capsule *22* are seated the rings *38* which in turn accommodate the ball bearings *39*. The outer races of said ball bearings, and said rings *38* are fastened in position upon the ends of the capsules *22* by the screw caps *40*.

Ball bearing *39* supports the outer end of the centrifugal shaft *33*; nut *41* bears endwise upon the inner race of said ball bearing and is held in position upon the centrifugal or gear shaft *33* by cotter *42*. The inner, contracted end of centrifugal or gear shafts *33* are supported by ball bearing *43* in hubs *44* extending on opposite sides from the hub *14*. Adjacent the inner supported ends the centrifugal or gear shafts *33* show bevel pinion formations *45*, into which mesh the bevel gear segments *46*. Segments *46* are fastened upon the inner ends of the blades *16* by way of screws *47*, and are centralized by pins *48*.

By way of the bevel gearing and the pitch of the helical flutes guiding the centrifugal weight *30* in the capsule *22*, we establish a straight line ratio between the pitch angle of the blade, and the effective radius of the centrifugal weight. This ratio may be adjusted, so that the torque and centrifugal force are substantially equal at all settings. But in addition we desire to compensate for the slight discrepancy discussed above. This is brought about by weight variations, the means serving this end being described presently:

A clearance recess *49*, which accommodates the annulus *50*, extends in the hubs *44* around the hub *14*. Upon opposite sides the threaded ends of screws *51* are engaged in said annulus and are locked in position by nut *52*. The head of each screw *51* is upon the inside of the hollow shaft *33*, and rotatably retains—by way of a non-friction washer—the cone *53*, over which extends the spirally contracted end of the helical tension spring *54*. The other end of said spring is threaded onto and is non-rotatedly engaged (e. g. welded) on the bushing *55*, which is longitudinally stationary and non-rotative in relation to weight *30* and is thus positioned in the hollow centrifugal shaft *33* by the rectangular pin *36* described above, said pin extending through a suitably broached transverse opening in said bushing.

These springs *55* are substantially at rest and do not exert any tension between bushing *55* and annular ring *50* when the centrifugal weights *30* are in their lowest position, in which they are shown. These springs are gradually extended as the centrifugal weights move apart under centrifugal force and increasingly counteract the centrifugal force; such counteraction deducts from the centrifugal force the amount to which that force exceeds the corresponding torque.

It should be noted that the annulus *50* is shown to be floatingly arranged so that the springs and the reactions may be equalized.

Ordinarily it is neither necessary nor desirable to adjust a variable propeller through all possible pitch positions. In a housing with the limited space of that of Fig. 1, the walls naturally limit

the movement of the gear segments. But the propeller expert ordinarily prefers to operate within well defined limits, and for such purposes stops at a high pitch position, as well as at a low pitch may be provided for, as they are shown in later figures.

In the chart of Fig. 2 the performance of a device of the type of Fig. 1 is exemplified; on the ordinate we measure torque and reaction. We relate the upper curve, a straight line which shows the centrifugal force, to the radius of the center of gravity on the abscissa. The lower, torque curve is plotted against degrees of the pitch angle.

In the arrangement of Fig. 1 the springs **54** are designed to overcome the discrepancy between the two curvees. A blade pitch of 18° relates to a speed of travel of a plane of 175 miles per hour, and roughly that speed changes at the rate of 25 miles for each 2 degrees of pitch angle.

Fig. 3 illustrates in accordance with item B above, that the discrepancy between torque and centrifugal force may be overcome by changing the path of the centrifugal weight. This arrangement is made under the presumption that the torque curve may deviate from the centrifugal force curve in fine fashion, so that the discrepancy in question may be overcome by arranging the centrifugal weight along a circular path.

In Fig. 3 the housing supports the blade in the same manner as illustrated in Fig. 1. But the front part **61** of the housing is enlarged and provides a chamber to accommodate the swinging centrifugal weight.

While it is ordinarily desirable to compound gearing in order to attain the high ratio of transmission necessary (in an arrangement illustrating Fig. 1 the gear ratio was 7:1) we show as a modification in Fig. 3 only a single pair of gears. One of these gears is the internal helical gear segment **62**, which is attached to the bottom of the blade **16** in a manner similar to the attachment of segment **46** in Fig. 1.

The centrifugal weight is represented in this figure by a helical gear segment **63**, which meshes with the internal helical gear segment **62**. The segment **63** is fulcrumed on the front part **61** of the propeller housing by a transverse shaft **64**.

It should be noted that during the angular movement of the centrifugal weight, which is directly transmitted by the helical gearing to the blade of the variable propeller, the effective radius of the centrifugal weight does not increase in keeping with the circular path of the centrifugal weight around the fulcrum at **64**. By adjustment of the pitch diameter of the gearing segment serving as centrifugal weight, by shifting the center of gravity thereof to a preferred point, and by adjusting the fulcrum in relation to the said center of gravity as well as in relation to the axis of the propeller shaft, the centrifugal reaction may be rendered equal at all times to the torque best adapted for the pitch of the propeller blade, if the discrepancy in question is in the order of a sine function. Other adjustments may be made by the use of irregular gearing, e. g. elliptic gearing or by adjusting the pitch of the helical gear segments from point to point.

If, a suggested above, there is a varying gear pitch at the various points of engagement of gears **62** and **63**, the pitch diameter of the gears is first chosen to yield the desired movement at an average lead of the gear pitch, and the lead of the gears is then adjusted relatively to that starting point. By changes in design of gear **63**, or by actually attaching weights at preferred points thereof, the centrifugally effective weight center of said level may be shifted in any desired direction. If said weight center is above the fulcrum **64** for all movement of the gear **63**, the centrifugal force will increase less than usual in relation to movement at the gear circle. But, as suggested above, the fulcrum **64** may be moved out for instance, i. e. away from the axis of the main shaft and close to and even above the center of the effective weight of gear **63**, so that the increase in centrifugal force becomes larger in relation to movement at the gear pitch circle. Thus a fuel compensation between centrifugal force and propeller torque may be obtained leading to the following operation:

Increasing speed of the main shaft will throw gear **63** further out until the propeller blade is adjusted to such a steep angle that the plane moves very fast and the energy thus consumed prevents a higher speed of the main shaft, or may even reduce the speed of the main shaft. In the latter case the centrifugal weight collapses towards the axis of the main shaft and reduces the propeller pitch angle. The function is therefore similar to that described in connection with the other embodiments.

An equivalent of the irregular gearing suggested for the embodiment of Fig. 3 is used in the illustration of the above-mentioned item C. The remaining figures concern such a modification:

In Figs. 5 and 6 the propeller blades are exemplarily presumed to be journalled in the propeller housing in exactly the same manner as was illustrated in Fig. 1. The gear segment **66** is shown at **65** to be transversely slidably dovetailed into the bottom end of the propeller blade **16**. A pin **48** and screws **47** again locate this gear segment in a preferred position upon the blade, and the screws **47** are shown to be safeguarded in a tightened position by wire seals **67** which are engaged upon lugs **68** extending from the inner end of ring **17**.

In the modification of Figs. 5 and 6 the gear segment **66** is a double segment engaging at opposite ends upon bevel pinions **45** of both centrifugal or gear shafts **33**, so that both blades as well as both centrifugal units are fully interconnected by gearing. This suggests to the experienced designer that the two or more blades of a propeller may all be balanced in accordance with this invention by a single centrifugal unit, although I have shown for purposes of symmetry a centrifugal unit in connection with each blade of the propellers shown in the drawings.

It is of course also understood, that in accordance with the arrangements of Figs. 5 and 6, the blades and centrifugal units of Fig. 1 may be positively interconnected by gearing, or that the blades of Figs. 5 and 6 may be made independent from each other by connecting each one to only one centrifugal unit in the manner suggested in Fig. 1, either arrangement having obvious advantages and disadvantages. In like manner, the features of any of the modifications shown in the drawings may be converted for the other modifications, or the elements of the specific combinations of the features may be replaced by equivalent elements known to those acquainted in the mechanical arts.

The capsules **22** of the centrifugal unit are shown to be arranged in the propeller housing of Figs. 5 and 6 in a manner similar to that disclosed in connection with the modification of Fig. 1, wire seals **70** being added in order to secure

the nuts **27** and the cap **40** in a tightened position, and the latter engaging the ball bearing **39** directly in the contracted outer end of the capsule **22**.

The centrifugal weights comprise in this modification a substantially rectangular center lug **71** rounded off on opposite sides to fit but clear the inside of the capsule; from lug **71** extend on opposite sides the hubs **72**, this integral assembly being axially slidably, but non-rotatably engaged upon the centrifugal or gear shaft **33**, in equivalence to the arrangement of Fig. 1.

But instead of engaging along the full outside by way of a spiral formation upon the fluting upon the inside of the capsules **22**, this modification shows stems **74** extending from the opposite rounded sides of the lug **71** of the centrifugal weight, said pivots supporting rollers **73** which engage in grooves upon the inside of capsules **22**.

For each of the two rollers **73** upon the opposite sides of the centrifugal weight, I provide a groove or slot **75** upon the inside of a capsule **22**, upon opposite sides thereof, in which the said rollers engage, in order to impart rotation to the centrifugal or gear shaft **33**. These grooves are shown as slots provided in a cylinder **76**, which is suitably fastened upon, for instance shrunk into the capsule **22**, whereas the grooves were directly cut into the inside of the capsules **22** in the modification of Fig. 1.

In the outside of the cylinder **76** I show helical grooves **77**, which serve to make this element lighter. These grooves give a bearing in the view of Fig. 5 concerning the exact extent of the slot **75**, indicating that the said grooves **75** are not exactly helically disposed, but deviate from a helical path, in order to compensate for the discrepancy between the torque and the centrifugal reaction, in accordance with the above mentioned item C. The exact disposition of the slots **75** will be hereinafter further described in connection with the chart of Fig. 4. It suffices to state here, that the position of the roller **73** in Fig. 5 exemplarily corresponds substantially to a pitch angle of 14° of the propeller blade, and that at this point the extent of the slot **75** approaches a 45° helix. Extending in both directions from this central position in deviation from said helix, the slot **75** is adjusted in order to compensate for the discrepancies between the torque and the centrifugal reaction.

While the sectioning of the housing in Fig. 6, and the sections of the part of the centrifugal units there shown, extend substantially in the plane of the propeller axis, I show the propeller housing also sectioned at two points at and near the stop screws **78** (between section lines **81**) in a position set back from the propeller axis substantially to the level of the pitch circumference of segment **66**. Thus the stop screws **78** engage suitable formations **79** on one side of the segment, when the segment is in one or the other of its extreme positions. Then the said formations **79** are respectively in the positions **79***a* and **79***b* indicated in dot-dash lines in the drawings, which are the maximum and minimum pitch variations permitted, the nut **80** locking the stop screws **78** in preferred position.

The suggestions of the drawings so far described may be readily applied to a propeller with more than two blades. In a symmetrical three-blade arrangement providing a centrifugal unit for each blade according to the modification of Fig. 1 or of the modification of Figs. 5 and 6, I merely adjust the gearing **46—45** or **66—45** for the new angle of 60° between the axes of the blades and the axes of the centrifugal units.

Such a variable pitch three-blade propeller is shown in the view of Fig. 7. The gears are assumed positively to interconnect all blades and centrifugal units, so that only one stop screw **78** for each of the maximum and minimum positions of movement of the blades is shown upon the front part **82** of the propeller housing.

In connection with Figs. 1 and 2 I note a complete balance between the blade torque and the centrifugal reaction at and near a low blade pitch angle of 10°, and the helical fluting on the outside of the weight and upon the inside of the capsule were there both disposed at 45°. As the pitch angle increases, the necessary correction was effected by the increasing counteraction of the spring.

But in plotting the slot **75** of Figs. 4, 5 and 6, I have placed the point at which the effective angle of said slot is exemplarily disposed at 45° at a value of 14° of the blade pitch angle in which position the centrifugal weight of Fig. 5 is shown. The said effective angle is the helix angle at which the slot **75** guides the roller **73** at the diameter of the centrifugal unit, where rollers **73** engage upon the sides of slots **75**. For the data of the chart of Fig. 4 that pitch diameter is 1.875''. For a blade torque of 473 inch-pounds at a blade pitch angle of 14, using a ratio of 6:1 between the gears **66** and **45**, the torque on the centrifugal or gear shaft is six times smaller than the blade torque and the angular movement of the centrifugal or gear shaft is six times larger, scales for these two values being provided to the extreme right and at the top of the chart of Fig. 4, respectively. For these conditions a helix angle of 45° is obtained at a blade angle of 14° if a centrifugal weight of .1306 pound is disposed at an effective distance from the axis of the propeller shaft of 3.625'', which is the effective centrifugal radius. The torque curve, i. e. the line marked "propeller blade twisting moment and weight reaction in inch pound" is then plotted to be parallel with the weight radius line at a blade pitch angle of 14°. In coarse steps the following table shows in the first column the blade pitch angle, in a second column the corresponding torque at a preferred propeller speed and normally loading the engine. Next to these figures are evaluated in the third, fourth, fifth and sixth column the torque on the centrifugal or gear shaft, the angles of said shaft based on a zero corresponding to a gear pitch angle of 8°, the effective radius of the centrifugal weight, and the helix angle at which the slot **75** guides said weight, respectively:

Blade pitch angle	Blade torque, inch-lbs.	Torque on gear shaft	Gear shaft angle	Effective centrifugal radius	Helix angle slot 75
				Inches	
8	362.64	60.44	0	3.061	47° 45′ 40″
10	400	66.67	12	3.243	46° 36′ 37″
12	438	73.00	24	3.431	45° 37′ 32″
14	473	78.83	36	3.625	45°
16	504	84.00	48	3.821	44° 41′ 20″
18	533	88.83	60	4.021	44° 32′ 53″
20	559	93.17	72	4.220	44° 33′ 57″
22	583	97.166	84	4.417	44° 40′ 12″

The helix angle of slot **75** is shown to be separately plotted in the chart of Fig. 4 against the angular positions of the centrifugal or gear shaft. To the torques plotted against blade pitch angles in Fig. 4 for a particular plane and for a preferred normal speed of its propeller (2400 R. P. M.) also

correspond—in level flight under normal atmospheric conditions—predetermined speeds of movement through the atmosphere. These speeds expressed in miles per hour, are added as a scale at the bottom of the chart of Fig. 4.

It is not possible to enumerate all practical considerations, which may lead the aircraft designer to modifications of the two exemplifications one of which is completely disclosed in Figs. 1 and 2, and the other in Figs. 4, 5 and 6, in order to adapt them to novel departures which are developed day by day in the contiguous elements of an aircraft in the quick progress of the aviation industry, it would even lead too far, here to explain all the considerations underlying the various features of the instant invention. A protractor scale is for instance indicated on the conical end face of the bearing extensions 19 of the housing 11 at the extreme right of Fig. 1.

It is common practice to provide such a scale either on the stationary bearing or on the blade, and a mark on the other one of these parts allows us to read off the exact angular position of the blade. In combination with such a scale the particular arrangement of the centrifugal unit facilitates an original setting as well as a resetting for readjustment of the gearing later; because the capsules 22 may be angularly positioned ad libitum before pins 26 are inserted; and for a quick change of the centrifugal radius relatively to the pitch angle—as it might be for instance desirable when the propeller is moved from one craft or motor to a different one—it is only necessary to relocate pins 26 in a new angular position of the capsules in the housing.

It is not necessary that the blades and centrifugal units are accommodated in the same plane normal to the axis of the propeller, the latter might even be placed upon the inside of the former, co-axially thereto. An allocation of the centrifugal weight to the front of a blade suggests itself.

The gear segment extending from the blade may, instead of by way of intermediary gearing, directly engage upon the gear formation on the outside of the centrifugal weight, in which case the weight is preferably non-rotative.

Direct gearing and an arrangement of the centrifugal unit to the front of the blade are illustrated in Fig. 3, except that the modification of Fig. 3 goes further, the weight there being swiveled instead of slidable.

The foregoing description of various modifications of this invention also discloses their operation. But the usefulness of the variable blade propeller of this invention will be better understood from the following exemplary detail consideration of its performance on the basis of various flying conditions and manoeuvers:

First: Assume that the plane is ready to take off. The brakes are locked, but the motor is running at the preferred speed of 2400 R. P. M. of the propeller shaft. Let us presume that the throttle remains set at this position unless otherwise noted. Under these conditions, while the aeroplane is stationary, the heavy load moves the blade back against the low-pitch stop.

Second: Now the brakes are released and the ship starts to move down the field. This eases the load on the engine, and the engine attempts to run faster as the ship gains headway. Let us assume that the speed of the propeller shaft has actually risen to 2450 R. P. M. The rise from 2400 to 2450 R. P. M. would increase the centrifugal force of the reaction weight and the resultant outward movement of the reaction weight would cause the blade pitch angle to increase. On account of the increased pitch the engine labors against a slight overload, and its speed will decrease to 2400 R. P. M. In the meantime the speed of the aeroplane has increased again, further unloading the propeller, so that the speed of the engine again increases; but the blade pitch is correspondingly increased, and again the propeller speed is pulled back to 2400 R. P. M. This play is repeated time and time again, but the step-up in revolutions per minute is actually not fifty, which was used as an example only, but a very few revolutions.

Third: This continues until the blades reach the maximum angle possible with the engine turning at 2400 R. P. M., or until the blades come up against the high pitch stops. This will produce the maximum air speed possible in level flight at the fixed throttle setting, as it is assumed that the ship has now taken off, climbed to the desired altitude and leveled off.

Fourth: At increased altitude an engine with a fixed propeller would increase its propeller speed due to lessened resistance of the thin air; but with my improved propeller, only the blade angle will increase and the engine will maintain at constant speed.

Fifth: Let it now be assumed that the ship is suddenly put into a steep climb. The engine speed momentarily decreases, reducing the centrifugal force of the reaction weights which move in centripetally, thereby decreasing the angle of the blade pitch so that the engine may immediately pick up speed again, resuming the average level of 2400 R. P. M. at a lower propeller pitch.

Sixth: In a steep dive the action would be the converse of that described in the preceding paragraph. Note that the pitch angle will be much higher at terminal velocity, in case no high pitch stop is provided.

Seventh: For the performance so far described a fixed throttle setting was presumed, yielding an average speed of the engine of 2400 R. P. M. Now let the throttle be pulled back, because it is desired to cruise the ship at a lower propeller speed. The engine speed decreases, and analogously to paragraph "fifth" the blade angle is reduced until the blade assumes a fixed setting most favorable in respect to engine speed and horsepower.

Eighth: When the engine is further throttled down for the purpose of landing, its speed again decreases, and the blade angle is correspondingly reduced until the low pitch stop is reached. In this final position the plane is ready to land or again to take off, or for a quick climb in case of some emergency.

The foregoing description of performance relates to a model in keeping with the chart of Figure 4, referring to a preferred speed of the engine or propeller shaft of 2400 R. P. M. In connection with the chart of Figure 2 that propeller speed is 2100 R. P. M.

A redesign of the propeller blade and items A, B and C have herein been separately suggested as means for making the blade torque equal to the centrifugal reaction. The use of one of these means does not preclude the simultaneous use of another or of all of the others.

However, it should be borne in mind that simplicity must be the keynote of aeroplane construction—and of this invention also, which solves an acute aviation problem in a predominantly practical way, with few elements lending

themselves to rugged construction, for the strenuous performance, with very little friction, so that the device is still delicately responsive.

Having thus described my invention in various modifications, yet I do not wish to be limited thereby, except as the state of the art and the appended claims may require, for it is obvious that various modifications and changes may be made in the method and form of embodiment of my invention, without departing from the spirit and scope thereof.

What I claim is:

1. In a variable pitch propeller, a housing, a propeller blade revolubly mounted in said housing, a centrifugal means, a helix guiding said centrifugal means in said housing outside of said propeller, a gear shaft, reduction gears operatively connecting said shaft to said blade, and means slidably but non-rotatively guiding said gear shaft in said centrifugal means.

2. In a variable pitch propeller, a housing, a propeller blade revolubly mounted in said housing, a centrifugal means, counteracting means operatively unaffected by centrifugal force and compensating for the discrepancy from a straight line relation between the force exerted in said centrifugal means and the torque of said blade, a helix guiding said centrifugal means in said housing, a gear shaft, reduction gears operatively connecting said shaft with said blade, and means slidably but non-rotatively guiding said gear shaft in said centrifugal means.

3. In a variable pitch propeller, a housing, a propeller blade revolubly mounted in said housing, a centrifugal means alongside of said blade, a tension spring for counteracting said centrifugal means, a helix guiding said centrifugal means in said housing, a gear shaft, reduction gears operatively connecting said shaft to said blade, and means slidably but non-rotatively guiding said gear shaft in said centrifugal means.

4. In a variable pitch propeller, a housing, a propeller blade revolubly mounted in said housing, a centrifugal means, an irregularly curved helix guiding said centrifugal means in said housing, the irregularity of the helix serving to compensate for discrepancy from a straight line relation between the force exerted in said centrifugal means and the torque of said blade, a gear shaft, reducing gears connecting said shaft with said blade, and means slidably but non-rotatively guiding said gear shaft in said centrifugal means.

5. In a variable pitch propeller, a housing, a propeller blade revolubly mounted in said housing, a centrifugal means, a helix of varying pitch guiding said centrifugal means in said housing, a gear shaft, reducing gears connecting said shaft with said blade, and means slidably but non-rotatively guiding said gear shaft in said centrifugal means, the pitch variations serving to compensate for discrepancy from a straight line relation between the force exerted by said centrifugal means and the torque of said blade.

6. In a variable pitch propeller, a housing, a propeller blade revolubly mounted in said housing, a centrifugal means, and helical gearing varying in pitch at different points of mesh and operatively connecting said centrifugal means with said blade, the pitch variations serving to compensate for discrepancy from a straight line relation between the force exerted by said centrifugal means and the torque of said blade.

7. In a variable pitch propeller, a housing, a propeller blade revolubly mounted in said housing, a centrifugal means, helical gearing varying in pitch at different points of mesh and operatively connecting said centrifugal means with said blade, and adjustable stops checking the movement of said gearing in one and in opposite direction, respectively, the pitch variations serving to compensate for discrepancy from a straight line relation between the force exerted by said centrifugal means and the torque of said blade.

8. In combination with the shaft and a pair of relatively angularly spaced and radially disposed revoluble blades of a variable pitch propeller arranged in a plane normal to the shaft, centrifugal weights interposed between said blades in said plane, means guiding said weights normal to the axis of said shaft, and positive gearing operatively connecting said weights with said blades at a linear ratio between the respective movements.

9. In combination with the shaft and a radially disposed revoluble blade of a variable pitch propeller, a centrifugal weight, means guiding said weight normal to the axis of said shaft, a second shaft normal to said propeller shaft and said blade, extending centrally into and rotated by said weight, and a pair of gears directly connecting said second shaft to said blade.

10. In a variable pitch propeller, a housing, a propeller blade revolubly mounted in said housing, a centrifugal means, and helical gearing varying in pitch at different points of mesh and operatively connecting said centrifugal means at an angle with said blade, the pitch variations serving to compensate for discrepancy from a straight line relation between the force exerted by said centrifugal means and the torque of said blade.

EDWIN H. GODFREY.