In accordance with the present invention, there is provided a rotor having good flight characteristics which is of simple design configuration and construction and requires little service and operates in a manner such that the blade stresses are maintained small. Such a rotor includes a number of rigid rotor arms of the rotor head which are arranged at a fixed cone angle extending upwardly. The rotor arms are designed as blade angle bearings and they support each blade element for rotation to permit adjustment of the blade pitch angle. The blades comprise a one-piece element which is bending soft in swivel and shock directions and consists of a neck portion of reduced cross section and a blade portion of usual airfoil configuration. The neck portion is formed as a continuation of an outer layer of the blade portion, the outer layer forming a support spar which surrounds an inner plastic layer core. The shock bending stresses to which such blades are subject is considerably reduced by providing the fixed cone angle. The cone angle is chosen to coincide with the natural attitude of the blade when the blade angle adjustment is completely collective so that the collective share of the shock bending stress at the blade roots is substantially eliminated in this manner.

A typical blade construction is such that the support spar which forms the outer layer of the blade portion is shaped in the form of an aerodynamic profile or wing section. The stiffness in shock directions depends substantially on the stiffness of the support spar. However, the stiffness in a swivel direction is largely determined by the design of the outer surface. With the invention, the swivel stiffness of the blade is reduced without major influence on the shock stiffness by dividing the blade into a neck section having approximately the dimensions and characteristics of the supporting spar of the blade section and forming it so that the material of the neck section extends into the blade section and provides an outer layer or spar of the blade section. The greater the length of the neck section, the softer the blade will be in the swivel direction without any substantial change in the shock stiffness.

The direct advantages of such a measure are small swivel bending moments and, as a consequence, less structural weight and smaller control forces. This latter effect is explained by the fact that if the shock and swivel frequencies are balanced, the control force components resulting from the shock motion and from the swivel motion are subtractive.

The rotor blades are advantageously made of a fiber-reinforced plastic having a support spar consisting essentially of fiber rovings running in a blade longitudinal direction. The fiber rovings extend from the blade tip to the blade root and also form the neck portion of the blade. A neck portion is made to a cross section to achieve approximately the same maximum bending strength in both a swivel and a shock direction. This means optimum utilization.

The inventive construction further provides that the first natural swivel frequency of the blade, governed by the length and the cross sectional shape of the neck section, lies below the rotor's operating frequency of rotation. A low swivel frequency is made possible by the introduction of the neck section of reduced cross section from the blade section. Due to the lowering of the natural swivel frequency of the blade below the critical value of the rotor's frequency of rotation, an extreme softness of the neck section is required which in turn reduces the swivel moments and hence permits a lightweight construction. The rotor system of the invention can be built considerably lighter in weight than rotor systems of known designs.

In order to obtain the moment of inertia required for the autorotation ability, it is proposed, therefore, accord
Accordingly it is an object of the invention to provide an improved blade construction for a helicopter which includes a neck portion of reduced dimension and a blade portion of air-foil configuration, the latter including an outer layer forming a support spar made of the material of the neck portion.

A further object of the invention is to provide a helicopter rotor which includes a rotor head having a plurality of radially extending rigid sleeve elements arranged at a fixed upwardly extending cone angle and which rotatably carry each blade to permit pitch angle changes thereof but which rigidly hold each blade in respect to other pivotal movements; the blade being constructed of a bendable material such as plastic and including a neck section of reduced dimension extending outwardly from the connection to the rotor head and an outer blade section of air-foil configuration having an outer layer formed of the same material as the neck section and as a direct continuation of the neck section.

A further object of the invention is to provide a helicopter rotor blade and helicopter rotor construction wherein the blades are mounted substantially rigidly at the rotor head except for permitting pitch changes and wherein each blade element is made of a bendable material such as plastic and includes a radially elongated neck section of reduced dimension and a blade section of air-foil configuration which comprises a plurality of layers, one layer of which is formed of the material of the neck section.

A further object of the invention is to provide a helicopter rotor and a helicopter blade construction which are 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 is illustrated and described a preferred embodiment of the invention.

Brief description of the drawings

In the drawings:

FIG. 1 is a partial top perspective and partial sectional view of a rotor head constructed in accordance with the invention;

FIG. 2 is a partial sectional and partial elevational perspective view of a rotor blade of the rotor of FIG. 1; and

FIG. 3 is a partial sectional and partial elevational view of the rotor indicated in FIG. 1.

Detailed description of the preferred embodiment

Referring to the drawings in particular, the invention embodied therein comprises a rotor head generally designated 1 having four rigid rotor arms which are rigidly affixed to the shaft 2 for rotation therewith. The arms 3 are formed as sleeves which rotatably receive root bushings 4 which are affixed to the inner ends or roots of blades generally designated 7. The root bushing 4 is rotatably mounted within the arm 3 to permit pitch angle changes of the blade 7. The blade pitching motion is controlled in a known manner by a steering rod (not shown) which is linked to a steering horn or angle member 5 which is affixed to the root bushing 4.

In accordance with the invention, the rotor blade 7 is provided with a mounting block or lining 6 which is rigidly affixed to the root bushing 4 and connected to the steering horn 5. The lining carries the inner end or neck 22 of the blade in a manner which permits neither shock nor swivel motion of the blade.

In accordance with a feature of the invention, the neck section 8 is of generally rectangular configuration and is of a reduced size in comparison to the main blade section 9. The main blade section extends to the blade tip portion 10 and is very stiff in respect to a swivel direction. The natural swivel frequency of the entire rotor blade 7 is determined essentially by the length as indicated in FIG. 1 and the cross sectional shape of the neck section 22. In the shock directions, both the blade section 9 and the neck section 8 have approximately the same stiffness so that when the neck length is varied, the natural shock frequency is not influenced substantially.

The rotor blade 7 is constructed of fiber-reinforced plastic which forms a solid rectangular portion 22 at the neck section 8 and an outer layer 23 of air-foil configuration at the blade section 9. The air-foil layer 23 is of generally crescent-shaped configuration and encloses in a form-fitting manner an inner core 25 of a foam plastic material. The material 22 of the neck portion 8 and the material 23 of the blade portion 9 comprise fiber rovings which extend in the blade section and a synthetic resin-saturated fiber mats which surround the central core 25 of foam plastic material. Because the spar portion 23 is a continuation of the neck portion 22, the cross sectional areas are approximately the same.

The cross sectional shape of the neck portion 8 is preferably chosen so that the proportion of the height h to width c is such that the maximum stresses caused by shock bending and by swivel bending are approximately equal to thus provide for optimum material utilization. After the cross sectional shape of the neck section 8 is fixed, the natural swivel frequency can be modified only by varying the length a.

Because of the fiber-reinforced plastic construction, the specific blade weight becomes very small, and thus the moment of inertia required for the autorotation can be obtained by an accumulation of material in the external area of the rotor blade in the vicinity of the outer end of the blade portion 9 as shown by the cross section 11 of FIG. 1. This may be also accomplished by additional weights at the tip 10. When the inert mass such as a weight 16 is moved further inwardly in the blade, a smaller material will be sufficient for a specified moment of inertia.

As indicated in FIG. 3, the rotor arms 3 are disposed at a cone angle a. By such a construction, each blade 7 receives an initial pitch angle which is approximately equal to the angle which the blade would assume at the gripping point during the operational location when the pitch angles are completely collective so that no bending moment results at the blade root.

While a specific embodiment of the invention has 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.

What is claimed is:

1. A rotor construction for a rotor of a type in which bendable blades are rigidly held at their radial inner ends in mounts permitting their rotational movement about a rotor radial line for pitch change, comprising a rotatable head having a plurality of radially extending mounting arm portions, a blade having an inner root portion supported on each mounting arm portion for rotation about a radially extending axis for pitch change, said arms holding said blades at a fixed configuration of rigid mount for pitch change, said blades comprising a radially extending outer blade portion of air-foil shape and a radially extending inner torsion-stiff neck portion, said inner neck portion being of uniform cross section less than the cross section of said outer blade section and located between said outer blade portion and said blade root portion, said outer blade portion being formed at least parti-
ally as a continuation of said neck portion and being of the same material thereas.

2. A rotor construction according to claim 1, wherein said blade is made of a fiber-reinforced plastic, said blade section having an outer spar layer of substantially crescent-shaped configuration having reinforced fibers extending in the longitudinal direction of said rotor blade, said neck section having a cross-section of a size to possess approximately the same bending strength in the lead-lag and in the flap directions.

3. A rotor construction according to claim 1, wherein the natural lead-lag frequency of said rotor blades as determined by the length of the neck section and the cross sectional shape of the neck section lies below the rotor's operating frequency of rotation.

4. A rotor construction according to claim 1, wherein said rotor blades have a mass distribution concentrated in said outer blade portion.

5. A rotor construction according to claim 1, wherein said neck section is of substantially rectangular configuration, said blade portion comprising a central core of a foam plastic material, said outer blade section comprising a spar of crescent-shaped configuration and comprising the same material as said neck section.

6. A rotor blade construction comprising a uniform radially extending outer blade section of airfoil shape having an inner core of foam plastic material and an outer layer of substantially crescent-shaped configuration of a fiber-reinforced plastic material defining a spar portion around said inner core, said blade including a radially inner neck section of considerable radial extent and having a substantially rectangular cross section of an area less than a major portion of the area of said blade section and being formed of the same material as said spar portion.

7. A rotor blade construction according to claim 6, wherein said neck section includes a transverse width greater in dimension than the height thereof.

8. A rotor blade construction according to claim 6, wherein said fiber rovings in said neck section and said spar portion extend in the longitudinal direction.

References Cited

UNITED STATES PATENTS
2,484,141 10/1949 Alex.
2,588,570 3/1952 Picairem.
3,000,446 9/1961 Warnken.

FOREIGN PATENTS
1,334,446 7/1963 France.

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416—226, 241