Dec. 6, 1960

C. F. DREXEL ET AL

RAM AIR TURBINE

2,963,093

Filed Oct. 7, 1955

3 Sheets-Sheet 1

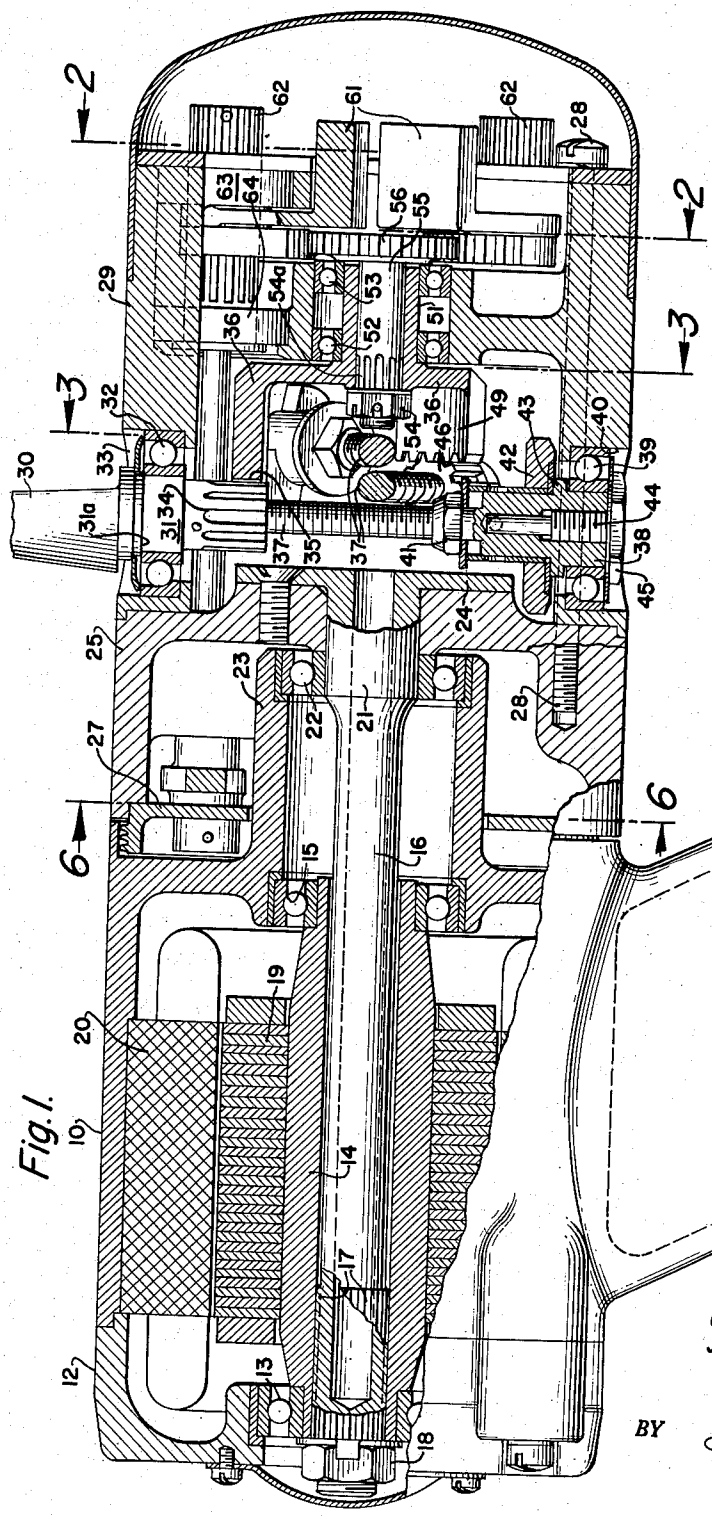


Fig. 1.

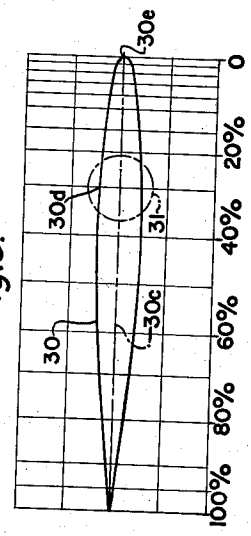


Fig. 9.

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Fig.2.

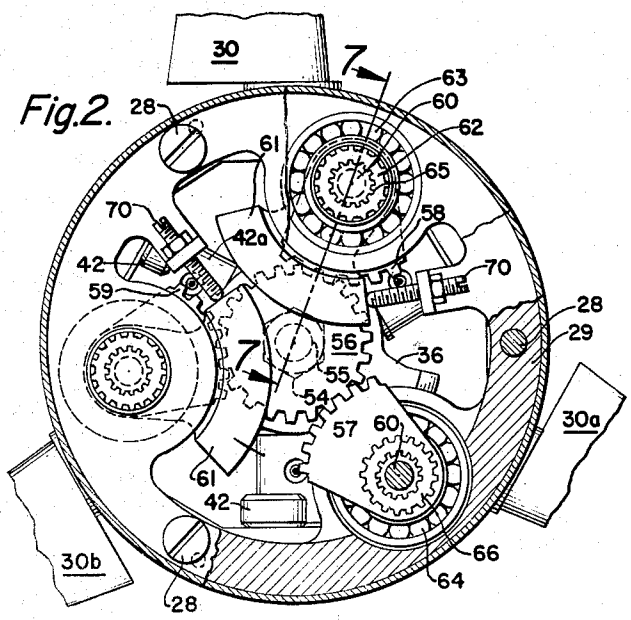


Fig.5.

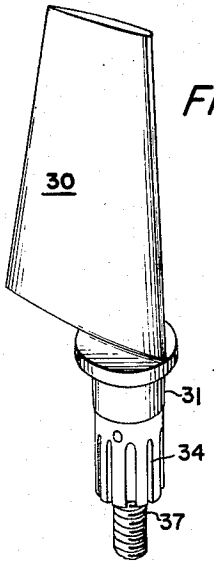


Fig.3.

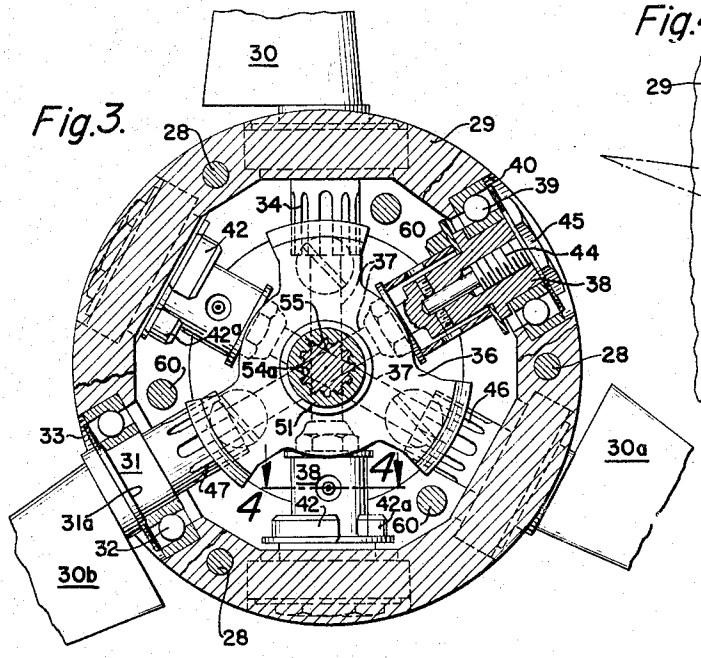
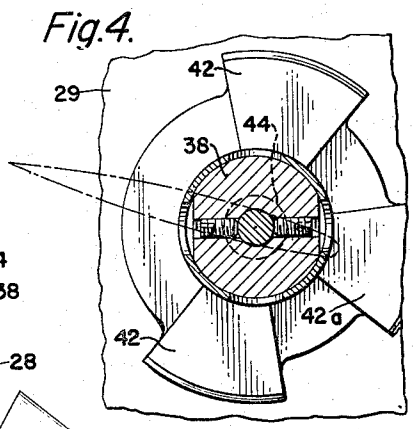


Fig.4.



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Fig.6.

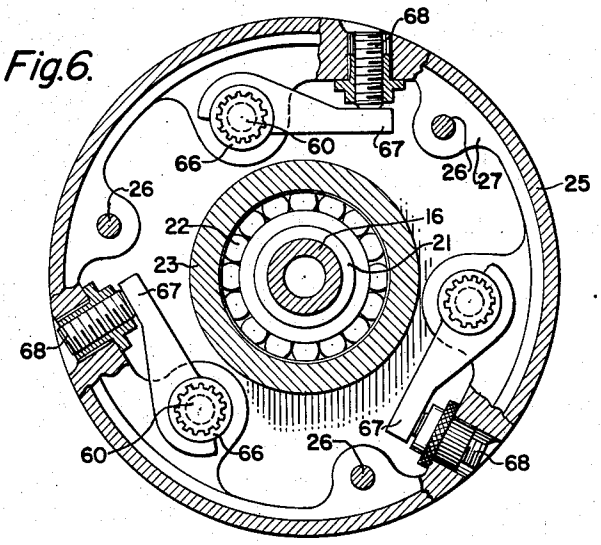


Fig.7.

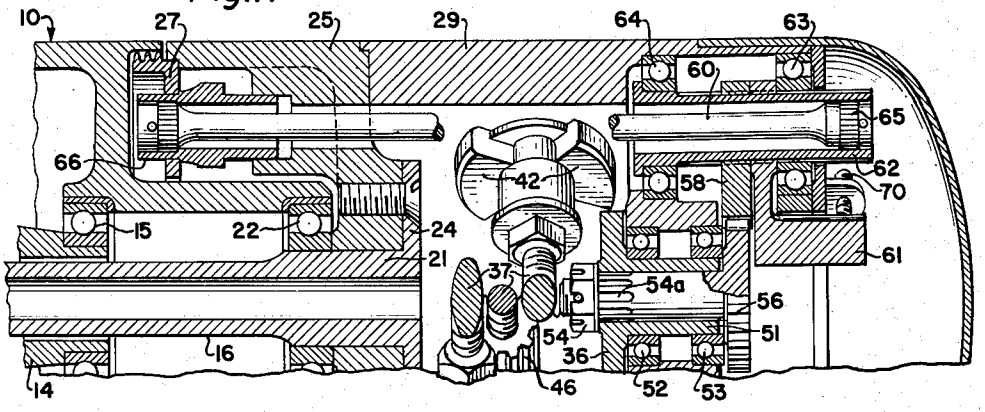
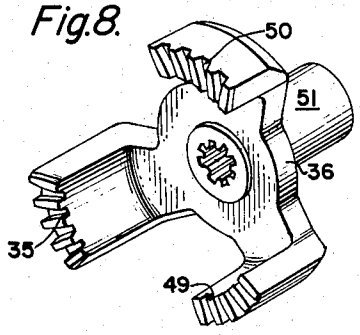


Fig.8.



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RAM AIR TURBINE

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7 Claims. (Cl. 170—68)

This invention relates to a ram air driven turbine and, more particularly, to improvements in turbines of the general type disclosed in Patent No. 2,777,524, dated January 15, 1957, to James E. Chapman, Charles F. Drexel, and James E. Young.

Ram air driven turbines of prior designs have been found unsuitable for driving alternators because they were incapable of operating within sufficiently close speed tolerances to insure a precise power output. It has been proposed to provide such turbines with centrifugally operated means to adjust the pitch of the turbine blades for controlling the speed of the turbine, but this expedient in prior designs has been found to be unsatisfactory due to the fact that the centrifugal forces of the rapidly moving blades impose such frictional loads on the blade bearings that the blades cannot be adjusted as quickly or as accurately as is necessary to secure the desired results. It has also been found that the inability of prior centrifugally operated mechanisms to control the speed of ram air driven turbines within the fine limits required, has been due, in part, to changing forces or loads imposed on the mechanism by aerodynamic disturbances occasioned by variations in the angles of attack of the turbine blades. It is an object of this invention to provide a ram air driven turbine having an improved centrifugally operated means for adjusting the blades which will avoid the objections of the prior devices by responding instantly and accurately to changes in rates of rotation of the turbine.

Another object of the invention is to provide a ram air driven turbine having means for balancing the centrifugal forces developed in the blades and thus eliminate the excessive loading of the bearings and the objections incident thereto.

A further object of the invention is to provide a ram air driven turbine having blades with shanks or tie bars which extend through the axis of rotation of the turbine and which are provided, on the opposite side of the axis from the blades, with counterweights which develop centrifugal forces to offset or counteract the similar forces developed in the blades during high speed operation of the turbine.

A still further object of the invention is to provide a ram air driven turbine having a plurality of blades extending radially from the axis of rotation of a main shaft, the blades having shanks spaced longitudinally of the main shaft and supported for rotary adjustment on opposite sides of the main shaft in antifriction bearings, the shanks being provided on the opposite side of the axis from the blades with counterweights to set up centrifugal forces when the turbine operates at high speed, such forces opposing those set up by the blades and thus relieving the antifriction bearings from excessive thrust.

A still further object of the invention is to provide a ram air driven turbine of the type set forth in the preceding paragraph with means for placing the blade shanks under tension to initially apply a thrust load to the bearings in a direction opposed to that applied by the centrifugal force, so that when the turbine is operated at high speed the centrifugal forces of the blades and counterweights will relieve the initially applied thrust load and the bearings will operate under little or no load and substantially without friction.

Another object of the invention is to provide a ram air driven turbine with blades designed to avoid the transmission of undesirable torque to the blade shafts and associated mechanisms, regardless of the angles of attack of the blades, such construction improving the operation of the device by eliminating any tendency of the automatic blade-adjusting mechanism to hesitate, lag or be sluggish in operation when the angles of attack of the blades are to be changed because of a variation in air speed.

Another object of the invention is to provide a ram air driven turbine with blades having an airfoil configuration which disposes the center of pressure of each blade at a predetermined location, and to arrange the blades on the turbine for adjustment about axes passing through the centers of pressure so that the application of undesirable aerodynamic forces to the blades when the pitch of the blades is changed, will be eliminated, special counterweight elements being provided to offset centrifugal forces incident to the particular relation of the blades and pitch adjustment axes.

Still another object of the invention is to provide a ram air driven turbine having a main shaft and a plurality of blades extending radially from the axis of rotation of such shaft, the blades being disposed for adjustment in planes spaced longitudinally of the axis of the main shaft, the turbine having means responsive to centrifugal forces for adjusting the blades, and having novel motion transmitting means between the centrifugal force creating means and the blades, to cause a simultaneous adjustment of the latter.

Other objects and advantages of the invention may be apparent from the following specification, appended claims, and accompanying drawings in which:

Figure 1 is a vertical longitudinal sectional view of a ram air turbine formed in accordance with the present invention, parts being broken away and other portions being shown in elevation to facilitate the illustration;

Figure 2 is a vertical transverse sectional view taken on planes indicated by the staggered line 2—2 of Figure 1;

Figure 3 is a similar view taken on planes indicated by staggered line 3—3 of Figure 1;

Figure 4 is a detailed sectional view on an enlarged scale taken on the plane indicated by the line 4—4 of Figure 3;

Figure 5 is a perspective view of one of the ram air turbine blades showing a portion of a shaft connected therewith;

Figure 6 is a vertical transverse sectional view taken on the plane indicated by the line 6—6 of Figure 1;

Figure 7 is a fragmentary sectional view taken on the plane indicated by line 7—7 of Figure 2;

Figure 8 is a perspective view of a spider gear employed to actuate the turbine blades about their pitch adjustment axes; and

Figure 9 is a diagrammatic view illustrating the cross-sectional shape of the present ram air turbine blades.

The terms "angle of attack" and "pitch" as used herein are substantially synonymous. However, the term "angle of attack" is employed principally in reference to the aerodynamic disposition of the turbine blades, while the term "pitch" is employed in reference to the mechanical position or the angular disposition of the chord of a selected blade with reference to a plane parallel to the longitudinal axes of the turbine and such blade.

As shown in Figure 1 of the drawings, a ram air turbine, according to the present invention, is provided with a stationary housing 10 having an aerodynamic strut 11 which serves as a support for the housing 10 when the

ram air turbine is disposed in projected operating position. The housing 10 is provided with an end cap 12 in which a bearing 13 is supported. This bearing 13 carries one end of a hollow rotor shaft 14 which is supported at its opposite end in a bearing 15 mounted in the housing 10. A shaft 16 extends through the hollow rotor shaft 14 and is engaged therewith by means of splines 17. The ends of shafts 14 and 16 are secured in axially fixed relation with the bearing 13 by means of a locknut 18. The shaft 14 carries a rotor structure 19 which co-operates with a field structure 20, the rotor and field structures comprising an alternator or generator for producing electrical power.

Shaft 16 is provided with an enlarged portion 21 journaled in a bearing 22 which is supported in an extension 23 of the housing 10. Integral with the shaft 16 is a flange 24 which supports the rotating structure of the ram air turbine. It will be noted that the axis of the shaft 16 is common to the rotating structure of the generator and the ram air turbine. The rotating structure of the ram air turbine comprises a spinner housing member 25 which is connected to the shaft flange 24 and which surrounds the extension 23 of the housing 10. Secured to the rear portion of the spinner housing member 25 by means of bolts 26, see Figure 6, is a plate 27 which forms the rear end of the turbine spinner housing. Fixed to the spinner housing member 25 by means of bolts 28 is the spinner housing member 29. This housing member 29 serves as a support or carrier for turbine blades 30, 30*a*, and 30*b* which project radially of the housing 29 and pivot about their axes at substantially right angles to the common axis of the shaft 16 and the spinner housing members 25 and 29. Since the turbine blades 30, 30*a*, and 30*b* and their connected centrifugal balancing mechanism is similar, the structural elements of the turbine blade 30 only are hereinafter described in detail.

As shown in Figure 1 of the drawing, the turbine blade 30 extends outwardly of the spinner housing members 25 and 29 and operates in the air stream which passes therearound. The blade 30 is provided with a hub 31 supported in a bearing 32 which is carried in a recess 33 in the housing member 29. The blade 30 is provided with gear teeth 34 which mesh with conforming teeth 35 of a blade synchronizing spider gear 36. Threadedly connected to the hub 31 is a shaft 37 having an enlarged opposite end 38 supported in a bearing 39 carried in a recess 40 in the housing member 29. Threaded onto the shaft 37 is a nut 41 which fixes a counterweight 42 against a shoulder 43 on the enlarged portion 38 of said shaft 37. The counterweight 42 is arranged to counteract and prevent torsional forces in the blade 30 resulting from centrifugal action, from affecting the operation of the pitch adjusting mechanism, as will be hereinafter described in detail.

A screw 44 is threaded into a conforming threaded hole in the end portion 38 of the shaft 37 and this screw 44 is provided with a large head 45 arranged to engage the inner race of the bearing 39 and retain the shaft 37 in a certain axial position relative to the bearings 32 and 39. The hub 31 of blade 30 is provided with a shoulder 31*a* to engage the inner race of the bearing 32 and when screw 44 is engaged with the inner race of bearing 39 and tightened, the shaft or tie rod 37 is stressed to apply an inward thrust or preload on the bearings 32 and 39. The blade 30, hub 31, and portions of the bearing 32 which are connected thereto, together with a portion of the shaft 37 extending on one side of the turbine axis, are designed to have a centrifugal force moment equal to that of the structure connected to the shaft 37 and extending radially of said axis in the opposite direction. Thus, the mass of the parts of each blade assembly on one side of the axis of the turbine balances the mass of the parts of the assembly on the opposite side of the axis. When the turbine is operated, the centrifugal forces of the parts of each blade assembly on each side of the turbine axis will be offset or balanced by those of the parts on the other side of the axis and the turbine will operate smoothly. The centrifugal forces of the parts of the blade assemblies will also tend to stretch the shafts or tie rods 37 and relieve the bearings 32 and 39 of the preload initially applied through the tightening of the screw 44. The bearings will, therefore, be subject to a minimum thrust load and will offer only normal resistance to rotation at the designed operating speeds of the turbine.

Figure 9 shows a typical cross section of the turbine blades. From this figure it is apparent that each blade is symmetrical about the mean chord 30*c* of such blade. This blade configuration provides a center of pressure 30*d* which, as shown in Figure 9, is located approximately 27% (between 25 and 30%) of the chord length from the leading edge 30*e* of the blade, and the latter is so located on the hub 31 that this center of pressure is disposed on the axis of pivotal movement of the blade in the bearings 32 and 39. Due to this arrangement, the relationship of the center of pressure to the axis of movement of the blade will remain constant even during pitch adjustment of the blade; this design, therefore, is particularly adaptable to spring biased, centrifugally operated, pitch adjusting mechanism, a form of which is employed in the present air driven turbine.

The location of the axis of pitch adjustment of each blade in the manner just described places the center of gravity of the blade at one side of the adjustment axis and when the turbine revolves, centrifugal forces may transmit undesirable torque to the blade. This effect is counteracted in the form of the invention illustrated, by providing the counterweight 42 with a section 42*a* which, as shown in Figure 4, is located on the opposite side of the axis of adjustment of the blade from the blade, per se. It should be obvious that the shape of the weight 42 may vary considerably from that shown, the important feature being the location of the center of gravity thereof so that the torque transmitted to the blade by centrifugal forces acting thereon will be counteracted by similar forces of the counterweight.

As shown in Figure 3 of the drawings, the turbine blades 30*a* and 30*b* are provided with gear portions 46 and 47, respectively, which are similar to the gear 34 of the turbine blade 30. The gear elements 34, 46, and 47 mesh with gear portions 35, 49, and 50 of the spider gear 36. The gear portions 35, 49, and 50 are axially spaced relative to each other in order to accommodate a staggered relationship of the shafts 37 of the turbine blades 30, 30*a* and 30*b*. This spider gear 36 is provided with a hollow shaft portion 51 journaled in bearings 52 and 53 carried by the spinner housing member 29. Fixed to the spider gear 36 by means of a locknut 54 and spline 54*a* is a shaft 55 which extends through the hollow shaft 51 and carries a gear 56 in meshing engagement with gear segments 57, 58, and 59 shown particularly in Figure 2 of the drawings.

Each of the gear segments 57, 58 and 59 is connected to a torsion bar and flyweight structure. In the present ram air turbine, there are three torsion bars and three flyweights, all of which are similar in construction. Therefore, a torsion bar 60, together with its connected flyweight 61, is herein described and shown in detail in Figure 7 of the drawngs. The gear segment 58 is fixed to a tubular member 62 journaled in bearings 63 and 64 which are supported in the spinner housing member 29. Fixed on the outer side of the tubular member 62, adjacent the gear 58, is the flyweight 61. One end 65 of the torsion bar 60 is fixed in the tubular member 62 and the opposite end of the torsion bar 60 is fixed in a tubular member 66 which is rotatably mounted in the spinner housing member 25 and end plate 27.

Referring to Figure 6 of the drawings, it will be seen that the tubular member 66 is provided with a projecting arm 67 which is engaged with an adjusting screw 68

threaded in the spinner housing member **25** and arranged to provide an adjustable stop for the torsion bar **60**.

A second adjustable stop means in the form of screws **70** is provided, as shown in Figure 2, for engagement by the flyweights at the forward ends of the torsion bars. When the screws **68** are adjusted inwardly, the arms **67** turn the torsion bars and tend to swing the flyweights **61** into engagement with the screws **70**. This engagement precludes further movement of the flyweight; continued adjustment of the screws **68** inwardly preloads the torsion bars **60**. The starting or initial pitch of the blades may be varied through the adjustment of the stop screws **70**.

Operation

When the present ram air turbine is supported in an air stream, the blades **30**, **30***a* and **30***b* tend to rotate the shaft **16** and spinner housing members **25** and **29** about the axis of the bearings **13**, **15**, and **22**. As the rotating mechanism of the turbine reaches a desired predetermined speed, any tendency toward exceeding such speed is automatically opposed by a change in pitch of the blades through the movement of the flyweights in opposition to the resistance of the torsion bars. When the flyweights swing outwardly under centrifugal force, the gears **57**, **58**, and **59** transmit rotary motion through gears **56** and **36** to the gear elements **34**, **46**, and **47** connected with the blades **30**, **30***a*, and **30***b*, respectively, and the pitch of the blades will be changed. Rotary movement of the flyweights imparts torsional stress to the bars **60** and when the speed of operation of the turbine decreases, the forces stored in the bars **60** will tend to return the blades and associated mechanism to the initial starting position; the design speed of the turbine will thus be maintained at different air stream speeds.

The counterweights **42** connected with the turbine blades are arranged to prevent centrifugal torsion forces, acting on the blades, from affecting the balanced operation of the torsion bars relative to the centrifugal flyweights **61** connected thereto.

It is recognized that the force balance between the centrifugally operated flyweights and the resilient torsion bars may be very delicate with respect to the maintenance of speed variations of the turbine within close tolerances. Therefore, it is desired to reduce rotational resistance in the present turbine blade bearings to a minimum. Centrifugal forces acting axially on the turbine blades are balanced by similar forces acting on mechanism diametrically opposed to the blades whereby the blade supporting bearings operate with a minimum of rotational resistance.

Due to the fact that the rotational speed of the present ram air turbine is precisely maintained, it may be used to operate an alternator or any other device requiring operation at a speed to be maintained within critical limits.

We claim:

1. In a ram air turbine having a central axis of rotation: a blade carrier supported coaxially with and disposed for rotation about said central axis of rotation; a pair of bearing means on said carrier at diametrically opposite sides of said central axis of rotation respectively; an assembly including a blade having a shaft means extending from one end of said blade and counterweight means on said shaft means, said shaft means being rotatably supported by said bearing means with the axis thereof intersecting and disposed substantially at right angles to said central axis of rotation, said counterweight means being disposed on the opposite side of said central axis of rotation from said blade, each of said pair of bearing means cooperating with the portion of said shaft supported thereby to resist axial shifting of such portion toward said central axis of rotation; means cooperating with at least one of said pair of bearing means initially loading said pair of bearing means to place the section of said shaft means between said pair of bearing means under tension, the portion of said assembly and the portion of the bearing means rotatable with said shaft means on one side of said central axis of rotation substantially counterbalancing the portion of said assembly and the portion of the bearing means rotatable with said shaft means on the opposite side of said central axis of rotation whereby substantially equal and opposite centrifugal forces are applied to relieve the initial load on said pair of bearing means upon rotation of said carrier at a predetermined speed.

2. In a ram air turbine having a central axis of rotation: a blade carrier supported coaxially with and disposed for rotation about said central axis of rotation; a pair of bearing means on said carrier at diametrically opposite sides of said central axis of rotation respectively; an assembly including a blade having a shaft means extending from one end of said blade and counterweight means on said shaft means, said shaft means being rotatably supported by said bearing means with the axis thereof intersecting and disposed substantially at right angles to said central axis of rotation, said counterweight means being disposed on the opposite side of said central axis of rotation from said blade, each of said pair of bearing means cooperating with the portion of said shaft supported thereby to resist axial shifting of such portion toward said central axis of rotation; resilient means tending to resist movement of said shaft means about its axis; flyweight means responsive to rotation of said blade carrier about said central axis of rotation to move said shaft means about its axis in opposition to said resilient means; means cooperating with at least one of said pair of bearing means initially loading said pair of bearing means to place the section of said shaft means between said pair of bearing means under tension, the portion of said assembly and the portion of the bearing means rotatable with said shaft means on one side of said central axis of rotation substantially counterbalancing the portion of said assembly and the portion of the bearing means rotatable with said shaft means on the opposite side of said central axis of rotation whereby substantially equal and opposite centrifugal forces are applied to relieve the initial load on said pair of bearing means upon rotation of said carrier at a predetermined speed.

3. In a ram air turbine having a central axis of rotation: a blade carrier supported coaxially with and disposed for rotation about said central axis of rotation; a plurality of pairs of bearing means on said carrier, each of said pairs being spaced axially and circumferentially on said carrier, the bearing means of each pair being disposed at diametrically opposite sides of said central axis of rotation; an assembly for each of said pairs of bearing means, said assembly including a blade having shaft means extending from one end of said blade and also including counterweight means on said shaft means, the shaft means of each assembly being rotatably supported by a pair of said bearing means with the axis thereof intersecting and disposed substantially at right angles to said central axis of rotation, said counterweight means and said blade of each assembly being disposed on opposite sides of said central axis of rotation, the bearing means of each pair on each side of said central axis of rotation cooperating with the portion of the shaft means supported thereby to resist axial shifting of such portion toward said central axis of rotation; means cooperating with at least one of each pair of bearing means to initially load said pairs of bearing means to place the section of the shaft means between the bearing means of each pair under tension, the portion of each said assembly and the portion of the bearing means rotatable with the shaft means of such assembly on one side of said central axis of rotation substantially counterbalancing the portion of such assembly and the portion of the bearing means rotatable with the shaft means of such assembly on the opposite side of said central axis of rotation whereby

substantially equal and opposite centrifugal forces are applied to relieve the initial load on each said pair of bearing means upon rotation of said carrier at a predetermined speed.

4. In a ram air turbine having a central axis of rotation: a blade carrier supported coaxially with and disposed for rotation about said central axis of rotation; a plurality of pairs of bearing means on said carrier, each of said pairs being spaced axially and circumferentially on said carrier, the bearings means of each pair being disposed at diametrically opposite sides of said central axis of rotation; an assembly for each of said pairs of bearing means, said assembly including a blade having shaft means extending from one end of said blade and also including counterweight means on said shaft means, the shaft means of each assembly being rotatably supported by a pair of said bearing means with the axis thereof intersecting and disposed substantially at right angles to said central axis of rotation, said counterweight means and said blade of each assembly being disposed on opposite sides of said central axis of rotation, the bearing means of each pair on each side of said central axis of rotation cooperating with the portion of the shaft means supported thereby to resist axial shifting of such portion toward said central axis of rotation; means connecting the shaft means for synchronized adjustment of said blades about the axes of said shaft means; flyweight means responsive to the rotation of said carrier about said central axis of rotation to move said shaft means to change the pitch of said blades; resilient means for resisting movement of said shaft means by said flyweight means; means cooperating with at least one of each pair of bearing means to initially load said pairs of bearing means to place the section of the shaft means between the bearing means of each pair under tension, the portion of each said assembly and the portion of the bearing means rotatable with the shaft means of such assembly on one side of said central axis of rotation substantially counter-balancing the portion of such assembly and the portion of the bearing means rotatable with the shaft means of such assembly on the opposite side of said central axis of rotation whereby substantially equal and opposite centrifugal forces are applied to relieve the initial load on each said pair of bearing means upon rotation of said carrier at a predetermined speed.

5. In a ram air turbine as recited in claim 4 wherein each counterweight means is disposed relative to its associated shaft means and blade to resist centrifugal torsion forces developed about the axis of such associated shaft means and blade.

6. In a ram air turbine having a central axis of rotation: a blade carrier supported coaxially with and disposed for rotation about said central axis of rotation; a plurality of pairs of bearing means on said carrier, each of said pairs being spaced axially and circumferentially on said carrier, the bearing means of each pair being disposed at diametrically opposite sides of said central axis of rotation; an assembly for each of said pairs of bearing means, said assembly including a blade having shaft means extending from one end of said blade and also including counterweight means on said shaft means, the shaft means of each assembly being rotatably supported by a pair of said bearing means with the axis thereof intersecting and disposed substantially at right angles to said central axis of rotation, said counterweight means and said blade of each assembly being disposed on opposite sides of said central axis of rotation, the bearing means of each pair on each side of said central axis of rotation cooperating with the portion of the shaft means supported thereby to resist axial shifting of such portion toward said central axis of rotation; centrifugally operated means to adiust the pitch of the blades in response to rotation of said blade carrier about said central axis of rotation, each of the blades having an aerodynamically balanced configuration and being located with the center of pressure substantially coincidental with its pitch adjustment axis; means cooperating with at least one of each pair of bearing means to initially load said pairs of bearing means to place the section of the shaft means between the bearing means of each pair under tension, the portion of each said assembly and the portion of the bearing means rotatable with the shaft means of such assembly on one side of said central axis of rotation substantially counterbalancing the portion of such assembly and the portion of the bearing means rotatable with the shaft means of such assembly on the opposite side of said central axis of rotation whereby substantially equal and opposite centrifugal forces are applied to relieve the initial load on each said pair of bearing means upon rotation of said carrier at a predetermined speed.

7. In a ram air turbine having a central axis of rotation: a blade carrier supported coaxially with and disposed for rotation about said central axis of rotation; a plurality of pairs of bearing means on said carrier, each of said pairs being spaced axially and circumferentially on said carrier, the bearing means of each pair being disposed at diametrically opposite sides of said central axis of rotation; an assembly for each of said pairs of bearing means, said assembly including a blade having shaft means extending from one end of said blade and also including counterweight means on said shaft means, the shaft means of each assembly being rotatably supported by a pair of said bearing means with the axis thereof intersecting and disposed substantially at right angles to said central axis of rotation, said counterweight means and said blade of each assembly being disposed on opposite sides of said central axis of rotation, the bearing means of each pair on each side of said central axis of rotation cooperating with the portion of the shaft means supported thereby to resist axial shifting of such portion toward said central axis of rotation; centrifugally operated means to adjust the pitch of the blades in response to rotation of said blade carrier about said central axis of rotation, each of the blades being symmetrical about a mean chord and located with the center of pressure coinciding with said pitch adjustment axis to preclude the production of torque about such axis when the pitch of the blade is changed; means cooperating with at least one of each pair of bearing means to initially load said pairs of bearing means to place the section of the shaft means between the bearing means of each pair under tension, the portion of each said assembly and the portion of the bearing means rotatable with the shaft means of such assembly on one side of said central axis of rotation substantially counterbalancing the portion of such assembly and the portion of the bearing means rotatable with the shaft means of such assembly on the opposite side of said central axis of rotation whereby substantially equal and opposite centrifugal forces are applied to relieve the initial load on each said pair of bearing means upon rotation of said carrier at a predetermined speed.

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