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2,566,696

ROLLER TRACK MOUNTING OF A VARIABLE PITCH PROPELLER

Filed Jan. 15, 1947

2 Sheets-Sheet 1

Fig. 1.

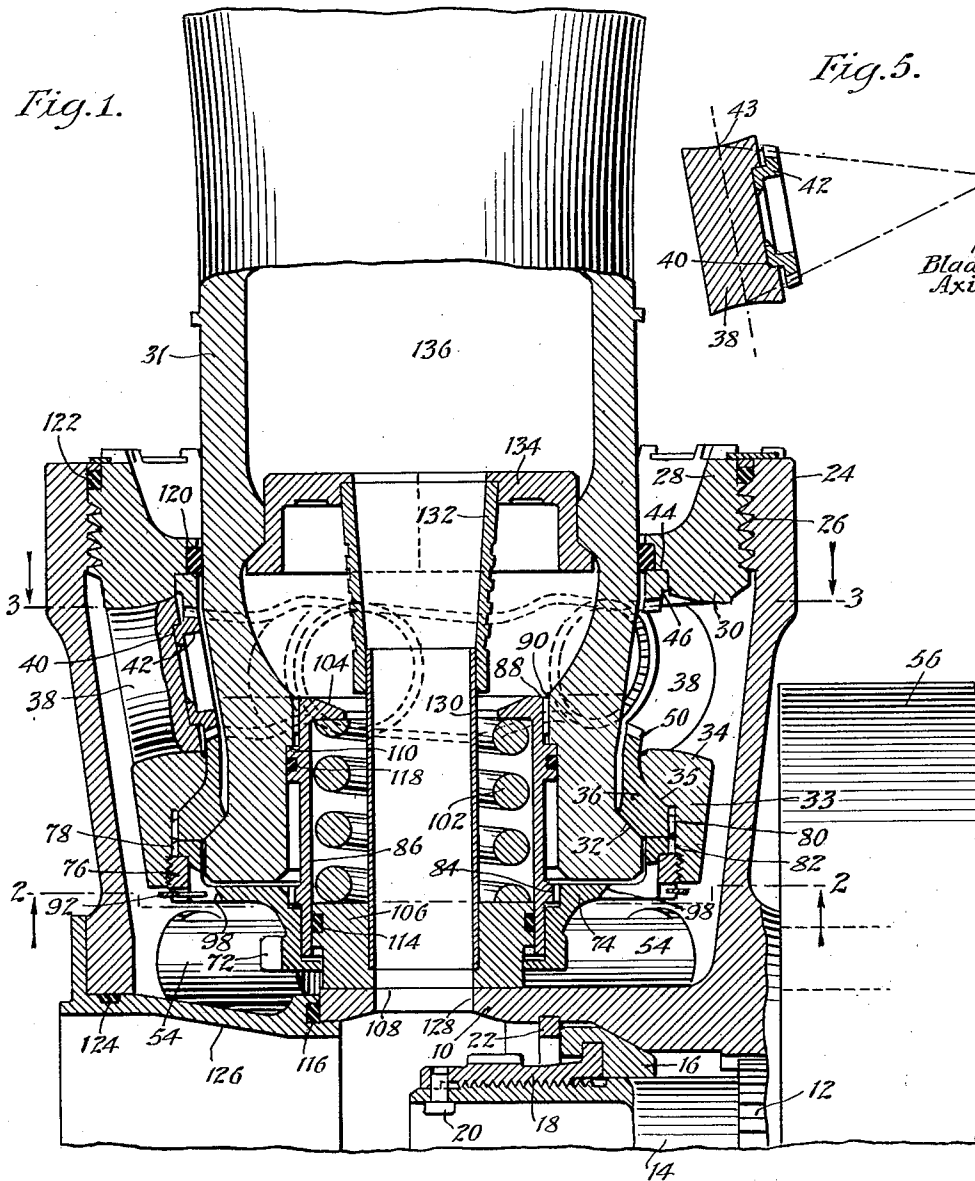


Fig. 5.

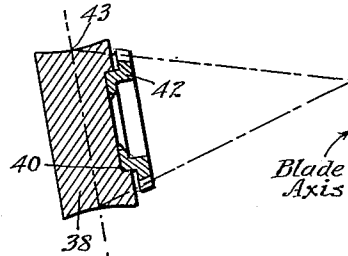
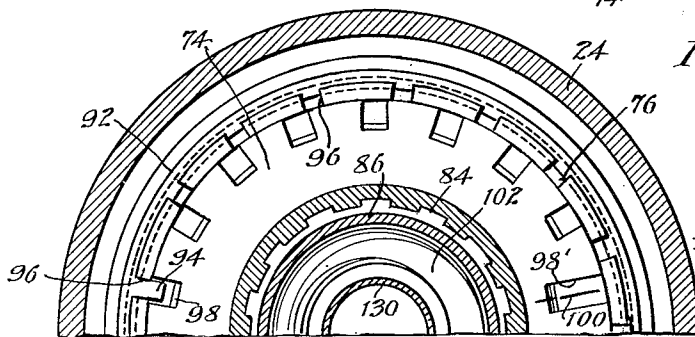


Fig. 2.



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2 Sheets-Sheet 2

Fig. 3.

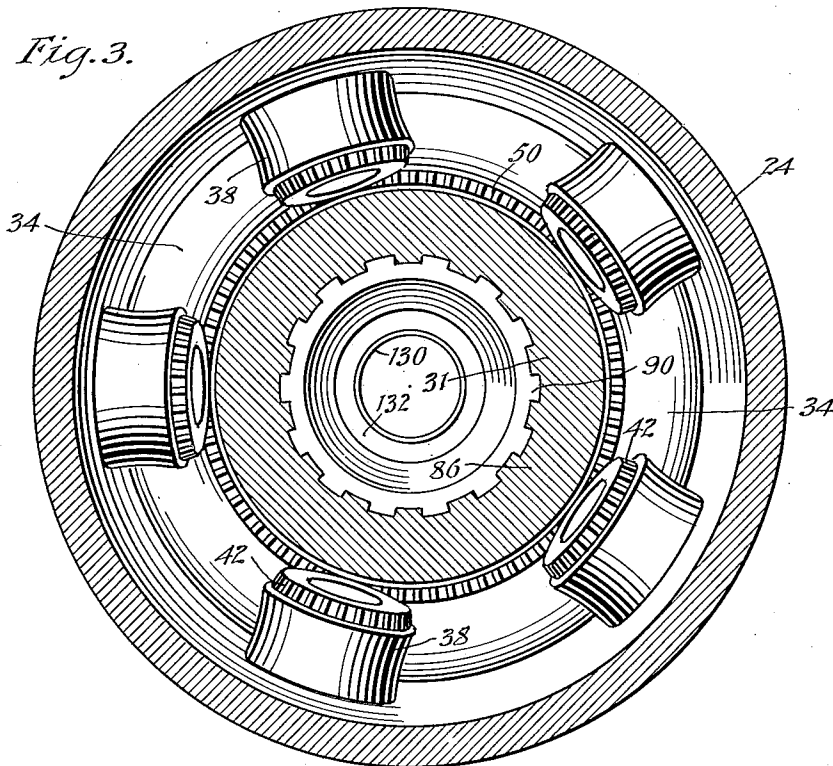
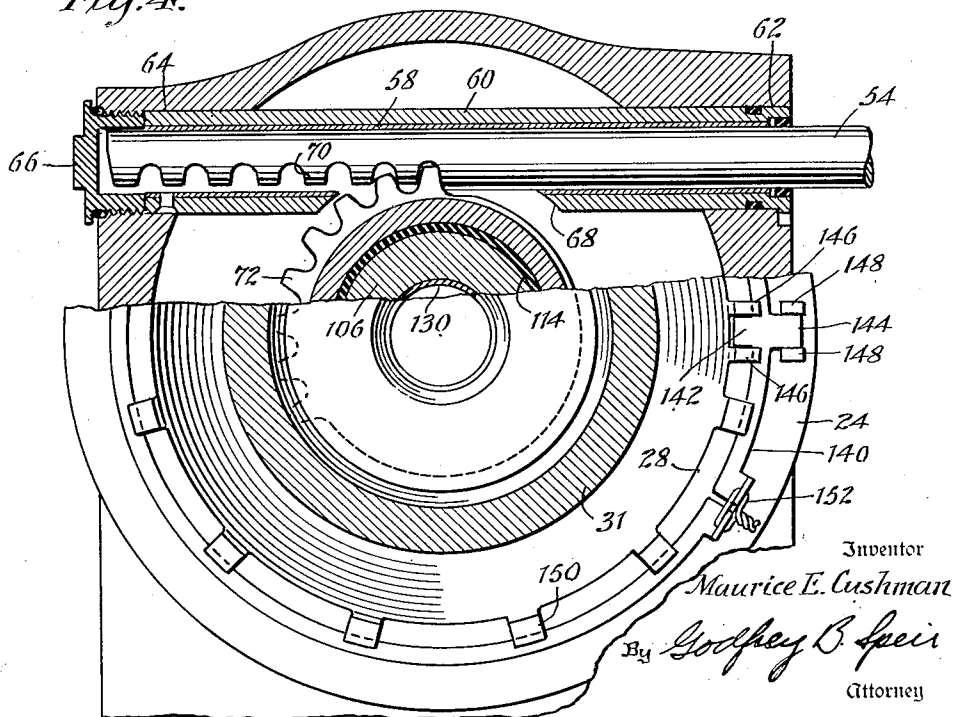


Fig. 4.



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UNITED STATES PATENT OFFICE

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ROLLER TRACK MOUNTING OF A VARIABLE PITCH PROPELLER

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Application January 15, 1947, Serial No. 722,253

14 Claims. (Cl. 170—160.11)

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This invention concerns controllable pitch propellers and relates particularly to improvements in blade mounting and retention means of the type in which twisting moments on each blade are compensated by means which produce opposing moments, leaving the blade free for pitch change by a low-power pitch changing motor.

This invention comprises in part, improvements on my co-pending application entitled "Variable Pitch Propeller," Serial No. 598,792, filed June 11, 1945, now Patent 2,533,358, issued December 12, 1950.

In general terms, this invention comprises a propeller hub having blade receiving sockets therein, and propeller blades having shanks disposed in said sockets. The socket and blade shanks are provided with opposed, separated cam tracks, and a plurality of rollers hold the cams apart and provide a low friction bearing to allow blade angle adjustment. The cams are so shaped that the centrifugal force on the blade is transformed to a counter moment on the blade, of such magnitude as to substantially equal the algebraic sum of the centrifugal and aerodynamic twisting moments on the blade. In order to attain this compensating effect, the rollers must be positioned accurately on the cam slopes and to this end, the rollers are provided with coaxial bevel pinions meshed with bevel gears rigid with the respective cam tracks. I further provide resilient means to enforce contact of the cams and rollers to retain proper roller position, and to support the blades in their proper axial position when the propeller is not rotating while allowing limited axial blade movement in the hub. The centrifugal force on the blade enforces cam and roller contact during operation. I further provide an arrangement in which blade stresses due to centrifugal force are imparted in a substantially conical path from the shank through the cams and rollers to the blade socket. Since in operation the blade may weave slightly with respect to the hub, I provide means to allow this motion without disturbing the alignment of the blade retention and pitch change driving means. To this end, the pitch changing mechanism is separately drivably connected to the blade and to the cam and roller mechanism.

Some of the objects of the invention will be apparent from the above brief explanation and additional objects are as follows:

a. To provide a blade retention system of the type described wherein the several parts of the system may be manufactured readily and may be assembled simply and with the assurance that

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when assembled, the parts will all be retained in their proper relationship to one another.

b. To provide a roller control system which is positive in effect and which minimizes the number of components previously considered necessary.

c. To provide a roller control system wherein "hour glass" type rollers are provided with control bevel pinions drivably secured thereto, the pitch cones of the bevel pinions intersecting the centroids of the roller surfaces which contact the coacting cams, whereby inherent stability of each roller is attained with only a single driving or control connection.

d. To provide a retention system which will permit the propeller blade to weave a slight amount during operation with respect to the rest of the retention system whereby lack of alignment of the propeller blade with the retention system can be tolerated without overstressing the retention system parts.

e. To provide cam slopes which will have the effect of balancing both blade centrifugal twisting moments and aerodynamic twisting moments of the blade against counter moments generated through the cams from the centrifugal force on the propeller blade.

f. To provide a substantially perfectly balanced low-friction blade retention system of such character that the forces needed to effect increase or decrease in blade pitch will be substantially only those necessary to overcome friction in the hub and blade retention assembly.

Further objects will become apparent in reading the annexed detailed description in connection with the drawings. These, however, are to be construed only as exemplary of the invention and are not to be construed as limiting its scope except as such limitations exist in the appended claims.

Referring to the drawings,

Fig. 1 is a longitudinal section through a portion of a propeller hub and blade according to the invention;

Fig. 2 is a fragmentary section on the line 2—2 of Fig. 1;

Fig. 3 is a section on the line 3—3 of Fig. 1;

Fig. 4 is a section looking axially along the propeller blade, broken away in part to show the arrangement of the pitch changing mechanism; and

Fig. 5 is a fragmentary detail of the blade retention system showing the arrangement of certain of its parts.

A propeller hub 10 is splined in the usual man-

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ner at 12 to a propeller shaft 14 leading from a reduction gear or prime mover, the hub being secured to the shaft by a split wedge ring 16 and a hub nut 18, the latter being screwed upon the shaft and secured from displacement by a pin 20. The wedge ring and nut together constitute a propeller puller in a manner well known in the art, the hub 10 having a spring ring 22 as an abutment which may be engaged by the wedge ring 16 to pull the propeller when the hub nut 18 is unscrewed.

The hub is provided with a plurality of similar unsplit, unitary, blade sockets one of which is shown at 24, these sockets being formed preferably as integral parts of the hub 10 and extending substantially radially outwardly from the hub. The sockets may number two, three, four or more according to the size and power capacity of the propeller. The socket as shown is provided at its outer end with internal threads 26 into which is screwed an internal nut 28, the inner face of which is formed with waved cam roller races as at 30. In the type of propeller chosen for illustration, the blades are capable of pitch adjustment from feathering or about 90° forward pitch to approximately 30° negative pitch, thereby having an overall pitch range of 120°. To meet this pitch range requirement, the cam surfaces 30 are formed as five similar cam surfaces, each of identical and modified sinusoidal form and the surfaces are crowned as indicated. A propeller blade 31 is fitted within the socket and is provided at its inner shank end with a peripheral spherical or sloping abutment 32 over which, prior to assembly, the nut 28 and then a blade race member 33 is passed, the race 33 having crowned waved cam surfaces 34 similar to and opposite the crowned waved surfaces of the race 30. Between the blade abutment 32 and an inner abutment portion 35 of the race member 33, a split ring 36 is fitted, having a sloped or spherical surface complementary to the blade abutment 32 and an outer sloped surface conformed to the sloped inner surface 35 of the member 33 so that when secured together, the split member 36 and the race member 33 are firmly engaged with one another, the member 36 engaging the blade shank abutment 32 to allow minor oscillation of the blade shank relative to the member 36 and the ring 33 with the rollers and nut 28 firmly holding the blade within the socket.

Between the race surfaces 30 and 34, a plurality of "hour glass" shaped rolls 38 are installed. The number of rolls is the same as the number of cam surfaces on the races 30 and 34 and each roll must be precisely positioned with respect to the cam surfaces so that each roll will support its proportional share of the centrifugal load imposed by the propeller blade. For positioning the rolls, my prior patent application previously mentioned provided a retainer whose motion was controlled by gearing but in the present invention, each roll is controlled in its motion with respect to the surfaces 30 and 34 without the use of any retainer. As shown in Figs. 1 and 5, one side of each roll 38 is recessed as at 40 and a bevel pinion 42 is provided with a hub fitted to the recess 40, the pinion being furnace brazed to the roll. The pitch cone of the bevel pinion is so arranged, as shown at Fig. 5, as to have its apex substantially coincidental with the axis of the propeller blade whereby the bevel pinion may roll truly around the blade axis. The roll surface and pitch cone are further coordinated so that the pitch cone intersects the roll surface

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substantially at the central diametral plane thereof as at 43. By this arrangement, an element of the bevel pinion pitch cone will pass through the roll surface at the point of maximum pressure contact of the roll with the coating cam surfaces 30 and 34. The roll position is thereby controlled by the bevel pinion without imposing twisting moments on the roll which would tend to cause its axis to deviate from intersection with the blade axis. It will be noted that the cams 30 and 34 are convex, and the roll surfaces 38 are concave. The rolls and cams are, however, relatively slightly convex so that the contact of the rolls on the cams is centered at the central plane of the rolls.

The internal nut 28 carrying the cam surfaces 30 is recessed as at 44 and a bevel gear 46 is fitted to the recess and furnace brazed thereto to comprise a permanent sub-assembly. The gear 46 has its effective pitch cone of waved form in conformance with the waved form of the cam surfaces 30, the gear 46 engaging the teeth of the roll pinions 42.

The split abutment element 36 likewise has bevel gear teeth formed at its upper end as at 50, the effective pitch cone of the teeth 50 being waved in conformance with the waved form of the cam surfaces 34, the gear teeth 50 also engaging the teeth of the roll pinions 42.

As the blade is changed in pitch by means to be described, the gear 50 rotates therewith while the gear 46 remains stationary. Thus, the roll pinions 42 are enforced to rotate so that their axes travel at substantially half the speed and distance of the propeller blade. The rolls 38 are constrained to non-sliding contact with the cam surfaces 30 and 34 and are timed to contact a certain portion of the cam surfaces for each pitch position of the propeller blade.

As previously pointed out, the cam surfaces 30 and 34 are profiled so that centrifugal force of the blade 31 is converted to a counter moment tending to rotate the propeller blade in one direction. This moment varies in accordance with the blade pitch setting, and the cam profile is so arranged that the counter twisting moment due to centrifugal force will equal the algebraic sum of the centrifugal twisting moments and the aerodynamic twisting moments on the propeller blade.

In earlier types of compensated propellers, the compensation was calculated on the basis of centrifugal twisting moments in the blades and the aerodynamic twisting moments while known to exist, were deemed to be so small and variable as not to justify compensation. This was principally due to the fact that propeller blades used with such propellers had low activity factors—that is, the ratio of chord to blade length was small. Recently, however, great attention has been given to the use of broad blades having a high activity factor. With broad blades, the aerodynamic twisting moments on the blade become significant in magnitude and their compensation is highly desirable along with compensation of centrifugal twisting moments, in order to minimize the torque necessary to alter blade pitch. The change in cam profiles necessary to incorporate aerodynamic twisting moment compensation varies with different propellers, blades and aircraft. In general, aerodynamic twisting moments tend to increase blade pitch in opposition to centrifugal twisting moments which tend to decrease pitch. While the centrifugal twisting moments can be precisely established from the

characteristics of the propeller blades used, over the entire pitch range, a compromise schedule must be arrived at to compensate aerodynamic twisting moments, for the aerodynamic moments vary in accordance with blade thrust and with the shift in center of pressure with different air-speeds and angles of attack. The aerodynamic twisting moments are of much less magnitude than centrifugal twisting moments. The cam corrections to compensate aerodynamic twisting moments in general amount to lessening the cam slope at certain pitch angles to attain balance between the counter moment due to centrifugal force on the one hand and the centrifugal and aerodynamic twisting moments on the other hand. A typical but non-limiting example would be a propeller in which aerodynamic twisting moments would be opposite to, and about 10% of, centrifugal twisting moments at take-off setting of about 20° pitch angle. The aerodynamic twisting moments would gradually diminish to 0 at about 50° pitch angle and might be additive to centrifugal twisting moments at higher pitch angles, reaching a value of about 2% of centrifugal twisting moments. The relationships of blade design and weight, airplane speed, engine power and R. P. M. must all be considered in arriving at a particular cam design for any one propeller model.

The structure previously described includes the blade retention and the roller and race assembly. The means by which pitch change is imparted to the blades will now be described insofar as the blade mounting is concerned. Referring to Figs. 1 and 4, I show a rack rod 54 for each propeller blade which extends from a pitch changing motor 56 at one end of the propeller, as shown, into the hub 10. This rack rod is reciprocable in a bearing 58 mounted in a sleeve 60 secured at one end in one propeller wall as at 62 and at its other end in a recess 64 in the other hub end wall. The recess 64 is closed by an appropriate plug 66. The sleeve 60 and bearing 58 are cut away at a central inner portion as at 68 to allow engagement of rack teeth 70 by a blade gear 72 drivably connected to the propeller blade. The gear 72 is a spur gear and as the blade rotates for pitch change, accompanied by axial movement of the blade along its axis, the teeth of the gear 72 slide across the teeth 70 of the rack 54.

The gear 72 is integral with a gear hub 74 which is secured by a nut 76 to the lower roller race member 33, said member having internal splines 78 formed therein engaged by coating splines 80 on the split member 36 and splines 82 on the periphery of the gear hub 74. By this construction, the members 36, 33 and 74 are drivably secured to one another so that turning of the gear 72 enforces identical turning of the members 36 and 33. The hub 74 is further provided with an internal spline 84 engaged by a driving sleeve 86 ascending into the hollow shank of the propeller blade 31, the outer end of the sleeve 86 having splines 88 engaging internal splines 90 in the propeller blade shank. Clearance is provided in the fit of the sleeve 86 in the blade shank, and small clearance is likewise provided in the spline connections 84 and 88 to enable slight articulation of the blade 31 with respect to the pitch changing gear 72. When such articulation occurs, the blade moves with respect to the members 33 and 36 on the spherical surface 32 as previously described. The nut 76 which locks the gear hub 74 to the members 33 and 36 is secured after assembly by a snap ring

92 (Fig. 2) having a lug 94 engageable with aligned slots 96 and 98 in the nut 76 and gear hub 74 respectively. A plurality of such slots are cut in each of said members to provide vernier adjustment. One of the slots 98 as shown in Figs. 1 and 2 at 98' is used as a reference point to enable assembly of the gear 72 on the blade shank in proper position, the blade shank being provided with a reference mark 100 to enable proper location of the parts.

Within the drive sleeve 86, a helical spring 102 is assembled, said spring bearing at its upper end on an abutment 104 integral with the sleeve 86 and bearing at its lower end on a plug 106 fitted at 108 on a flat exterior surface of the hub 10. The sleeve 86 is constrained against outward axial movement in the blade shank by a shoulder connection 110 so that the spring 102, when the blade is assembled in the hub, exerts an expansive force between the hub and the blade to enforce initial contact of the roller and cam elements. The spring furthermore will exert sufficient force so that when the propeller is not rotating, the blade bearings will be pre-loaded and the blade will be prevented from drooping in the hub. The helical spring will have sufficient yield while still exerting substantial force, to allow the blade to move axially in its socket throughout all pitch positions of which the blade is capable.

Ring seals indicated at 114, 116, 118, 120, 122 and 124 are installed in the blade retention assembly to prevent leakage of lubricant from the hub.

The hub construction shown is adapted for heated gas propeller blade de-icing, wherein heated air or gas may enter the propeller hub through a front hub adapter 126 coaxial with the hub, thence passing outwardly into each blade through an opening 128, a liner 130 within the spring 102 and coaxial with the blade, through a nozzle 132 at the liner outer end, through a split blade shank plug 134 secured within the blade 31 and thence into the hollow 136 of the blade itself. As is known in the art, the hot gas entering through the conduit system just described, warms the hollow propeller blade and passes from the blade through an appropriate opening in the tip thereof, to prevent the formation of ice or to remove ice which may already have formed on the propeller blade.

It was mentioned previously that the retaining nut 28 and the bevel gear 46 were separate parts copper brazed to one another and likewise that the rolls 38 and the bevel pinions 42 were brazed to one another. The mode of fabrication of these two sub-assemblies along with the proper heat treatment thereof to attain desired physical characteristics is of interest. The respective parts are first machined in their annealed state, the gear is plated to protect it from decarburization during brazing, and the parts are furnace brazed to one another. The cam faces 30 and the faces of the roller 38 must have great hardness and the case must be of substantial depth. The gear teeth preferably should have a shallow carburized, hard case. The carburizing and hardening processes are accomplished with the two elements assembled. A deep carburized case is imparted to the cam and roller faces by heating the parts in a carburizing atmosphere. Thereafter, the parts are normalized and the carburizing protective plating is stripped from the gear and pinion teeth. The sub-assemblies are heat treated in a carburizing salt, this step

serving to impart a thin case to the gear teeth and at the same time to develop the proper grain characteristics in the entire assembly. After the salt carburization, they are quenched and drawn to proper hardness. The carburizing and heat treating steps are conducted at temperatures well below the brazing temperature so that the sub-assemblies retain their structural integrity throughout heat treatment. After heat treatment, the roller and cam surfaces are ground to finished form.

Referring briefly to Fig. 4, I show locking means for the nut 28 in the socket 24 comprising a lock ring 140 having inwardly and outwardly extending tabs 142 and 144 respectively engaging locking lugs 146 and 148 on the nut and blade socket. The lock ring 140 is engaged in lugs 150 in the nut 28, the lugs being provided with notches within which the ring 140 is seated to prevent it from displacement under the influence of centrifugal force. The ends of the lock ring are secured to one another as at 152 by safety wire. There is only one proper assembled position of the nut 28 in the hub socket and accordingly, only one set of locking notches are provided. The one proper position of the nut 28 is obtained when corresponding portions of the cam surfaces 30 and 34 are in alignment so that the cam surfaces and the rolls between them are in the proper timed relation to afford compensation of the several moments tending to change blade pitch during propeller operation.

In the assembly of the retention system, the ring 28 with its seals is first passed over the shank of the propeller blade after which the race member 23 is passed over the shank of the blade. Thereupon, the split member 35 is assembled on the shank and the member 33 is engaged thereover. The drive sleeve, spring 102 and associated parts are inserted and the blade gear 72 is installed, the parts just mentioned then being secured in assembled relation on the blade by the internal nut 75. Thereupon, the rolls 38 are adjusted to assure proper meshing of the pinions 42 with the gears 46 and 50 by index lines on the cams and rolls, and the blade nut is pushed down and clamped to the blade by a special wrench. The blade, cam and roller assembly is then inserted in the socket 24 and the nut 28 is screwed into the socket to its proper position, the lock ring 140 is installed and the clamp wrench removed. Thereafter, the pitch changing motor 56 and the rack rods 54 are assembled on the hub, the rack teeth 70 being engaged with the gears 72 of the several blades so that all the blades will have the same pitch.

In the cam and roll control system, the gears 50 and 46 respectively rigid with the cam faces 34 and 30 are described as having effective pitch cones which are waved in conformance with the waved forms of the cam surfaces. In view of the fact that the maximum cam slope departs only a few degrees from a plane normal to the blade axis, the teeth of the gears 46 and 50 may be cut with uniform circumferential spacing, rather than with uniform spacing along the pitch cone which follows the cam shape, since the pitch of the teeth will vary only a minute amount along the pitch cone. The inner and outer end faces of the teeth may be cylindrical. One method of fabricating these gears consists in cutting a plurality of uniformly circumferentially spaced teeth all having planar flanks of zero pressure angle and all having the same height, in the planar end face of the crown gear blank. After cutting the

teeth, which are tapered with the tooth flank planes intersecting at the gear axis, the ends of the teeth are ground to conform substantially with the pitch cone defined by the cam profile, and the corners of the teeth are rounded off slightly. This produces a crown gear with teeth of varying height which are, nevertheless, all equally effective due to their substantially zero pressure angle. The tooth forms of the pinions 42 are so designed as to mesh smoothly with these crown gear teeth.

Though but a single embodiment of the invention has been illustrated and described, it is to be understood that changes may be made without departing from the spirit or scope thereof, as will be apparent to those skilled in the art. Reference should be had to the appended claims for a definition of the limits of the invention.

I claim:

1. In a variable pitch propeller, a hub having a blade retention socket, a blade having its shank extending into said socket, a substantially annular roller race having a waved outer surface secured to said shank, a bevel gear rigid with the race having its pitch line waved similarly to the waved surface of the race, a substantially annular roller race having an inner waved surface and a correspondingly waved bevel gear, said second roller race being secured to said hub socket, and a plurality of rollers between said roller races and bearing on both, having bevel pinions concentric and rigid therewith, the bevel pinions engaging the bevel gears associated with said races.
2. In a variable pitch propeller, a hub having a blade retention socket, a blade having its shank extending into said socket, a substantially annular roller race having a waved outer surface secured to said shank, a bevel gear rigid with the race having its pitch line waved similarly to the waved surface of the race, a substantially annular roller race having an inner waved surface and a correspondingly waved bevel gear, said second roller race being secured to said hub socket, a plurality of rollers between said roller races and bearing on both, having bevel pinions concentric and rigid therewith, the bevel pinions engaging the bevel gears associated with said races, and the pitch cones of said bevel pinions intersecting the centroids of respective rollers, the pitch cones of said bevel pinions having apices coincident with the blade axis.
3. In a variable pitch propeller, a hub having a blade retention socket, a blade having its shank extending into said socket, an inner substantially annular roller race having a waved outer surface secured to said shank, a bevel gear rigid with the race having its pitch line waved similarly to the waved surface of the race, a substantially annular roller race having an inner waved surface and a correspondingly waved bevel gear, said second roller race being secured to said hub socket, and a plurality of rollers between said roller races and bearing on both, having bevel pinions concentric and rigid therewith, the bevel pinions engaging the bevel gears associated with said races, the securing of said inner race to said blade, the contacts of said rollers with said inner race, the contacts of said rollers with said second race, and the securing of said second race to said hub socket all lying substantially on the surface of a construction cone coaxial with the hub socket, said cone diverging outwardly toward the socket end, whereby the path of load

transfer from said blade to said socket lies on the surface of said construction cone.

4. In a variable pitch propeller, a hub having a blade retention socket, a blade having its shank extending into said socket, a substantially annular roller race having a waved outer surface secured to said shank, a bevel gear rigid with the race having its pitch line waved similarly to the waved surface of the race, a substantially annular roller race having an inner waved surface and a correspondingly waved bevel gear, said second roller race being secured to said hub socket, a plurality of rollers between said roller races and bearing on both, having bevel pinions concentric and rigid therewith, the bevel pinions engaging the bevel gears associated with said races, a pitch changing member substantially coaxial with said blade, and independent driving connections from said member to said blade and from said member to said first mentioned roller race and bevel gear.

5. In a variable pitch propeller, a hub having a blade retention socket, a blade having its shank extending into said socket, a substantially annular roller race having a waved outer surface secured to said shank, a bevel gear rigid with the race having its pitch line waved similarly to the waved surface of the race, a substantially annular roller race having an inner waved surface and a correspondingly waved bevel gear, said second roller race being secured to said hub socket, a plurality of rollers between said roller races and bearing on both, having bevel pinions concentric and rigid therewith, the bevel pinions engaging the bevel gears associated with said races, said blade being free for limited axial movement in said hub socket, and resilient means bearing at its ends on said hub and on said blade to preload said rollers and races and to hold them in engagement in the absence of centrifugal force on said blade.

6. In a variable pitch propeller, a hub having a blade retention socket, a blade having its shank extending into said socket, the shank having an abutment at its inner end, a substantially annular roller race having a waved surface and freely slidable over said shank, split abutment means between said race and said shank abutment and bearing on each to secure the race after assembly thereof substantially rigid with said blade but capable of allowing weaving of said blade with respect to said roller race under the influence of operating stresses, said abutment means having a bevel gear whose pitch cone is waved similarly to the race waved surface, said pitch cone intersecting said waved surface substantially at the annular centroid thereof, a second substantially annular roller race having a waved surface and a correspondingly waved bevel gear whose pitch cone intersects the waved surface of the roller race at the annular centroid thereof, said second race being secured to said hub socket, and a plurality of rollers between said roller races each having bevel pinions concentric and rigid therewith engaging said gears, said bevel pinions having pitch cones intersecting the centroids of respective rollers, said pitch cones having their apices coincident with the blade axis and having generatrices thereof substantially coincident with generatrices of the pitch cones of said bevel gears.

7. In a variable pitch propeller, a hub having a blade retention socket, a blade having its shank extending into said socket, the shank having an abutment at its inner end, a substantially annular roller race having a waved surface and freely

slidable over said shank, split abutment means between said race and said shank abutment and bearing on each to secure the race after assembly thereof substantially rigid with said blade but capable of allowing weaving of said blade with respect to said roller race under the influence of operating stresses, said abutment means having a bevel gear whose pitch cone is waved similarly to the race waved surface, said pitch cone intersecting said waved surface substantially at the annular centroid thereof, a second substantially annular roller race having a waved surface and a correspondingly waved bevel gear whose pitch cone intersects the waved surface of the roller race at the annular centroid thereof, said second race being secured to said hub socket and a plurality of rollers between said roller races each having bevel pinions concentric and rigid therewith engaging said gears, said bevel pinions having pitch cones intersecting the centroids of respective rollers, said pitch cones having their apices coincident with the blade axis and having generatrices thereof coincident with generatrices of the pitch cones of said bevel gears, said races, rolls and blade shank abutment being so aligned as to provide a substantially conical stress path from said blade socket to said shank abutment, the axis of the conical stress path being coaxial with the socket axis.

8. In a variable pitch propeller, a hub having a blade retention socket, a blade having its shank extending into said socket, the shank having an abutment at its inner end, a substantially annular roller race having a waved surface and freely slidable over said shank, split abutment means between said race and said shank abutment and bearing on each to secure the race after assembly thereof substantially rigid with said blade but capable of allowing weaving of said blade with respect to said roller race under the influence of operating stresses, said abutment means having a bevel gear whose pitch cone is waved similarly to the race waved surface, said pitch cone intersecting said waved surface substantially at the annular centroid thereof, a second substantially annular roller race having a waved surface and a correspondingly waved bevel gear whose pitch cone intersects the waved surface of the roller race at the annular centroid thereof, said second race being secured to said hub socket and a plurality of rollers between said roller races each having bevel pinions concentric and rigid therewith engaging said gears, said bevel pinions having pitch cones intersecting the centroids of respective rollers, said pitch cones having their apices coincident with the blade axis and having generatrices thereof coincident with generatrices of the pitch cones of said bevel gears, a pitch changing member substantially coaxial with said blade, and independent driving connections from said member to said blade and from said member to said first mentioned roller race and bevel gear.

9. In a variable pitch propeller, a hub having a blade retention socket, a blade having its shank extending into said socket, the shank having an abutment at its inner end, a substantially annular roller race having a waved surface and freely slidable over said shank, split abutment means between said race and said shank abutment and bearing on each to secure the race after assembly thereof substantially rigid with said blade but capable of allowing weaving of said blade with respect to said roller race under the influence of operating stresses, said abutment means having a bevel gear whose pitch

cone is waved similarly to the race waved surface, said pitch cone intersecting said waved surface substantially at the annular centroid thereof, a second substantially annular roller race having a waved surface and a correspondingly waved bevel gear whose pitch cone intersects the waved surface of the roller race at the annular centroid thereof, said second race being secured to said hub socket and a plurality of rollers between said roller races each having bevel pinions concentric and rigid therewith engaging said gears, said bevel pinions having pitch cones intersecting the centroids of respective rollers, said pitch cones having their apices coincident with the blade axis and having generatrices thereof coincident with generatrices of the pitch cones of said bevel gears, said blade being free for limited axial movement in said hub socket, and resilient means bearing at its ends on said hub and on said blade to preload said rollers and races and to hold them in engagement in the absence of centrifugal force on said blade.

10. In a variable pitch propeller including a hub having a blade retention socket and a blade having its shank extending into said socket; means for swivelly retaining said shank within said socket and for axially moving said blade upon swivelling comprising opposed relatively movable cam races drivably secured to said socket and shank respectively, rollers interposed between said races, and means for retaining the angular position between the axes of said rollers and said races in a certain relationship for each relative swivel position between said blade and hub, said means comprising a toothed member coaxial and rigid with each roller, and teeth rigid with each of said opposed races engaged with said toothed member.

11. In a variable pitch propeller including a hub having a blade retention socket and a blade having its shank extending into said socket; means for swivelly retaining said shank within said socket and for axially moving said blade upon swivelling comprising opposed relatively movable cam races drivably secured to said socket and shank respectively, rollers interposed between said races, and means for retaining the angular position between the axes of said rollers and said races in a certain relationship for each relative swivel position between said blade and hub, said means comprising a toothed member coaxial with each roller, and teeth rigid with each of said opposed races engaged with said toothed member, said toothed member comprising a bevel pinion whose pitch cone intersects the centroid of said roller and whose apex is substantially coincident with the blade axis.

12. In a variable pitch propeller including a hub having a blade retention socket and a blade having its shank extending into said socket; means for swivelly retaining said shank within said socket and for axially moving said blade upon swivelling, comprising opposed relatively movable waved cam races drivably connected with said socket and shank respectively, rollers interposed therebetween, means for retaining the angular position between axes of the rollers and said cam races in a certain relationship for any relative swivelling position between said blade and hub, said rollers each having toothed members thereon and rigid therewith, and teeth adjacent to each of and rigid with said opposed races engaging said toothed member, arranged on a pitch line which waves in an axial direc-

tion in substantial conformance with the wave of said cam races.

13. In a variable pitch propeller including a hub having a blade retention socket and a blade having its shank extending into said socket; means for swivelly retaining said shank within said socket and for axially moving said blade upon swivelling, comprising opposed relatively movable waved cam races drivably connected with said socket and shank respectively, rollers interposed therebetween, means for retaining the angular position between axes of the rollers and said cam races in a certain relationship for any relative swivelling position between said blade and hub, said rollers each having toothed members thereon, and teeth adjacent to each of and rigid with said opposed races engaging said toothed member, arranged on a pitch line which waves in an axial direction in substantial conformance with the wave of said cam races, said toothed members being rigid with respective rollers and comprising bevel pinions whose pitch cones intersect the central bearing portions of respective rollers.

14. In a variable pitch propeller including a hub having a blade retention socket and a blade having its shank extending into said socket; means for swivelly retaining said shank within said socket and for axially moving said blade upon swivelling, comprising opposed relatively movable waved cam races drivably connected with said socket and shank respectively, rollers interposed therebetween, means for retaining the angular position between axes of the rollers and said cam races in a certain relationship for any relative swivelling position between said blade and hub, said rollers each having toothed members thereon, and teeth adjacent to each of and rigid with said opposed races engaging said toothed member, arranged on a pitch line which waves in an axial direction in substantial conformance with the wave of said cam races, said toothed members being rigid with respective rollers and comprising bevel pinions whose pitch cones intersect the central bearing portions of respective rollers, said pitch cones having apices substantially coincident with the axis of said blade.

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