United States Patent

[11] **3,578,877**

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Ottobrunn bei Munich, Germany
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[33] **Germany**
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[54] **ROTOR CONSTRUCTION WITH ELASTIC INTERCONNECTION OF OPPOSITE BLADES**
9 Claims, 5 Drawing Figs.

[52] **U.S. Cl.** **416/134,** 416/136, 416/140
[51] **Int. Cl.** **B64c 27/48**
[50] **Field of Search** 170/160.53, 160.58, 160.5, 160.51; 416/131, 134, 135, 136, 138, 140, 141

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ABSTRACT: A four blade rotor construction for helicopters includes means for rotatably mounting each blade at equally spaced angular locations around the rotor hub. Diametrically opposed rotor blades are connected with each other by torsion elastic bands or endless members which are stretched across the center of the rotor head with one of the bands being arranged to pass through and intersect the other. The endless bands are formed of laminations of torsion elastic bands and the laminations of one of the bands which connects one pair of blades are arranged in a substantially vertical orientation and the laminations of the other band which interconnects the two adjacent blades are arranged in a substantially horizontal plane. The clearance between the two band loops at the center of the rotor head is such that collective and cyclic pitch controls are possible.

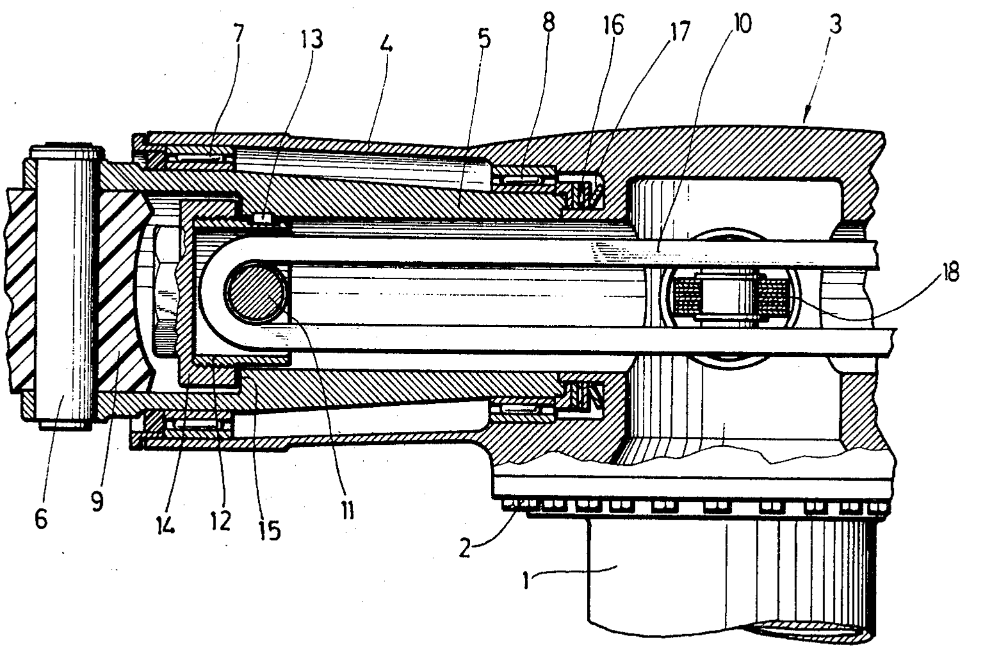

FIG. 1

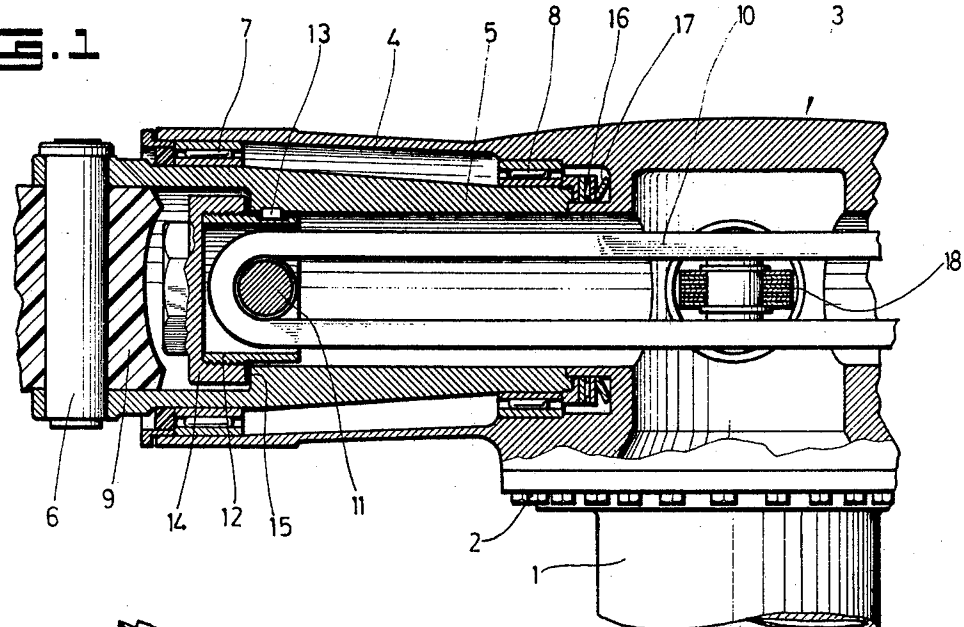

FIG. 2

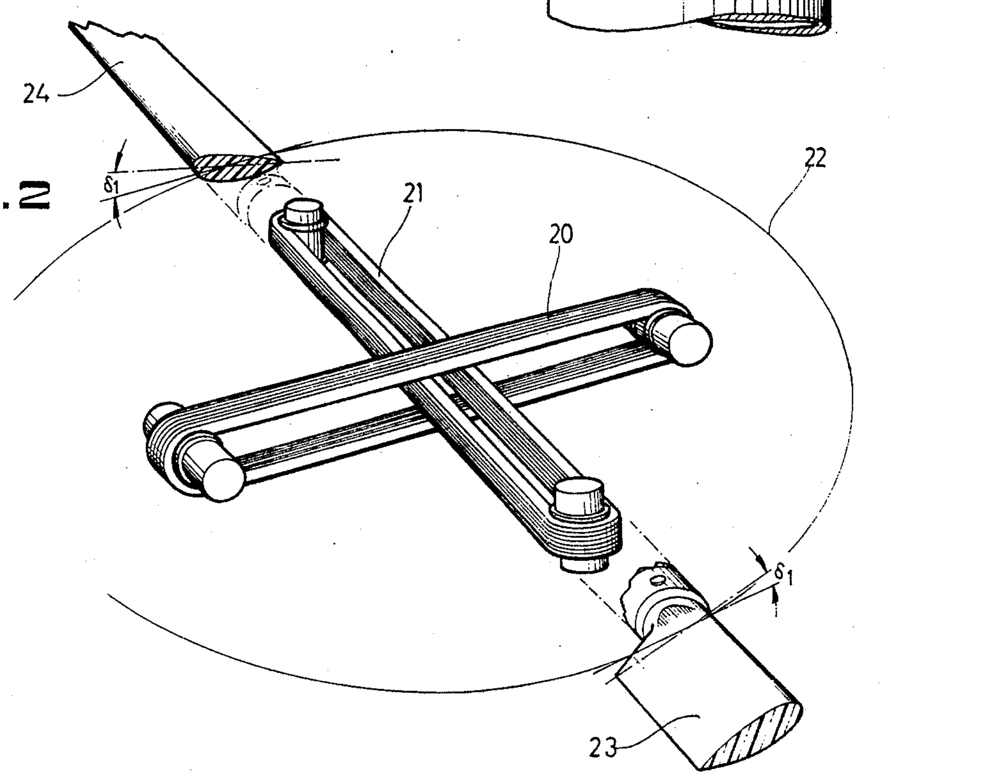

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FIG. 3

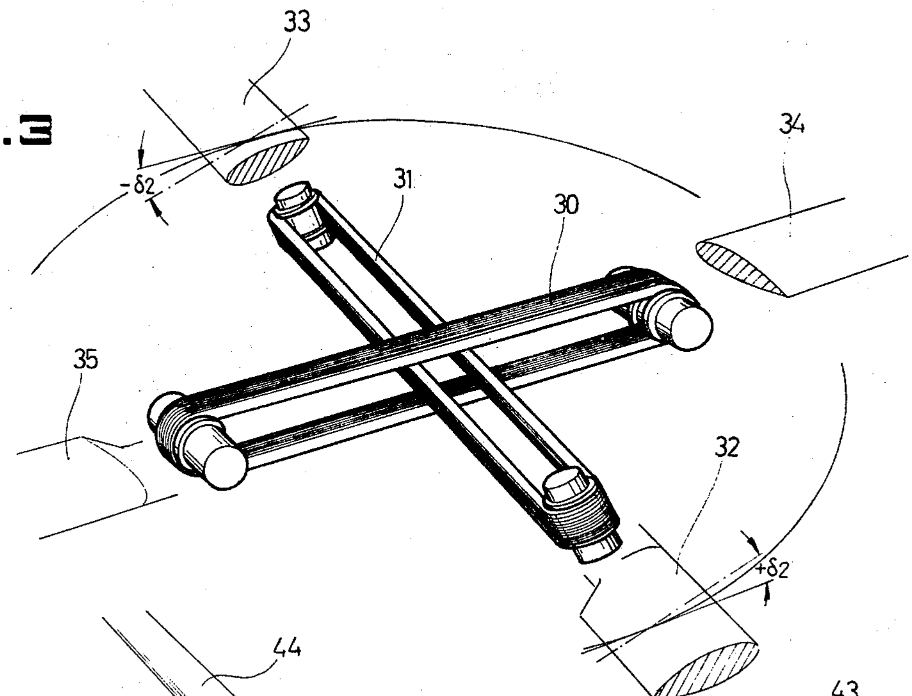


FIG. 4

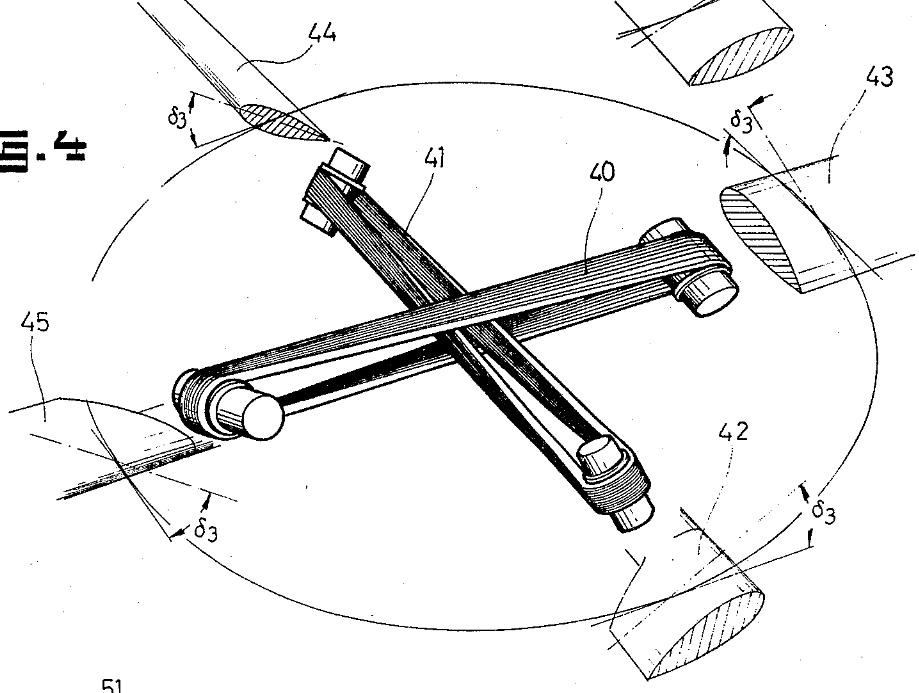
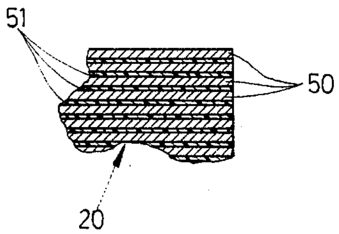


FIG. 5



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ROTOR CONSTRUCTION WITH ELASTIC INTERCONNECTION OF OPPOSITE BLADES

SUMMARY OF THE INVENTION

This invention relates, in general, to the construction of rotors of helicopters and, in particular, to a new and useful four blade rotor construction for helicopters having blades which are rotatably mounted in the head and are connected at their connecting respective opposite blades intersecting centrally in the head.

Rotors for helicopters are known which include traction laminations of a pack of laminations of an interconnecting band which is associated with a pair of rotor blades. In such construction, the laminations are arranged in alternating layers which are separately centrally connected to a bolt arranged coaxially to the axis of the rotor head. By such an arrangement, each pack of laminations, which is secured to the center of the rotor head against displacement and rotation during angular movement of the rotor blade, may be twisted only up to the limit of its centric clamping in the head. This means that the specific torsion for the entire twisting angle range related to the free torsion length of the pack of laminations is very great.

If each rotor blade is to have, for a collective incidence in range of

$$0^\circ \leqq \delta_{collective} \leqq +16^\circ \quad (1)$$

and cyclic incidence range of

$$-11^\circ \leqq \delta_{cyclic} \leqq +11^\circ \quad (2)$$

this results in a total incidence range of

$-11^\circ + 27^\circ$,

hence 38°. This incidence range is transmitted to the pack of lamination and twists the latter or half a lamination length so that the specific torsion is

$$D=\frac{38^\circ}{L/2} \text{ or } D=\frac{76^\circ}{L} \quad (3)$$

The maximum specific angle or twist is achieved with full collective and cyclic incidence in a positive direction and is

$$\alpha_{specific}-\frac{+27^\circ}{L/2}=\frac{+54^\circ}{L} \quad (4)$$

For constructional and aerodynamic reasons, it has been attempted to keep the rotor head diameter and the length of the laminations as small as possible. But since the specific torsion must not exceed a maximum admissible value, this value becomes the quantity determining the dimensions of the rotor head under certain conditions. A reduction of the specific torsion is only possible in the rotors of the known or suggested types by lengthening the laminations.

In accordance with the present invention, an improved helicopter rotor is provided by connecting opposite pairs of rotor blades with laminated bands constructed so that specific torsion is considerably reduced and thus it is possible to use bands with shorter laminations or the fatigue strength of the laminations of conventional length can be considerably increased. The problem is solved in accordance with the invention by using laminations which are constructed as portions of endless stretched loops or bands. The laminations of one band connect one pair of blades and are arranged substantially in a vertical orientation whereas the laminations of the other band connects the adjacent pair of blades and they are arranged in a horizontal plane and conducted through the loop of the vertical laminations. The clearance of the two loops and the lamination width are so tuned to each other that both collective and cyclic pitch controls are possible without impairing the respective crossed laminations. Because of such an arrangement, the cyclic pitch no longer contributes to the torsion of the laminations. Since a positive cyclic angle of incidence of a rotor blade always corresponds to an equal negative cyclic angle of incidence of the opposite rotor blade, the entire pair of rotor blades including the pack of laminations is tipped in a cyclic pitch control about the axis of the angular adjustment.

In collective pitch control, the two opposing rotor blades are turned equally but in opposite directions whereas in cyclic pitch control, they are turned equally in the same direction. The sum of the collective blade angles of the two opposing blades is distributed over the entire length of the lamination so that we obtain for the above-mentioned example:

$$D=\frac{2x(+16^\circ)}{L}=\frac{+32^\circ}{L} \quad (5)$$

Since the torsion from the untwisted form of the pack of laminations is only possible in a direction corresponding to the positive incidence of the blades, the value of the torsion is at the same time the value of the maximum specific angle of twist.

$$\alpha_{specific}=\frac{+32^\circ}{L} \quad (6)$$

The specific angle of twist can be further reduced in accordance with another feature of the invention by arranging each rotor blade so that it has an angle of incidence which is approximately in the center of the entire collective incidence range. From this fixed presetting each blade can be turned by the same amount corresponding to half the collective incidence range in a positive and in a negative direction. Thus, the specific angle of twist of the pack of laminations is reduced by half, but it can appear in both directions of twist. The following relationship is present

$$\alpha_{specific}=\frac{+16^\circ}{L} \quad (7)$$

In accordance with another feature of the invention, the tension of the laminations can be adjusted and readjusted during assembly because of the use of fastening devices which permit a shift of position of each rotor blade and the securing of the rotor blade in its suspension sleeve free from play. In order to insure that the freedom from play will be present during all operating states of the rotor, spring elements are provided which bear on the rotor head and on the blade sleeve.

Since the individual laminations of the bands interconnecting opposite pairs of rotors are displaced toward each other by twisting, intermediate layers of material with a substantially lower friction with respect to the laminations are employed. For example, for steel laminations, intermediate layers of tetrafluoroethylene are employed. The intermediate layers are arranged between the individual steel laminations in order to reduce the wearing of these laminations by friction. The laminations may be made such that they lie parallel to the axes of the the bolts about which they are looped to secure them to the associated rotor blade in the manner of a number of laminations or a pack. On the other hand, each pack of laminations can also consist of a number of fitted loops or of a long band wound in several layers. All elastic materials with sufficient prolonged alternating strength stress, for example, spring steel or fiber reinforced plastics may be used for the lamination material.

Accordingly, it is an object of the present invention to provide a four blade rotor for helicopters in which the roots of opposing blades are interconnected by stretched loops of laminations and, wherein adjacent bands intersect centrally in the rotor head and one advantageously passes through the other and wherein one is advantageously arranged in a horizontal plane and the other in a vertical plane.

Another object of the invention is to provide an improved rotor head construction for helicopters wherein the rotor blades are mounted in sleeves at their roots for rotation at respective fixed locations on the rotor head and wherein the rotor head is hollow to provide passage for endless bands which interconnect the roots of opposing rotor blades, and wherein the blades may be adjustably secured in position by interconnecting or locking sleeve elements.

A further object of the invention is to provide a rotor head for a helicopter which is simple in design, rugged in construction and economical to manufacture.

The various features of novelty which characterize the invention are pointed out with particularity in the claims annexed to and forming a part of this specification. For a better understanding of the invention, its operating advantages and specific objects attained by its use, reference should be had to the accompanying drawings and descriptive matter in which there are illustrated and described preferred embodiments of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

In the Drawings:

FIG. 1 is a partial side elevational and partial sectional view of a rotor head for a helicopter constructed in accordance with the invention;

FIG. 2 is a schematic top perspective view of the interconnecting bands for opposed rotor blades of the rotor head indicated in FIG. 1;

FIG. 3 is a view similar to FIG. 2, but with the loops tipped for cyclic pitch of the rotor blades;

FIG. 4 is a view similar to FIG. 2, but with the loops twisted for collective pitch; and

FIG. 5 is a partial sectional view on an enlarged scale of a pack of laminations forming the connecting bands.

GENERAL DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to the drawings, in particular, the invention embodied therein comprises a four blade rotor construction for helicopters, which includes a rotor shaft **1** which is secured by means of bolts **2** to a rotor head **3** for rotation therewith. The rotor head **3** carries a number of rotor arms having bearing sleeves **4** corresponding to the number of rotor blades **9**. Each blade **9** carries a blade root sleeve **5**, which is secured to the blade by one or more securing bolts **6**. The blade root sleeve **5** extends into the associated bearing sleeve **4** and is rotatably supported therein at two axially spaced locations on roller bearings **7** and **8**. The bearings **7** and are arranged as far apart as possible in order to provide an adequate supporting force for each blade and to accommodate forces originating from the swinging and striking movements of the blades.

The rotor head **3** includes four equally spaced bearing sleeves **4** and each two opposing blade root sleeves which are rotatably supported therein are connected together by packs of laminations designed as loops or endless bands **10** and **18**.

In accordance with a feature of the invention each blade root sleeve **5** carries a clamping ring **12**, which is secured by a wedge **13** against rotation in respect to its associated root sleeve. The clamping carries a cross bolt or loop-holding member **11** around which each loop **10** or **18** is directed. An initial stress can be imparted to the loop **10** by adjusting a retaining nut **14** which is threaded on the clamping ring **12** and which bears against a collar **15** of the blade root sleeve **5**. The blade root sleeve **5** is pulled by the tightened loop **10** by the threading of the retaining nut **14** and stresses one side of a cup spring **17**. The spring **17** contacts an axial bearing **16** arranged at the end of the root sleeve and bears at its opposite or inner end against the rotor head **3**. The cup spring **17** ensures centering, free from play, of the two opposing blade angle sleeves **5**, **5** with respect to the axis of rotation of the rotor even at full rotor speed when the laminations of the bands **10** are expanded by centrifugal forces.

In the arrangement indicated in FIG. **2**, two crossed loops or bands **20** and **21** are arranged in the untwisted state with the loop **20** disposed in a generally vertical orientation or plane and the loop **21** in a horizontal orientation. The loop **21** passes through the loop **20** and the breadth and width of the loops are so selected that the loops do not interfere with each other in their movement in all collective and cyclic blade angles.

In the representation of the embodiment of FIG. **2**, all of the blades are arranged at a fixed positive setting angle $\delta_1=+8°$. At the maximum collective angle of incidence, where δ_1 maximum $= +16°$ each rotor blade is therefore only twisted by an additional 8°. The loop over its entire length therefore is twisted by two times +8° or +16°. At the minimum collective angle of incidence, the twist δ_1 minimum $= 0°$ and, correspondingly, there will be a twist in the amount of not more than −16°.

In the embodiment of FIG. **3**, loop members **30** and **31** are shown as schematically connecting blades **34** and **35** and **32** and **33**, respectively. The blades **32**, **33**, **34** and **35** are arranged so that they do not have any fixed setting angle δ_1. The rotor blades **32** and **33** connected with the loop **30** assume an angle of incidence δ_2 determined by the inclination of the loop **30**. Thus, rotor blade **32** is imparted with a positive incidence angle and rotor blade **33** has a negative incidence angle. The rotor blades **34** and **35** are indicated as not having any fixed incidence angle settings.

In the embodiment indicated in FIG. **4**, the loops **40** and **41** are shown as being schematically connected between blade paths **43** and **45** and **42** and **44**, respectively. The position of the loops **40** and **41** corresponds to the position where collective pitch control is effected. All rotor blades **42**, **43**, **44** and **45** are set by the same positive angle δ_3. Both the loop **40** and loop **41** twist by the same amount.

In the sectional view indicated in FIG. **5**, the pack of laminations for a loop member generally designated **20**, advantageously comprises steel laminations **50** between which are inserted intermediate layers of tetrafluoroethylene **51**. The material **51** is of less friction than the material of the laminations **50** in order to reduce deterioration of the laminations by friction.

While specific embodiments of the invention have been shown and described in detail to illustrate the application of the inventive principles, it will be understood that the invention may be embodied otherwise without departing from such principles.

I claim:

1. A four blade rotor for helicopters comprising, a rotatable rotor head, four rotor blades symmetrically carried by said rotor head for rotation therewith about a central head axis and having root portions rotatably supported in said head for blade angle variation, and first and second endless laminated torsion-elastic loop members connecting the root portions of respective diametrically opposed rotor blades, said first endless laminated loop member passing entirely through said second endless laminated loop member, means rotatable mounting each of said blades to said rotor head, and spring means between said mounting means and said rotor head for centering each of said blades relative to said rotor head free of play.

2. A four blade rotor for helicopters comprising a rotatable head having four angularly symmetrically arranged and radially opening receiving sleeves for the respective rotor blades, means rotatably mounting said head for rotation about a substantially central axis, a rotor blade having a blade root sleeve rotatable mounted in each of said receiving sleeves, a clamping ring carried in said receiving sleeve and having a bolt member extending across the axis of said blade, means securing said clamping ring to said receiving sleeve for rotation with said receiving sleeve and said blade for varying the pitch angle of said blade, first and second endless loop members engaged around said bolt members of respective diametrically opposed rotor blades, said first and second endless loop members intersecting centrally within said rotor head and one of said first and second endless loop members passing through the other, a retaining nut threaded over said retaining ring and bearing against said root sleeve, said nut being threaded to shift the position of said retaining ring axially along said root sleeve for varying the tension on said first and second loop members.

3. A four blade rotor construction, according to claim 2, wherein said rotor head has a ledge abutment at the interior of each of said receiving sleeves, the root sleeves of each of said blades being spaced from said ledge abutment, and spring means disposed between said root sleeve and said ledge abutment and centering each of said root sleeves around said head free of play.

4. A four blade rotor construction, according to claim 2, wherein said means mounting said root sleeve within said rotor head receiving sleeve comprises two axially spaced roller bearing sets.

5. A four blade rotor for helicopters comprising a rotatable rotor head, four rotor blades symmetrically carried by said rotor head for rotation therewith about a central head axis and having root portions rotatably supported in said head for blade angle variation for rotation about axes lying in substantially a common plane, and first and second endless laminated torsion-elastic loop members connecting the root portions of respective diametrically opposed rotor blades, said first endless laminated loop member passing entirely through said second endless laminated loop member, said first endless laminated loop member having laminations which are arranged substantially in a vertical plane, said second endless laminated loop member having laminations which are arranged in a substantially horizontal plane.

6. A four blade rotor for helicopters comprising a rotatable rotor head, four rotor blades symmetrically carried by said rotor head for rotation therewith about a central head axis and having root portions rotatably supported in said head for blade angle variation for rotation about axes lying in substantially a common plane, first and second endless laminated torsion-elastic loop members connecting the root portions of respective diametrically opposed rotor blades, said first endless laminated loop member passing entirely through said second endless laminated loop member, and means carried by each of said rotor blades adjacent their root portions for adjustably connecting and tensioning the associated first and second endless laminated loop members.

7. A four blade rotor for helicopters comprising a rotatably rotor head, four rotor blades symmetrically carried by said rotor head for rotation therewith about a central head axis and having root portions rotatably supported in said head for blade angle variation for rotation about axes lying in substantially a common plane, first and second endless laminated torsion-elastic loop members connecting the root portions of respective diametrically opposed rotor blades, said first endless laminated loop member passing entirely through said second endless laminated loop member, a bolt member extending across the axis of each of said blades with which said respective ones of said first and second endless laminated loop members are engaged, and means adjustably positioning said bolt member on each of said blades.

8. A four blade rotor for helicopters comprising a rotatable rotor head, four rotor blades symmetrically carried by said rotor head for rotation therewith about a central head axis and having root portions rotatably supported in said head for blade angle variation for rotation about axes lying in substantially a common plane, first and second endless laminated torsion-elastic loop members connecting the root portions of respective diametrically opposed rotor blades, said first endless laminated loop member passing entirely through said second endless laminated loop member, a sleeve having a cross bolt therethrough, means adjustably mounting said sleeve in respective ones of each of said root portions for radial inward and outward adjustment, said first and second endless laminated loop members being looped over corresponding diametrically opposite cross belt bolts of said blades.

9. A four blade rotor for helicopters comprising a rotatable rotor head, four rotor blades symmetrically carried by said rotor head for rotation therewith about a central head axis and having root portions rotatably supported in said head for blade angle variation for rotation about axes lying in substantially a common plane, and first and second endless laminated torsion-elastic loop members connecting the root portions of respective diametrically opposed rotor blades, said first endless laminated loop members passing entirely through said second endless laminated loop member, said first endless laminated loop member extending substantially vertically and having horizontal lamina, said second endless laminated loop member extending horizontally and having substantially vertical arranged lamina.