United States Patent

Velkoff

[15] **3,695,780**

[45] **Oct. 3, 1972**

[54] **WHEEL-TYPE AIRSCREW HAVING PRE-TENSIONED BLADE SUPPORTS**

[72] Inventor: **Henry R. Velkoff,** 6715 Beren St., Worthington, Ohio 43085

[22] Filed: **Oct. 19, 1970**

[21] Appl. No.: **82,016**

[52] **U.S. Cl.** **416/189,** 416/195, 416/205

[51] **Int. Cl.**.....**B64c 27/20**

[58] **Field of Search**.....416/225, 2, 189, 196, 240, 416/132, 192

[56] **References Cited**

UNITED STATES PATENTS

543,460	7/1895	Bramwell	416/195
1,065,263	6/1913	Mees	416/195 X
3,047,251	7/1962	Lewis	416/189 X

FOREIGN PATENTS OR APPLICATIONS

2,189	3/1932	Australia	416/195

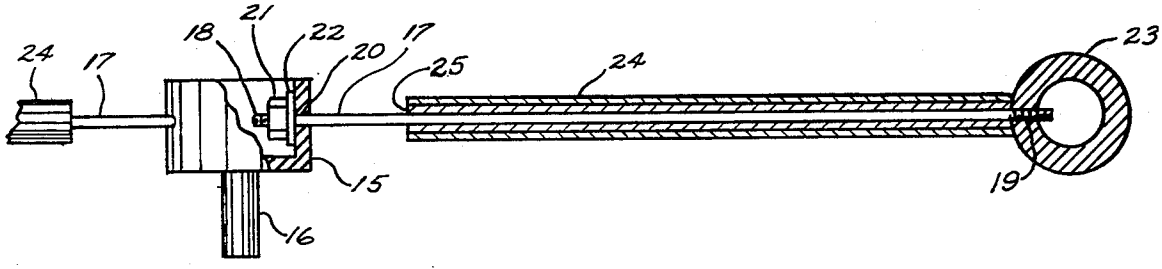
Primary Examiner—Everette A. Powell, Jr.

Attorney—William S. Rambo

[57] **ABSTRACT**

A wheel-shaped rotor for a helicopter or similar aircraft characterized by an inner hub, a plurality of airfoil blades extending outwardly from the hub portion, an outer rim or ring connected with and joining the outer end portions of the blades, and wherein the blades are supported by pre-tensioned spoke members extending between the hub and outer rim members of the rotor.

10 Claims, 15 Drawing Figures



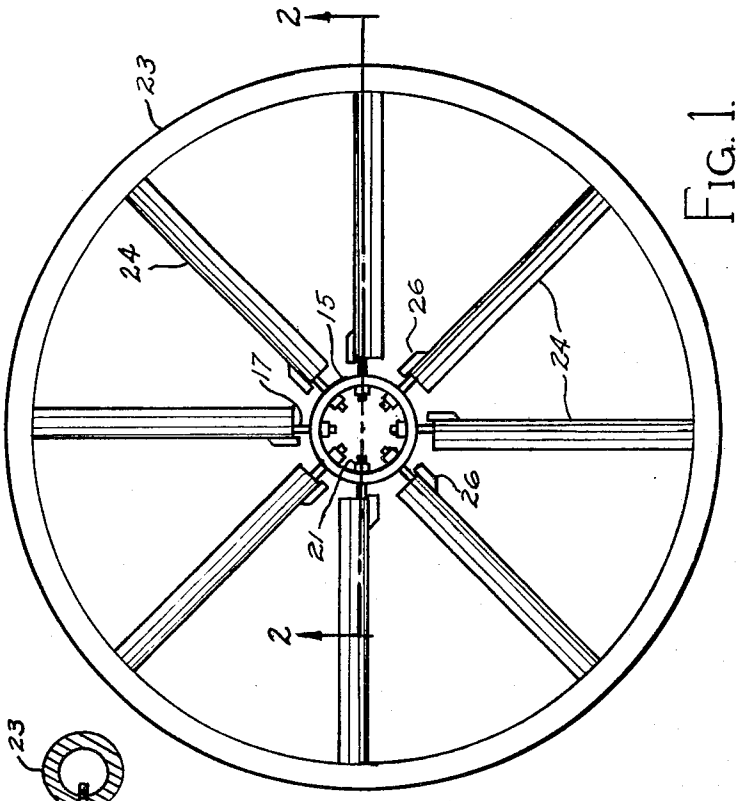


FIG. 1.

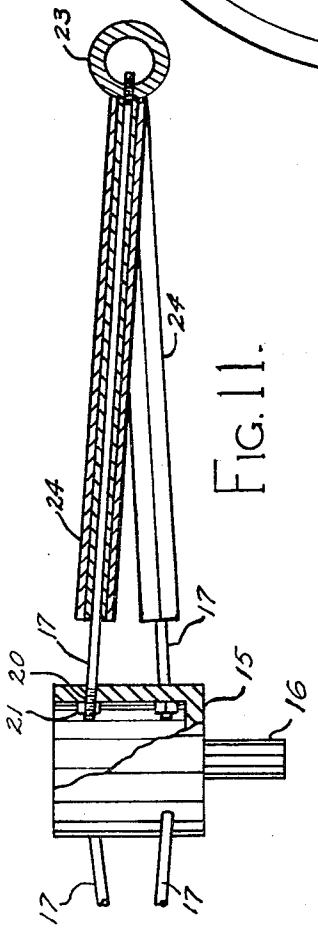


FIG. II.

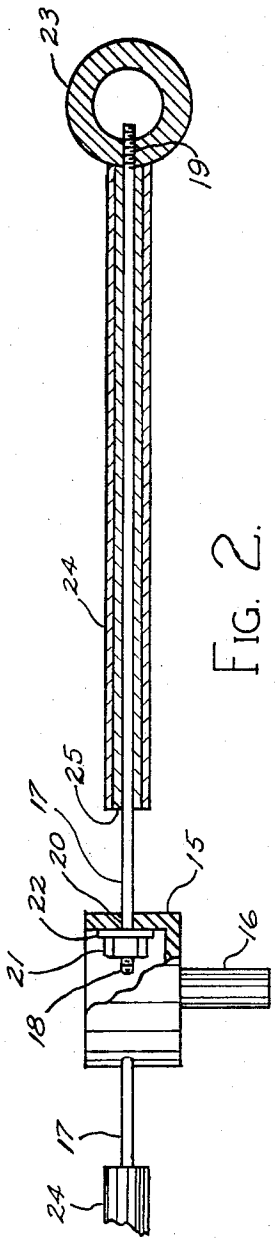


FIG. 2.

INVENTOR.
HENRY R. VELKOFF
BY
W. V. Rinaldo
ATTORNEY

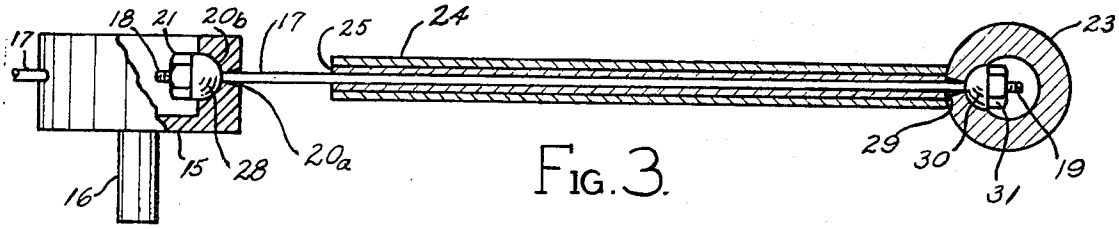


FIG. 3.

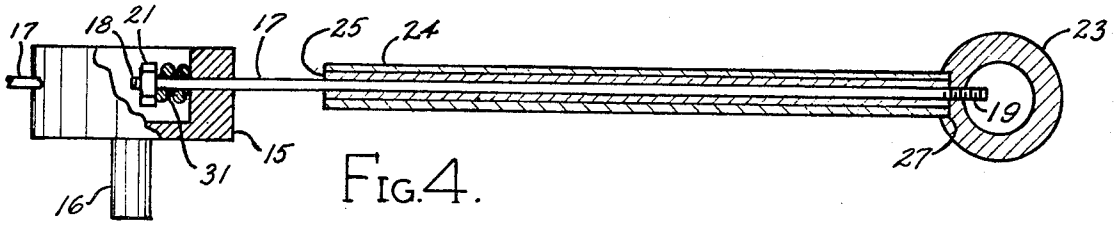


FIG. 4.

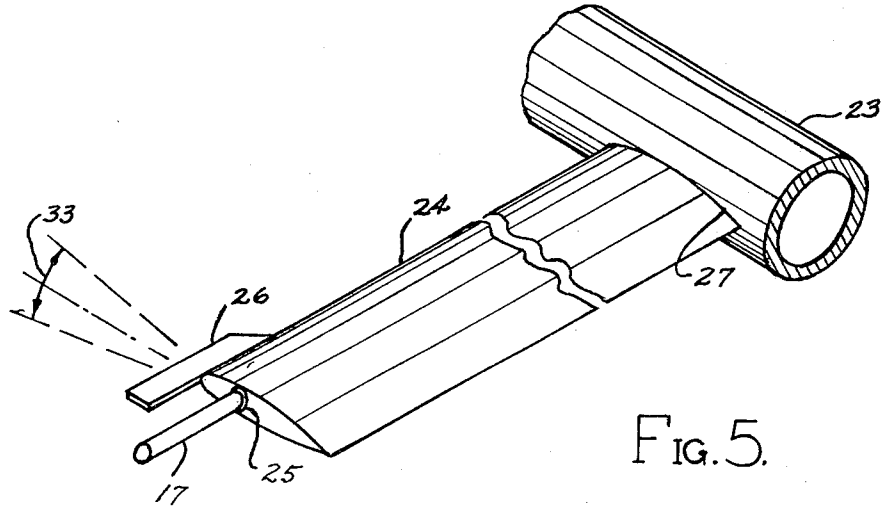


FIG. 5.

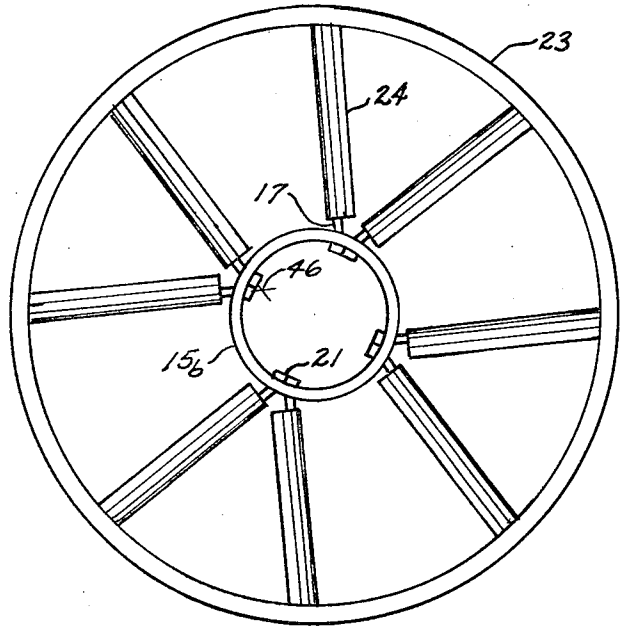


FIG. 8.

INVENTOR.
HENRY R. VELKOFF
BY
W. A. Ramko
ATTORNEY

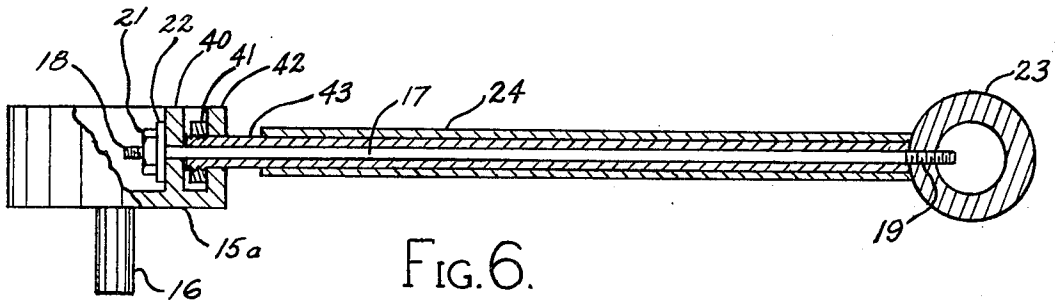


FIG. 6.

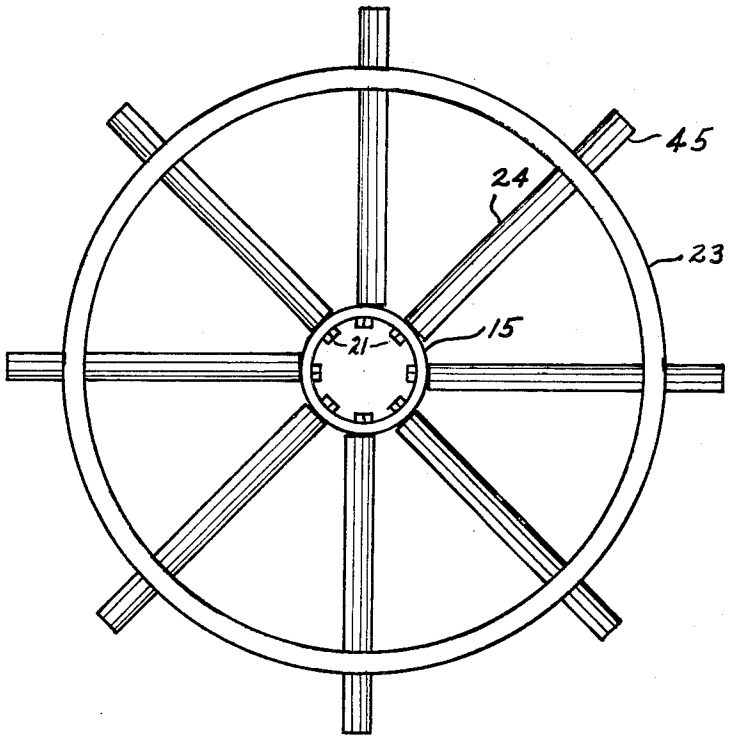


FIG. 7.

INVENTOR.
HENRY R. VELKOFF
BY
W. X. Ramsey
ATTORNEY

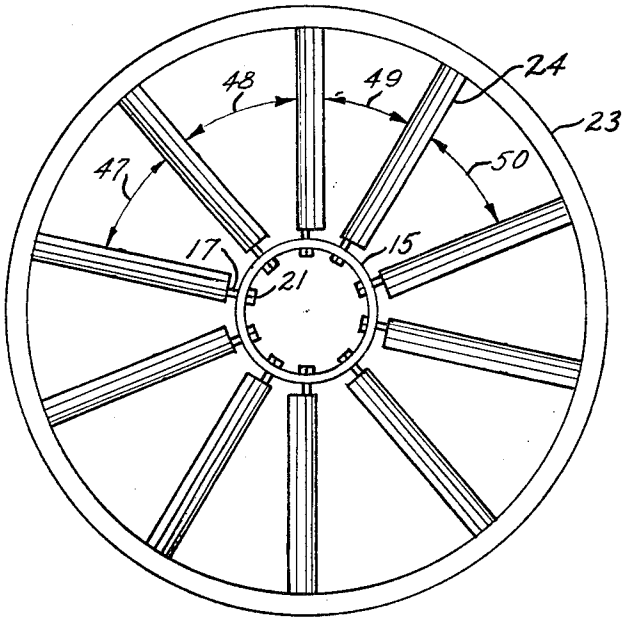


FIG. 9.

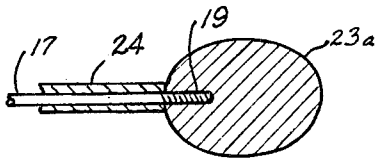


FIG. 10a.

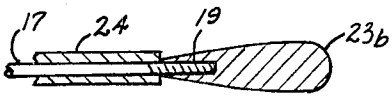


FIG. 10b.

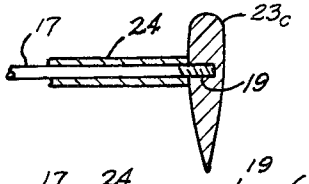


FIG. 10c.

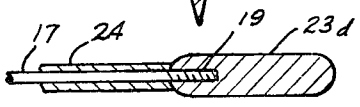


FIG. 10d.

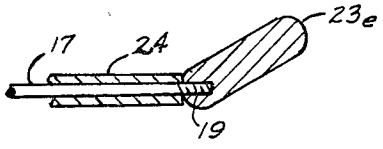


FIG. 10e.

INVENTOR.
HENRY R. VELKOFF
BY
W. N. Rambo
ATTORNEY

WHEEL-TYPE AIRSCREW HAVING PRE-TENSIONED BLADE SUPPORTS

BACKGROUND OF THE INVENTION

This invention relates generally to rotors or airscrews for helicopters and similar aircraft, and more particularly to a wheel-type airscrew or rotor in which a plurality of airfoil blades are mounted on a system of pre-tensioned spokes or struts connected between an inner hub member and an outer, circular rim member.

The airfoil blades of conventional helicopter and autogyro rotors or airscrews are usually mounted directly onto a central hub. Such blades are either attached directly to the hub in a cantilever fashion, or in some helicopter rotors, the blades are mounted to the hub by means of hinges. With a hinged mounting, the blades are held in their operating position by virtue of the high value of centrifugal force which pulls the blades radially outward. In all these usual methods of blade attachment, the outer ends or tips of the blades are not restrained by any mechanical means. The blades are free to move about the hinges or flex under the action of imposed aerodynamic loadings, centrifugal force, or any other load forces encountered.

Because the blades are mounted solely at the hub, and because the rotational velocity of the blade tips is somewhat limited by aerodynamic factors, the blade must be relatively heavy and the speed of rotation of the rotor becomes lower as the diameters of the rotors or propellers are increased. To prevent excessive blade vibrations and excessive blade deflection due to the pull of gravity when the rotor is at rest, it has been the usual practice to limit the number of rotor blades to a relatively small number.

Also, because the blades of conventional airscrews are subjected to very high tensile stresses and loadings of both a steady and oscillating nature, the strength characteristics of such blades are a critical item in their design. Fatigue is also a major consideration in airscrew blade design, and securing adequate fatigue life for any such blade is an extremely difficult task.

The rotors of conventional helicopters are subject to a wide variety of vibration difficulties, because the tips of the rotor blades are unsupported and the blades are thus free to bend and deflect. Such bending motions can lead to high stresses and also to severe vibrations in the fuselage of the aircraft. In certain rotor designs, unstable oscillations can occur in which blade motions increase to such a large extent that self-destruction of the rotor and helicopter has occured. A typical action of this type is the so-called "ground resonance."

Conventional rotors and propellers also tend to produce very high noise levels during their operation. This noise level is usually attributable to the extremely high tip speeds and airloads on the blades. High tip speeds are incorporated in certain conventional rotor designs in order to reduce the weight of the rotor.

While it has heretofore been proposed to connect the outer ends or tips of the blades of an airscrew with a circular ring or rim member (see for example: U.S. Pat. Nos. 1,141,337 to Haydon; 1,635,966 to Stanton; 1,843,643 to Kimball; 2,366,795 to Lamoreaux; and 3,273,824 to Owens), so far as I am aware, it has never been proposed to construct a rotor or airscrew in which a plurality of airfoil blades are movably carried by a like number of pre-tensioned spoke or strut elements

which extend between and are connected under tension with an inner hub assembly and an outer, circular ring member.

SUMMARY AND OBJECTS OF THE INVENTION

The present invention contemplates an aircraft rotor or airscrew which comprises an inner hub assembly, a plurality of elongated airfoil blades extending radially or non-radially outwardly from the hub assembly, an outer, circular ring or rim connected with the blades at or toward the outer ends thereof, and wherein each of the blades is carried for relative movement on a spoke or strut member which extends between and is connected under tension with the inner hub assembly and the outer rim member of the rotor.

The primary object of this invention is to provide an improved rotor or airscrew for a helicopter or similar aircraft which is characterized by a higher degree of dynamic stability, reduced noise levels and less vibration in operation than conventional rotors.

A further object of the invention is to provide a rotor or airscrew having improved static and dynamic balance characteristics and minimal blade droop, blade coning and blade flapping characteristics.

Another object is to provide a rotor or airscrew which may embody a greater number of airfoil blades than conventional rotors, but in which the chord dimensions and weight of the individual blades are considerably reduced in comparison with those of the blades of conventional rotors. This coupled with a fixed axis of rotation of the blade by reason of the outer rim member, results in considerable reduction in weight of the blade controls of the aircraft.

A still further object of the invention is to provide a rotor or airscrew in which the airfoil blades are largely relieved of aerodynamic, dynamic and other structural loads by the presence of the pre-tensioned spoke or strut members, and in which the various loads are more evenly distributed throughout the several structural members of the rotor.

These and additional objects and advantages of the present invention will become more readily apparent from the following description.

BRIEF DESCRIPTION OF THE DRAWINGS

In the accompanying drawings:

FIG. **1** is a top plan view of an airscrew according to the present invention;

FIG. **2** is an enlarged, fragmentary, vertical sectional view taken along a plane indicated by the section line **2—2** of FIG. **1**;

FIGS. **3** & **4** are similar views showing modified strut-tensioning mechanisms;

FIG. **5** is a fragmentary perspective view of one of the rotor blades and a segment of the outer rim member;

FIG. **6** is a view similar to FIGS. **2–4**, but showing an alternative mounting arrangement for the hub of the rotor blade;

FIGS. **7**, **8** & **9** are diagrammatic top plan views showing modified rotors according to the invention;

FIGS. **10***a*–**10***e* are diagrammatic cross-sectional views showing various modified configurations for the outer rim member of the rotor; and

FIG. 11 is a fragmentary, longitudinal vertical sectional view taken through another modified rotor in which the alternating blades and spokes have their axes disposed in vertical angular relation to one another.

DESCRIPTION OF PREFERRED EMBODIMENTS OF THE INVENTION

Referring now to FIGS. 1 & 2 of the drawings, there is illustrated a rotor or airscrew for a helicopter or similar aircraft which comprises a central or inner hub **15**, preferably of tubular cylindrical form, to which is drivingly connected a depending axial shaft **16**. The shaft **16** and hub **15** are adapted to be driven in axial rotation by a suitable prime mover and drive train of the aircraft, not shown. Extending radially outwardly from the hub **15** are a plurality of elongated tension spokes or struts **17** which may take the form of elongated cylindrical metal rods or shafts having threaded inner and outer end portions **18** and **19** respectively. The inner end portions **18** of the spokes **17** extend through bearing openings **20** formed in the side wall of the hub **15** and are threadedly engaged with adjustable tensioning members such as nuts **21**. Bearing washers **22** are preferably positioned on the spokes **17** between the nuts **21** and the inner wall surface of the hub **15**.

The outer end portions **19** of the spokes **17** are threadedly or otherwise securely connected with an outer, circular ring or rim member **23** which may possess a tubular cylindrical cross-sectional configuration, as illustrated particularly in FIG. **2**, or which may take any one of the solid cross-sectional aerodynamic shapes illustrated in FIGS. **10***a* through **10***e* of the drawings. The outer ring or rim member **23** is preferably of rigid, integral, circular form, and preferably defines the outer periphery of the rotor.

Carried on each of the spokes **17** is an airfoil blade **24** which preferably possesses an aerodynamic cross-sectional shape as shown in FIG. **5**. The blades **24** are preferably journalled for limited axial sliding and rotational or tilting movement on the spokes **17**, and toward this end the blades are provided with substantially axially coextensive tubular bearing sleeves **25**. The inner end portions or roots of the blades **24** are spaced slightly outwardly from the hub **15** and are provided with pitch control tabs or levers **26** which are connected, through conventional linkage, not shown, to the blade pitch controls of the aircraft. The outer ends of the blades **24** may be disposed either in rotative abutment with the inner surface of the outer rim member **23**, as shown in FIGS. **2** & **3**, or they may be non-rotatively secured in shape-conforming recesses or pockets **27** formed in the inner surface of the outer rim member, as shown in FIG. **4**. In the latter event, the main body portions of the blades **24** will be subjected to torsional twisting or warpage to effect the desired pitch control.

The threaded inner end portions **18** and the nuts **21** provide an adjustable means for placing the spokes or struts **17** under tension between the hub **15** and the outer rim **23**. The nuts **21** are adjusted so as to place the spokes **17** under slight tensile stress when the rotor is at rest. At the same time, the tensile forces within the spokes **17** are such as not to cause warpage or buckling of the outer rim **23**. Thus, by pre-tensioning the spokes **17**, the rotor will be maintained in static balance and the blades are prevented from drooping to any material extent when the rotor is at rest, as well as when in rotation. Pre-tensioning of the spokes **17** also places the outer rim in light compression when the rotor is at rest. During rotation of the rotor, centrifugal forces tend to increase the tension of the spokes **17** and relieve compression forces on the rim **23** and place the blades in compression. Thus, the blades **24** of the rotor are largely relieved of any tensile stress and each blade assembly possesses a high degree of structural redundancy. The pre-tensioning of the spokes **17** greatly adds to the structural integrity of the rotor and insures distribution of load forces throughout the spokes, hub and rim components of the rotor.

The tensioned spokes **17** also function to provide definite and fixed pitch axes for the blades **24** and this, coupled with the large bearing area provided by the elongated spokes, tends to minimize bearing pressures and greatly reduces the forces required to effect changes in the pitch of the blades. Also, by adjusting the tension of the spokes **17**, the lateral and transverse natural frequencies of the blades may be adjusted to obtain optimum values.

FIG. **3** illustrates a modified arrangement for connecting the opposite threaded ends **18** and **19** of the spokes **17** to the hub and rim members of the rotor to permit limited angular displacement and/or pivoting of the spoke relative to the hub **3**. In this modified construction, the circumferential side wall of the hub **15** is formed with inwardly tapered, frustoconical bearing openings **20***a* which communicate with adjacent semispherical, concave recesses or sockets **20***b* formed in the inner wall surface of the hub to thus provide generally hourglass-shaped bearing openings for the inner end portions of the tension spokes **17**. Slidably carried on the inner end of each spoke **17** between the nut **21** and the socket **20***b* is a cooperatively sized, semispherical bearing member **28**. Similarly, the outer end portion of each of the spokes **17** extends through an hourglass-shaped bearing opening **29** formed in the inner wall of the outer rim **23** and is provided with a semispherical bearing member or plug **30** and a tensioning nut **31**. Thus, the spokes **17** may be pre-tensioned by adjusting the nuts **21** on the inner threaded ends **18** of the spokes **17**, but the semispherical bearing members **28** and **30**, in cooperation with the oversized bearing openings **20**a and **29**, will permit limited angular pivoting movement of the spokes **17** relative to the hub **15** and outer rim **23** in response to aerodynamic and dynamic loads. This relieves the spokes of bending moments which might otherwise be applied thereto under certain aerodynamic load conditions.

FIG. **4** of the drawings illustrates another modified means of providing controlled tension in the spokes **17** of the rotor. In this arrangement, a compression spring **31** is mounted between the inner wall of the hub **15** and each of the tensioning nuts **21**. By adjusting the nuts **21** the springs may be preloaded so as to apply the desired pre-tension to the spokes **17**. FIG. **4** also illustrates the outer ends of the blades **24** of the rotor mounted within cooperatively shaped and sized recesses or pockets **27** formed in the inner wall surface of the rim **23**. This arrangement serves to restrain the outer ends of the blades against pitch or tilting movement at the outer rim, but permits limited pitch control of the main body

portions of the blades **24** by torsional twisting thereof about their fixed outer ends, as indicated by the pitch-change angles **33** in FIG. **5**. Typical changes of pitch angles of the main body portions of the blades range from −10° to 25° relative to the plane of the rotor and may be effected through any suitable conventional control linkages, not shown, connected with the pitch control horns or arms **26** of the blades.

FIG. **6** illustrates a further modification in which the inner hub member **15***a* is formed with relatively spaced apart inner and outer concentric side walls **40** and **42** respectively. Each of the blades **24** is formed or otherwise provided with an internal tubular member **43** carried in coaxial relation to the tension spoke **17**, and extending through a bearing opening **44** formed in the outer side wall **42** of the hub. The inner end of the member **43** is connected to the outer flange or wall **42** of the hub by a nut **41** and functions in concert with the pre-tensioned spoke **17** to transmit forces from the blade to the hub. The inwardly extended tubular member **43** may also be employed to transmit pitch change movement to the blade **24**.

FIG. **7** shows a variation in rotor design wherein each of the blades **24** is provided with an outer tip extension **45** which projects a distance radially outwardly beyond the outer rim **23**. In this modification rotor design, the blade extensions **45** are normally of fixed pitch and are rigidly carried by the outer rim **23**, while the main blades **24** are supported for pitch change movement on the pre-tensioned spoke or strut members **17**.

While the tension spokes **17** and blades **24** of the rotors previously described have their axes disposed radially in equal angular, symmetrical relation to the axis of rotation of the rotors, the blade and spoke pattern of the rotor may be varied to provide for non-radial and unequal angular spacing of the blades between the hub and outer rim members of the rotor.

For example, FIG. **8** shows a rotor in which the blades **24** and their pre-tensioned struts or spokes **17** are arranged in non-radial, unequal angular disposition between the hub **15***b* and the outer rim **23** and with their axes converging at points disposed outwardly from the axis of rotation of the rotor, as indicated at **46**. At the same time, the blades and spokes are arranged in radially opposite pairs or sets so as to provide a weight balanced assembly about the axis of rotation of the rotor. This arrangement provides a greatly increased torsional or chordwise stiffness of the rotor assembly.

FIG. **9** illustrates a rotor in which the axes of the spokes **17** and blades **24** are disposed radially of the axis of rotation of the rotor, but wherein the axes of adjacent blades are arranged at various different angles, as indicated at **47**, **48**, **49** and **50**. However, a net balance of weight, lift and centrifugal forces is obtained by proper selection of blade spacing around the azimuth, or by other suitable means, such as counterweighting. The chord dimensions of adjacent blades may also be varied to obtain various aerodynamic effects. The primary advantage of unequal blade spacing and chord dimensions is to reduce the build-up of forces, movements, vibrations, and acoustic noise by breaking up the simple harmonic summation which occurs with evenly spaced blades.

FIG. **11** of the drawings illustrates still another variation of spoke and blade arrangement. In this instance, the adjacent spokes **17** and blades **24** of the rotor are angularly offset in a vertical plane and provide an assembly somewhat similar to the spokes of a bicycle wheel with the axis of successive blades and spokes being disposed in acute angular relation at the outer rim **23**. Toward this end, the bearing openings **20** formed in the cylindrical side wall of the hub **15** are successively staggered so that one spoke **17** extends in a slightly downwardly inclined angle from the hub to the rim, while the next adjacent spoke extends in a slightly upwardly inclined angle toward the rim, and so forth. This angular staggering of the spokes and blades provides a high degree of vertical stiffness or rigidity within the overall rotor.

As previously indicated, FIGS. **10***a*–**10***e* illustrate various different cross-sectional configurations for the outer rim member of the rotor. In FIG. **10***a*, the outer rim **23***a* possesses a generally elliptical cross-section. In FIG. **10***b* the rim **23***b* is of horizontally elongated tear drop configuration, whereas FIG. **10***c* shows the rim **23***c* as possessing a vertically elongated tear drop configuration. The outer rims **23***d* and **23***e* shown respectively in FIGS. **10***d* and **10***e* are of generally flattened oval shape, with the rim **10***d* being disposed generally in a horizontally plane and the rim **10***e* being disposed at an upwardly tilted angle relative to the plane of the rotor.

In view of the foregoing, it will be seen that the present invention provides a propulsion rotor or airscrew for a helicopter or similar aircraft which is characterized by tensioned blade-carrying spokes or struts extending either radially or non-radially between a central driving hub and an outer rim member disposed at or near the outer ends of the blades of the rotor. The present rotor construction makes possible numerous variations in number, size and relative angular arrangement of the blades. The pre-tensioned spoke or strut members function to distribute loads more uniformly over the entire rotor assembly and greatly reduce the loads normally imposed on the airfoil blades of a conventional helicopter rotor.

While presently preferred embodiments of the invention have been illustrated and described in detail, it will be understood that various other modifications in details of construction and design may be resorted to without departing from the spirit of the invention and the scope of the following claims.

I claim:

1. A rotary airscrew comprising a central hub; an annular rim positioned in outwardly spaced, encircling relation to said hub; a plurality of spoke members extending between and connected with said hub and said rim; means connected with said spoke members and applying tension thereto when said airscrew is at rest and in motion; and an airfoil blade carried for relative movement on each of said spoke members and free from tension forces applied to said spoke members by said means.

2. An airscrew as defined in claim **1**, wherein said means is adjustable to vary the tension in said spoke members.

3. An airscrew as defined in claim **1**, wherein said spoke members extend radially between said hub and rim and occupy substantially a common plane when said airscrew is at rest.

4. An airscrew as defined in claim 1, wherein said spoke members are arranged in non-radial disposition between said hub and rim.

5. An airscrew as defined in claim 1, wherein the axes of said spoke members are disposed in varying angular relation to adjacent spoke members.

6. An airscrew as defined in claim 1, wherein said spoke members are connected for limited pivoting movement relative to said hub and rim.

7. An airscrew as defined in claim 1, wherein said airfoil blades are at least in part rotatively carried on said spoke members for pitch adjustment.

8. An airscrew as defined in claim 1, wherein each of said airfoil blades includes an outer end portion fixedly secured to said rim but is torsionally adjustable to effect pitch change.

9. An airscrew as defined in claim 1, wherein adjacent spoke members are connected to said hub in vertically offset relation to one another and lie in angularly related planes convergent at said rim.

10. An airscrew as defined in claim 1, including means connected with said airfoil blade to effect a pitch change of said blade.

* * * * *