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Walsh et al.

[11] **3,752,600**

[45] **Aug. 14, 1973**

[54] **ROOT PADS FOR COMPOSITE BLADES**

[75] Inventors: **Thomas C. Walsh,** New Britain; **David Street,** East Granby, both of Conn.

[73] Assignee: **United Aircraft Corporation,** East Hartford, Conn.

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[52] **U.S. Cl.** **416/219,** 416/230, 416/241

[51] **Int. Cl.** **F01d 5/30**

[58] **Field of Search** .... 416/230, 241, 241 A, 416/219–221

[56] **References Cited**

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Primary Examiner—Everette A. Powell, Jr.
Attorney—Charles A. Warren

[57] **ABSTRACT**

A composite filament reinforced rotor blade having a splayed root construction is provided with a pad on each side of the blade in the area of transition between the airfoil portion and root portion of the blade. The pad is designed to be wedged between the blade and its corresponding disc slot during rotor operation and to transmit blade centrifugal forces from the blade to the disc in such a manner so as to produce a compressive force on the surface of the blade in the transition area for preventing delamination of the filaments within the blade. In one embodiment of this invention, the pads on either side of the blade are connected by a flexible band closely fitting along the underside of the root portion to prevent metallic wedge-shaped inserts, which are sometimes used in the root, from being expelled therefrom.

2 Claims, 3 Drawing Figures

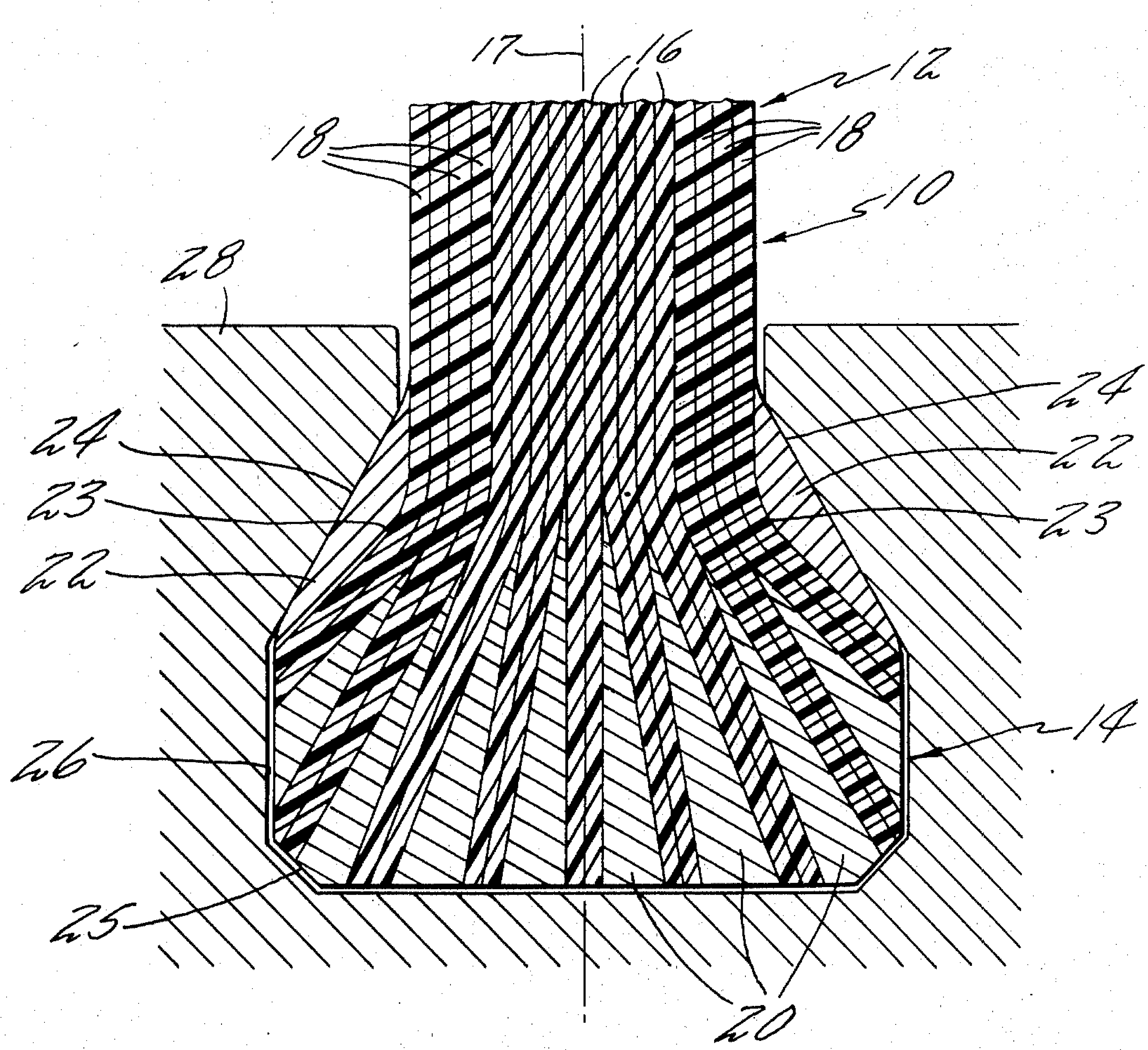

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FIG. 1

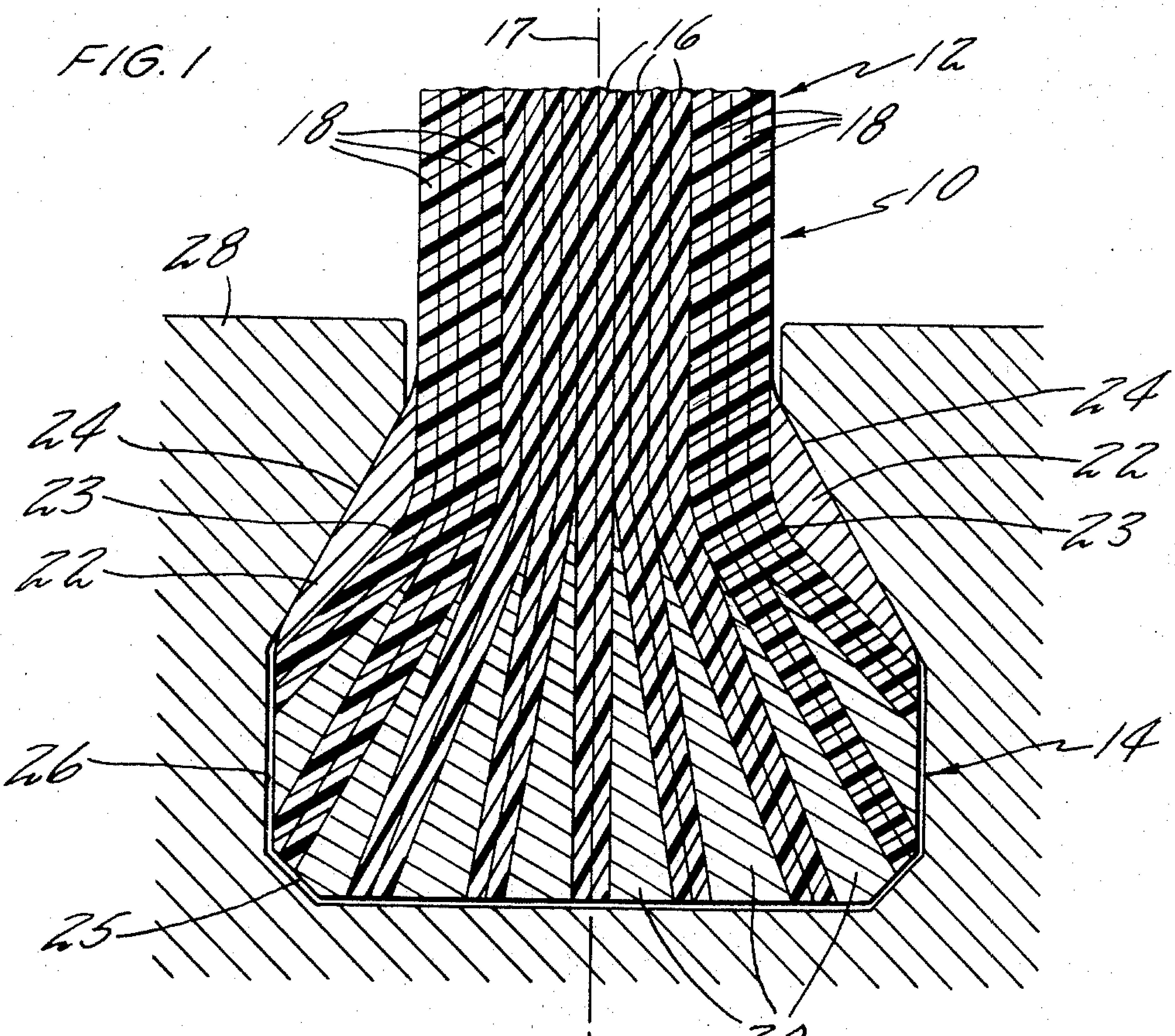


FIG. 3

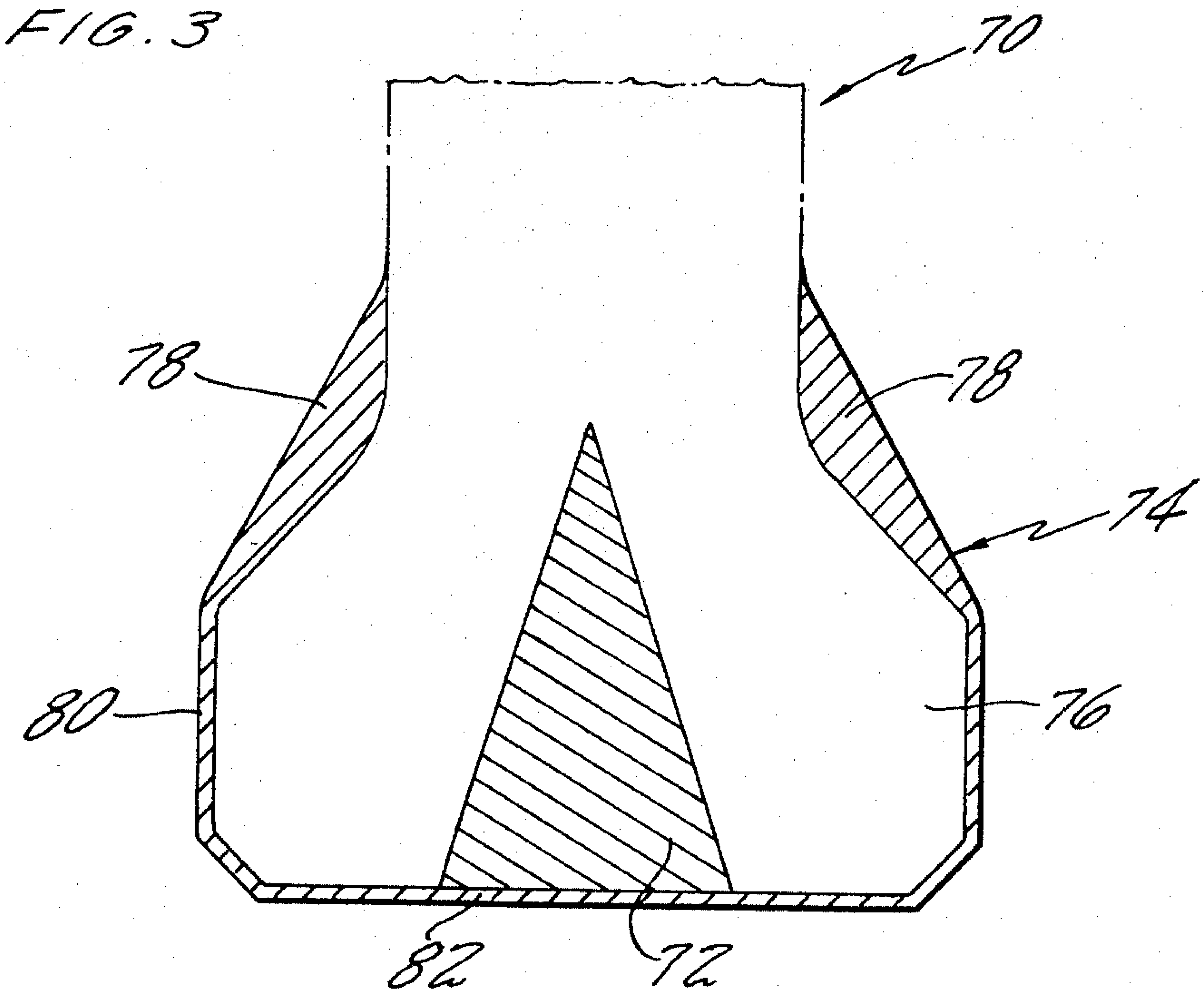
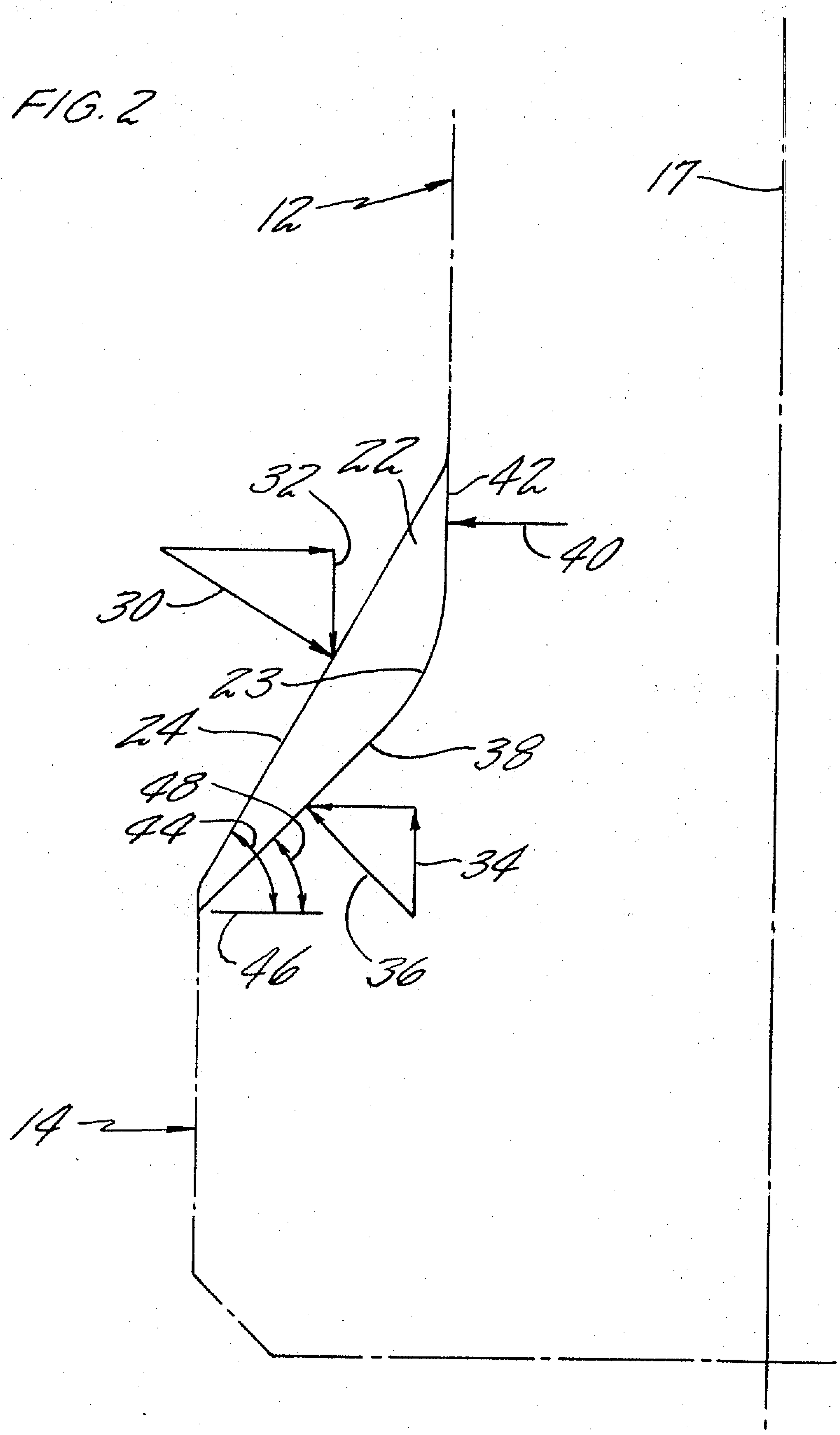


FIG. 2



ROOT PADS FOR COMPOSITE BLADES

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to a filament reinforced composite rotor blade and more particularly to means for increasing the integrity of the blade in the area of the root.

2. Description of the Prior Art

Filament reinforced composite rotor blades, having an airfoil and a root portion, have undergone considerable research and development in recent years in view of their high strength to weight ratio. These blades may be made, for example, from carbon filaments in an epoxy matrix, boron filaments in a polyimide matrix, boron filaments in an aluminum matrix, or other high strength non-metal filaments in a suitable matrix material. One example of such a blade is described in U.S. Pat. No. 3,679,324 to Stargardter having the same assignee as the present invention.

One difficulty common to the manufacture and use of some composite components and particularly blades is that although the filaments are extremely strong in tension they may be too brittle and weak in compression and shear for many applications. Problems are thus encountered in transferring loads from a composite component such as a blade into a metallic component such as a disc without damaging the filaments.

One technique for making composite blades is to extend the composite airfoil portion of the blade radially into the root portion and to then bond to each side of the composite material a metal tang to form the finished root which may, for example, be dovetail shaped. The extremely high operational shear stresses between the tang and the composite material is a disadvantage of this technique. Additionally, high compressive stresses on the composite may result in filament damage.

A well-known technique for avoiding some of these problems is to splay the composite material from the base of the air-foil to form the root portion; one or more wedged shaped inserts are put between the splayed material and bonded thereto to fill the gaps therebetween and to provide compressive and shear strength in the root. The operational shear stresses are distributed over the surfaces of the inserts.

However, by splaying the composite into the root a serious problem is created: the centrifugal force on each of the filaments tries to pull each filament out of the blade, resulting in a net reaction force against the disc slot parallel to but offset from the blade's centrifugal force; this creates a couple which acts in the transition area between the airfoil and the blade root and tries to delaminate the composite filaments. The root is particularly vulnerable in this area because this is where the individual groups of filaments begin to splay, giving the delamination process a place to start. The matrix material holding the filaments together is often not sufficiently strong to prevent such delamination.

Prior art designs include several blade root configurations which provide a compressive force in at least some areas of the root; but these techniques usually lack the ability to provide a compressive force where it is most needed, that is, at the base of the airfoil where the filaments are still radial and in the transition area where the filaments begin to splay into the root. In some prior art designs, the root retention scheme results in a net force which actually increases the delaminating couple.

A further potential problem with filament reinforced composite blades having a splayed root is the tendency for the wedge-shaped inserts in the root to be squeezed out from between the bundles of splayed filaments during centrifugal loading. This tendency will be more pronounced when only one or two inserts are used, because then the inserts must necessarily have a large wedge angle creating larger shear forces.

SUMMARY OF THE INVENTION

Accordingly, an object of the present invention is to increase the integrity of a filament reinforced composite rotor blade in the area of the root.

Another object of the present invention is to prevent the delamination of filaments in the root area of a filament reinforced composite rotor blade having a splayed root construction.

A further object of the present invention is to prevent wedge-shaped inserts used in a filamentary reinforced composite blade splayed root from becoming dislodged therefrom.

According to the present invention a rotor assembly is provided comprising the combination of a disc having a plurality of blade receiving slots in its periphery, a plurality of blades mounted in said slots, a pad on each side of the root of said blade, each pad having a surface which is contoured to mate with said root and a surface which is contoured to mate with said blade receiving slot, said surfaces of each pad converging away from the airfoil portion of said blade. More particularly, each pad mates with the blade root in the transition area between the root and the airfoil portion of the blade and may extend on either side of the transition area for some distance. The splayed portion of the blade root extends under each pad, so that the pad becomes wedged between the root and the disc during rotor operation. Because the pads are so wedged they need not be bonded to the root; however, a bond may be desirable for ease of assembly and to assure precise location of the pad; additionally, a bond eliminates a metal-composite interface where rubbing could result in damage to the composite filaments.

The converging surfaces of each pad convert the radially outward, centrifugal force of the blade into a net force directed toward the surface of the blade along the entire area of the blade which is in contact with the pad. An equal and opposite force is created in the same area on the other side of the root by the other pad. The result is a net compressive force on the surface of the blade in the transition area of the root; this compressive force counteracts the couple which is trying to delaminate the filaments; the compressive force may also increase the density and uniformity of the composite material in the transition area of the blade, serving to increase the net tensile strength of the blade.

In accordance with another embodiment of the present invention, the pad on one side of the blade root may be connected to the pad on the other side of the blade root by means of a band integrally joined to each pad, and contoured to closely fit around the underside of the blade root. The band must be flexible enough to allow the pads to be pressed into the transition area of the root during rotor operation. The band serves to prevent wedge-shaped inserts in the root from becoming dislodged. Dislodging of an insert may very well be catastrophic since the splayed blade root would be likely to collapse from lack of the restraining insert and could then slide out of the disc slot under the centrifugal pull of the blade. Generally, in this embodiment, the band and pads are not bonded to the blade.

The foregoing and other objects, features and advantages of the present invention will become more apparent in the light of the following detailed description of the preferred embodiments thereof as illustrated in the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a sectional side elevation view of a portion of a rotor blade assembly embodying the invention.

FIG. 2 is an illustrative view of the operational forces acting on the invention.

FIG. 3 is an illustrative sectional side elevation view of an alternate embodiment of the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIG. 1, a blade 10 having an airfoil 12 and a root 14 is shown. The blade is comprised of a plurality of plies 16, 18 which are bonded together in a stack. Each of the plies 16, 18 is comprised of unidirectional filaments embedded in a matrix material, such as boron filaments in a polyimide resin matrix. Generally, the filaments are aligned in a span wise direction, parallel to the longitudinal axis 17 of the airfoil 12. However, some of the outer plies 18 may be arranged so as to orient the filaments at an angle with the regard to the longitudinal axis 17 to increase the torsional strength of the blade. As is shown in FIG. 1, the plies 16, 18 are splayed from the base of the airfoil 12 to form the root 14 (known as a splayed root) of dovetail shape. Metallic, wedge-shaped inserts 20 are bonded between the plies to assure that the plies are maintained in their proper positions and to provide additional strength in the root. As shown, one insert 20 is used between every two plies 16, 18; however, a lesser or greater number may be used. Larger numbers of inserts are preferred so as to more evenly distribute operational shear loads between the many plies.

In accordance with the present invention a pad 22 is disposed at each side of the blade root in the transition area 23 between the airfoil 12 and the root 14. The outer pad surface 24 and the remaining exposed surface 25 of the root 14 form a dovetail shape which is configured to be received into a dovetail shaped slot 26 in a disc 28 having an axis perpendicular to the sheet of the drawing in FIG. 1. During operation the blade 10 is thrown outward by centrifugal force causing the surfaces 24 of the pads 22 to come into contact with the disc slot 26. In the configuration shown the operational loads on the blade 10 will be transferred from the blade into the pads 22 and subsequently into the disc 28. The pads 22 may extend across the full axial length of the blade root 14 so as to distribute the load over as large a surface area of the blade as possible to reduce the possibility of filament damage; however, if desired, and if other factors dictate, the pads need not extend across the entire axial length.

The pads 22 are configured so as to become wedged between the disc and the blade against the surface of the blade in the transition area 23; therefore it is unnecessary to bond the pads to the blade. Although a bond is unnecessary it is preferred so as to prevent damage to the outermost blade ply due to possible rubbing between the pad and the blade surface. All substantial shear loads between the pad 22 and the blade 10 are eliminated due to the said wedging action of the pads between the blade and the disc.

The configuration of the pads 22 is best shown and described by reference to FIG. 2, which illustrates a simplified analysis of the forces acting on the pads. The net resultant force 30 on the surface 24 of the pad 22 is created by the centrifugal load on the blade and is the reaction force between the pad 22 and the disc slot 26 (FIG. 1); because the centrifugal load on the blade is distributed equally to each side of the blade root, the radial component 32 of the force 30 is equal to ½ of the centrifugal load on the blade; this radial force 32 is balanced by the radial component 34 of the resultant force 36 on the underside surface 38 of the pad 22. One of the objects of this invention being to prevent delamination of the filaments within the blade, it is necessary to provide a force directed toward the surface of the blade in the area where delamination is most likely to occur; that is, a compressive force on the blade is desired in the transition area 23 between the airfoil and root where the plies 16, 18 begin to splay. Another object is to provide this compressive force for a short distance radially outward of the transition area 23 at the base of the airfoil 12 where the plies are essentially radial. To achieve these objects a net resultant force 40 directed toward and perpendicular to the surface 42 of the pad 22 is needed. This is accomplished by having the angle 44, as measured from the surface 24 to a line 46 perpendicular to the longitudinal center line 17 of the blade, larger than the angle 48 between the surface 38 and the line 46; that is, the surfaces 24 and 38 must converge in a direction away from the airfoil 12. Although the forces on the pad 22 as shown in FIG. 2 are represented by resultant forces 30, 36, and 40, it should be appreciated that these forces are distributed essentially evenly over the surfaces of the pad; these forces against the pad surfaces in contact with the blade surface are balanced by equal and opposite reaction forces against the surface of the blade 10. The pad on the other side of the root creates similar forces acting on the blade. There will thus be a net compressive force in the transition area 23 and along the radial surface 42 of the airfoil. The larger the difference between the angles 44 and 48 the greater will be the resultant force 40 and thus the greater will be the compressive force on the blade in this critical area. These angles should be adjusted so that this net compressive force is large enough to prevent delamination of the plies within the blade but not so large that it damages the filaments within the blade. For example, in a blade of the present embodiment comprising carbon filaments in an epoxy resin wherein the volume ratio of carbon to epoxy is about one to one and the maximum centrifugal force acting on the blade is 79,000 lbs., it has been found that under this condition an angle 44 of 60° and an angle 48 of 45° works well.

FIG. 3 shows a composite blade 70 similar to the blade 10 of FIG. 1 but having only a single wedge-shaped insert 72. A shoe 74 is provided around the root 76 of the blade; the shoe is of a one-piece construction and comprises pads 78, one on each side of the root, located and shaped similar to the pads 22 of FIG. 1; these pads are connected by a band 80 which fits closely around the underside 82 of the root to prevent the insert **72** from becoming dislodged. The band **80** is flexible enough to permit the pads **78** to contact the blade **70** under operational loads so that the pad will create a compressive force on the blade in a manner similar to the pads **22** hereinabove described.

Although the invention has been shown and described with respect to preferred embodiments thereof, it should be understood by those skilled in the art that various changes and omissions in the form and detail thereof may be made therein without departing from the spirit and scope of the invention.

Having thus described typical embodiments of our invention, that which we claim as new and desire to secure by Letters Patent of the United States is:

1. A rotor assembly comprising the combination of:

a disc having a plurality of substantially axially extending blade receiving slots circumferentially spaced around its periphery, each side of each of said slots including a flat, radially inwardly inclined centrifugal load bearing surface;

a plurality of blades mounted in said slots, said blades comprising a plurality of plies compressed in a stack, said plies including high strength nonmetallic filaments embedded in a matrix material, each blade including an airfoil and a splayed root, said airfoil including a substantially radial surface disposed adjacent and radially outwardly of said splayed root, said splayed root including a wedge shaped metallic insert, each side of said splayed root including a flat surface inclined radially inwardly; and

a pad disposed on each side of said blade, each pad having a first surface and a second surface, said first surface mating with said blade in the area of transition between said airfoil and said root over a substantial portion of the blade root axial length, said first surface including a substantially radial portion which mates with said radial surface of said airfoil and a flat inclined portion which mates with said inclined surface of said root, said second surface being flat and mating with said centrifugal load bearing surface of said blade receiving slot, said second surface converging with respect to said inclined portion of said first surface in a direction away from said airfoil.

2. A rotor assembly according to claim **1** wherein each of said pads is bonded to the surface of said blade.

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