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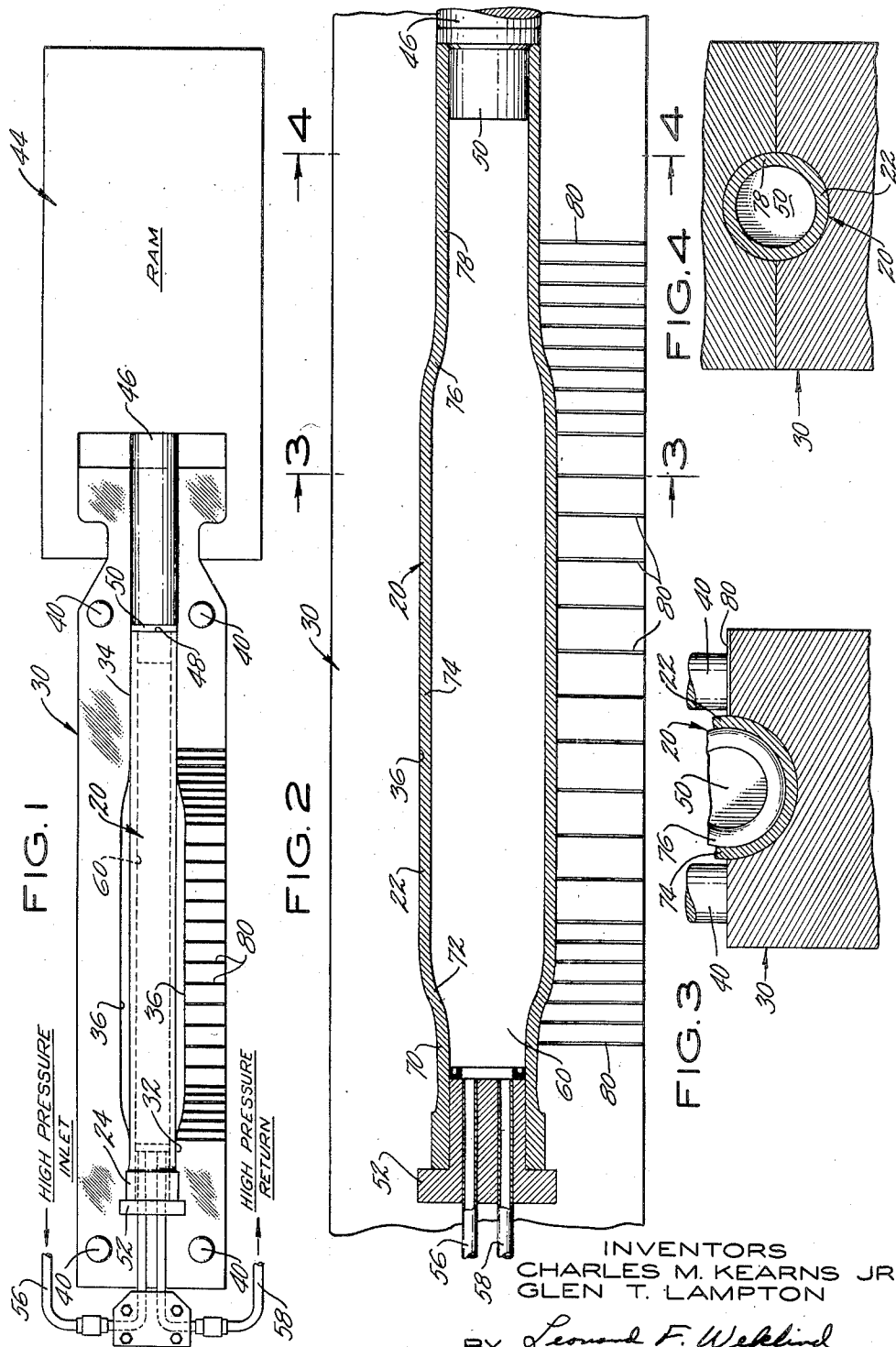
C. M. KEARNS, JR., ET AL

2,652,121

HOLLOW PROPELLER BLADE WITH BULBED CORE

Filed June 6, 1950

3 Sheets-Sheet 1



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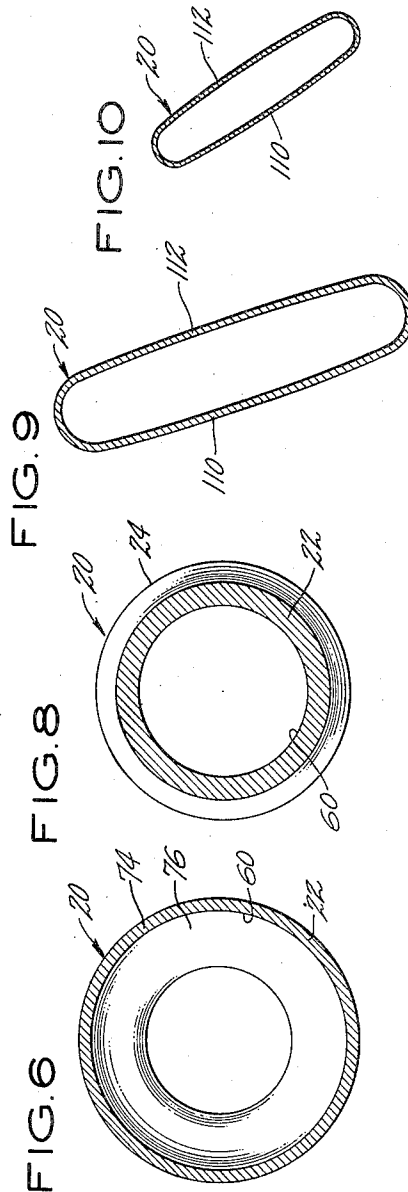
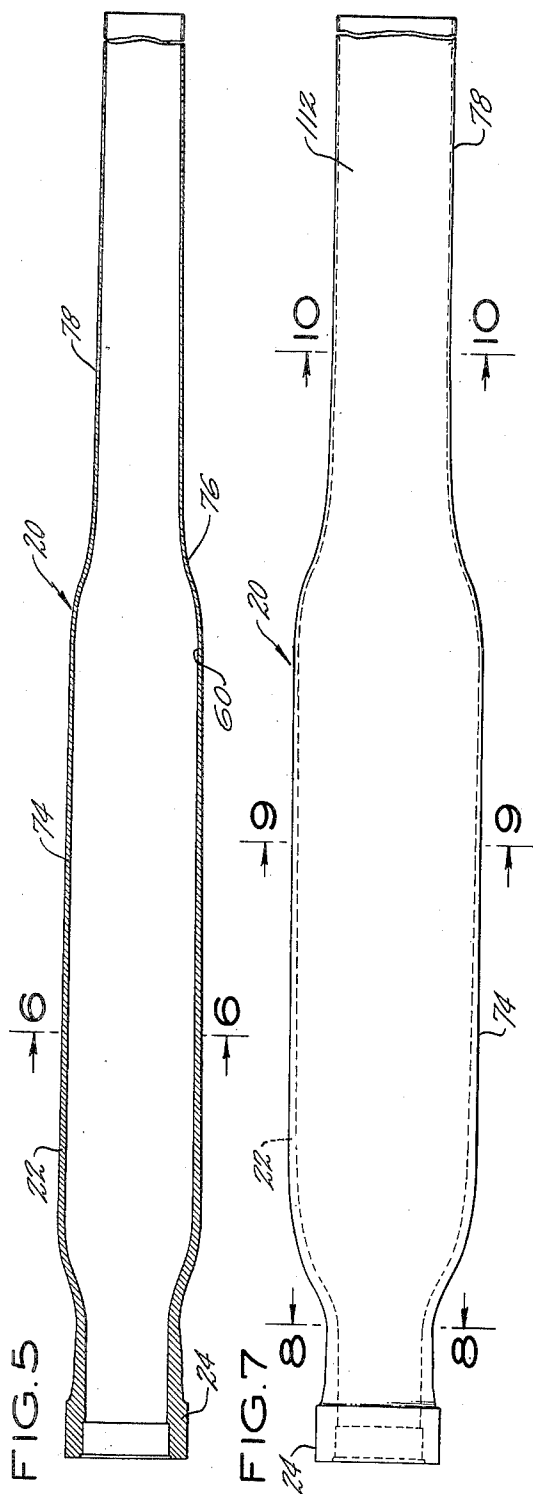
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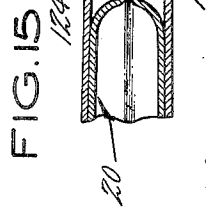
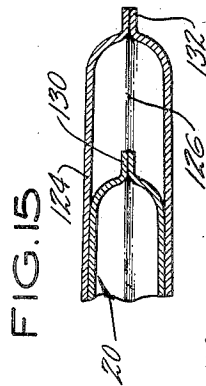
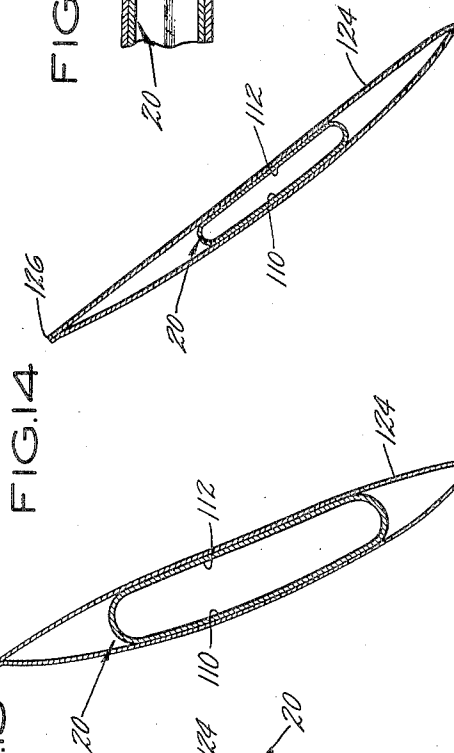
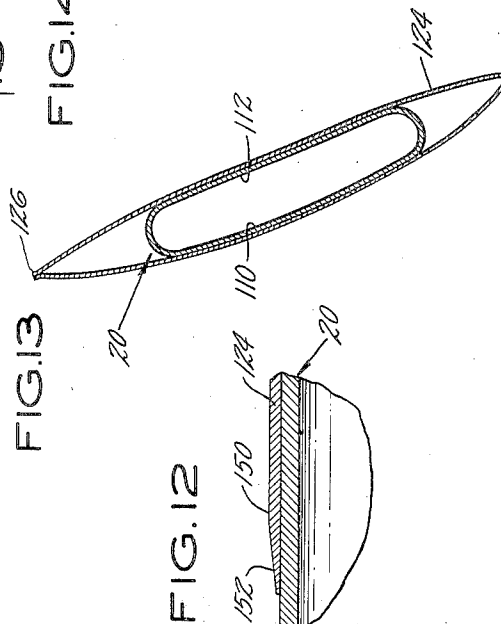
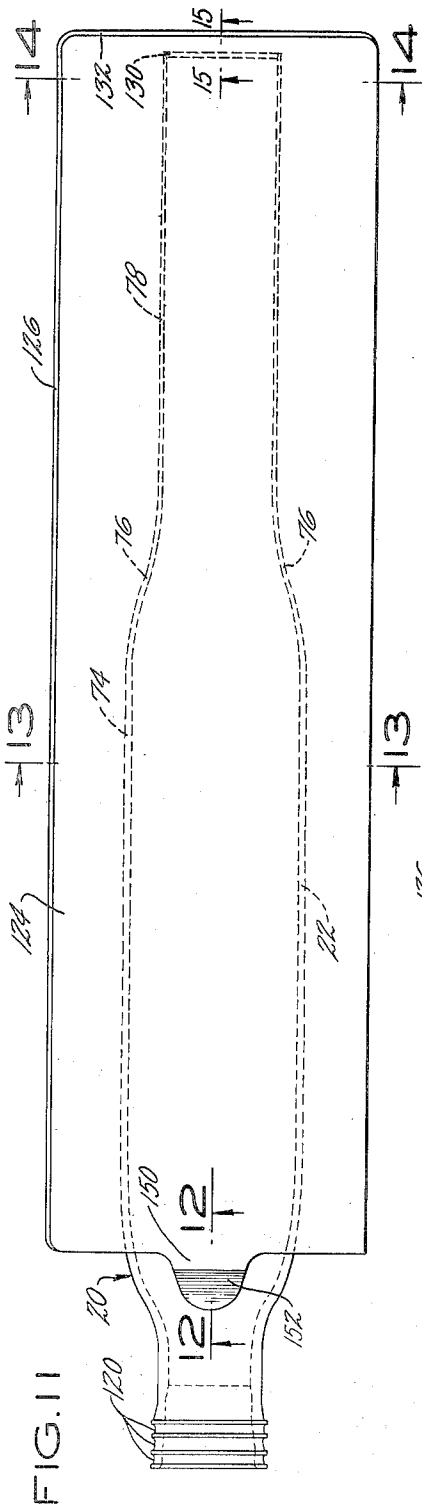
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HOLLOW PROPELLER BLADE WITH BULBED CORE

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3 Sheets-Sheet 3



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2,652,121

HOLLOW PROPELLER BLADE WITH
BULBED CORE

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Application June 6, 1950, Serial No. 166,458

2 Claims. (Cl. 170-159)

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This invention relates to improvements in aircraft propeller blades and more specifically to hollow metal propeller blades.

It is an object of this invention to provide an improved construction for hollow metal propeller blades whereby increased stiffness characteristics are obtained while maintaining the weight of the entire blade at a minimum.

Another object of this invention is to provide a hollow propeller blade having an improved core member upon which is mounted an outer blade shell.

A primary feature of this invention resides in the provision of a core having an increased area of attachment for the outer blade shell, the increased area being located adjacent the inboard end of the shell thereby reducing stress concentrations due to bending in edgewise and flatwise directions.

A further object of this invention is to provide a hollow metal blade having a central core member of the type described so as to reduce the amount of chordwise shell overhang beyond the core member.

A still further object of this invention is to provide a core member having a relatively large bonded area of the core to the shell in the inboard section of the blade thereby providing a greater area for load transfer from the shell to the core in the blade vicinity where stress concentrations are known to be high.

Another object of this invention is to provide a hollow metal propeller blade having increased cross-sectional moments of inertia and section moduli while having little or no increase in cross-sectional areas of the core and shell material in the inboard region of the blade.

These and other objects will become readily apparent from the following detail description of the drawings in which:

Fig. 1 is a plan view of a tubular core member positioned in the lower half of a bulbing die mechanism.

Fig. 2 is a slightly enlarged view similar to Fig. 1 illustrating the tubular core member after the bulbing operation has been performed.

Figs. 3 and 4 are cross-sectional illustrations taken along the lines 3-3 and 4-4, respectively, of Fig. 2.

Fig. 5 is a cross-sectional view of the blade core member illustrating the general configurations and wall dimensions of the core after another step in fabrication thereof.

Fig. 6 is a cross-sectional view taken along the line 6-6 of Fig. 5.

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Fig. 7 is a cross-sectional view of the core member after it has been partially flattened, the flat surface being illustrated in plan form.

Figs. 8, 9 and 10 are cross-sectional views taken along the lines 8-8, 9-9 and 10-10, respectively, of Fig. 7.

Fig. 11 is a plan view of the assembled propeller blade after the outer shell has been positioned over the core member.

Figs. 12, 13, 14 and 15 are cross-sectional views taken along the lines 12-12, 13-13, 14-14 and 15-15, respectively, of Fig. 11. Fig. 12 is enlarged for better illustration.

In hollow metal propeller blades of the type described herein, the core member is the primary load carrying component, so it is desirable to impart the necessary stiffness to the core and improve the load carrying capacities thereof. To this extent, then, it is desirable to provide high values of cross-sectional moments of inertia (section stiffness) about both major and minor section neutral axes in the region of the shank in order to achieve; first, high values of section modulus which will lower the vibration stress, and second, high natural vibration frequencies which will also tend to minimize vibration stresses. These objectives can best be achieved with a large diameter core which provides large values of section stiffness with minimum cross-sectional area.

Referring to standard beam theory,

$$\text{Bending stress} = \frac{\text{Bending moment}}{\text{Section modulus}}$$

and

$$\text{Section modulus} = \frac{I}{C}$$

where I is the moment of inertia (section stiffness) and C is approximately equal to one-half blade thickness. It can be seen that the stress can be minimized by increasing the section modulus, which can be increased in turn by raising the moment of inertia I . This may be done by adding to the wall thickness of the hollow blade core. Such a procedure, which makes little change in the core diameter, will result in a relatively large increase in weight for a small increase in I because the added material is located near the neutral axes of the section. The greatest increase for given weight is obtained by increasing the diameter of the core since the mass is then moved a greater distance from the neutral axis and I increases with the square of the distance between the mass and these axes.

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The stress resulting from a vibratory excitation is a function of the amplitude of that vibration, and the amplitude increases rapidly as the frequency of the excitation approaches the natural frequency of the vibrating system. Since the frequency of the exciting force acting upon a propeller blade is determined by the rotational speed of the propeller, it is therefore highly desirable to raise the natural vibration frequency of the blade to a value well in excess of the frequency represented by the rotational speed.

An increase in moment of inertia will increase the natural frequency of the blade since, for a uniform beam,

$$\text{Natural frequency} \cong \sqrt{\frac{E}{U} \times \frac{I}{L^4}}$$

where,

E =modulus of elasticity of the material

U =mass per unit length

I =cross-sectional moment of inertia

L =length of the beam

As stated above, an increase in the core moment of inertia can be achieved most efficiently by increasing the core diameter.

The enlargement of the core member further provides a high ratio of core section stiffness to shell section stiffness at the inboard end of the shell to minimize the stress concentration attendant upon the delivery of the shell loads to the core. This feature can also be best achieved most efficiently by a large diameter core.

At the same time enlargement of the core diameter provides a large area of bond between the core and the shell at the shank to permit the use of the optimum configuration of the inboard end and also to minimize the amount of shell overhang at the leading and trailing edges in order to reduce the secondary shell stresses due to local deflections.

Utilizing a large diameter core over the full length of the blade, however, would result in excess weight and centrifugal twisting moment over the tip region of the blade where it is not required for structural reasons. Such construction would possibly result in a blade tip section having greater thickness than that required for any other reason except to physically accommodate the core inside the leading and trailing edges.

A bulbed core as illustrated in this invention therefore obtains all the advantages of a large diameter core at the shank while enabling the use of a more efficient, smaller diameter core at the tip thereby providing a blade with maximum strength and aerodynamic efficiency for a given weight, centrifugal load and centrifugal twisting moment.

The particular construction of the blade and core of this invention is best illustrated by describing the fabrication steps and method utilized in producing a blade of this type.

Referring to Fig. 1, an elongated metal tube 20 is shown having a wall 22 of substantially uniform thickness and a blade inboard end 24 which is slightly enlarged or thickened to provide for later machining so as to form elements of the blade retention mechanism. The core member 20 may be positioned in a die 30 which has wall portions 32 and 34 which snugly contact the tubular core 20 and slightly enlarged walls 36 which provide the proper configuration for the core 20 when a portion thereof is expanded in diameter.

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The die mechanism may include dowels 40 for aligning and positioning the upper encasing portion of the die assembly and may also include a ram mechanism 44 which includes a plunger 46 for exerting a force at the blade tip end 48 of the core member 20 in an axial direction. A plug 50 seals off the outer end of the core member 20 while a plug 52 seals the root end of the core member 20 to provide a fluid tight connection for high pressure hydraulic lines 56 and 58, respectively.

Extremely high fluid pressure is directed to the central hollow portion 60 of the core member 20 while a force is applied by the plunger 46 against the outer end of the core member so as to expand or bulge a portion of the core member to the dimensions of the wall 36 of the die. Inasmuch as this bulging operation will somewhat shorten the length of the core member 20, the plunger 46 of the ram mechanism 44 aids in overcoming the die frictional forces along the walls 34. This bulging operation may be performed in a single pass or in several individual passes each resulting in a slightly greater enlargement of the diameter of the core member 20 in the portion illustrated. In the case of a two pass operation an insert may be used along the wall 36 of the die 30 so as to limit the diametrical expansion of the core member 20 to about half the final expansion desired.

As illustrated in Fig. 2, the core member 20 assumes the bulbous configuration illustrated so that its normal diameter, as for example at 70, is gradually increased at 72 so as to produce an enlarged portion 74, which portion is again gradually diminished in diameter through the section 76 back again to a normal diameter at 78. The particular configurations of the enlarged and normal sections of the core member 20 are better shown in the cross-sectional illustrations of Figs. 3 and 4. A plurality of slots 80 may be provided on the upper surface of the lower half of the die 30 to provide guides for pins which may be used in conjunction with templates in gauging the contour of the bulbed portion of the core member 20.

Although it may be desirable initially to begin fabrication on a hollow tubular core member which has a varying or tapering wall thickness, it is preferred that the tapering operation be performed after the bulbing process has been completed. To this end then, and as illustrated in Figs. 5 and 6, the enlarged section 74 of the core member 20 may have its outer surface machined after bulbing to achieve the desired taper.

In order to obtain a desirable taper in the outboard section 78, which section has been maintained at the normal diameter of the original tube during the bulbing operation, the section 78 is subsequently cold rolled. In addition to providing a desired taper in the wall thickness of the core section 78, the cold rolling operation serves to extend the length of the core member back to a desirable length since, as mentioned above, the tube is somewhat shortened during the initial bulging operation.

The particular expanding method and tapering method described may readily be performed by means of swaging and the like.

Figs. 7 to 10 illustrate the plan form configuration of the core member 20 after it has been partially flattened so as to provide upper and lower major surfaces 110 and 112. During the flattening operation dies are used in order to get a desirable contour of the surfaces 110 and 112

so that when the outer shell is positioned thereon the airfoil shape of the shell will conform to, and intimately contact the major surfaces 110 and 112 of the core member 20. This flattening process may be done as a separate operation on the core alone or simultaneously with the outer shell.

As illustrated in Figs. 11 to 15, the root end of the core member 20 may be machined so as to provide a plurality of bearing races 120 which will provide cooperating blade retention mechanism for mounting the blade in a hub.

The outer shell 124 is preferably performed by doubling over a sheet of metal and seam welding together the major edges of the sheet to form a blade trailing edge 126. The tip or open end of both the shell and the core member 20 may also be crimped together and seam welded so as to form a core tip 130 and a blade tip 132 as seen in Fig. 15. Since the outer shell 124 is usually preformed, it is telescoped over the core member 20 and positioned relative thereto, as for example by X-ray mechanism or other means. Since the major flat surfaces 110 and 112 of the core member 20 have been preformed to be in substantially completely juxtaposed relation with the shell, it is thereafter possible to interpose solder between these mating surfaces and to gradually heat the entire assembly in a mold with a proper flux added so that the entire assembly will be fastened together firmly and heat treated simultaneously.

In order to provide for a smooth path of load transfer at the inboard end of the shell, a tab 150 (Figs. 11 and 12) may be provided so that an abrupt termination of the shell will not cause local detrimental stresses which may tend to produce cracks in the shell in this vicinity. The edges of the tab 150 may further be smoothly bevelled as indicated at 152 (Fig. 12) to provide a gradual diminishing of thickness of the shell material.

The particular soldering and bonding process for attaching the shell to the core does not form a specific part of this invention and is more clearly described and claimed in patent application Serial No. 484,254, filed April 23, 1943, now Patent No. 2,511,858, by Glen T. Lampton.

Referring to Fig. 11, it is readily apparent that the bonding area between the shell 124 and the core 20 is increased adjacent the root end of the blade while at the same time a reduction has been provided in the shell overhang in a chordwise direction beyond the fore and aft edges of the core member 20. Further, by gradually decreasing this bonded or contacting area (in an outboard direction) as clearly illustrated by the diverging contour of the core member 20 at point 76, stress concentrations are maintained within acceptable limits at the outboard threshold of the enlarged portion 74.

Also, the enlargement 74 of the core member 20 provides increased stiffness both to the core and to the shell in the inboard semi-span of the blade which inboard region is obviously subjected to the greatest bending loads both in the plane of the blade and in planes transversely thereto.

Although only one embodiment of this invention has been illustrated and described herein, it is apparent that various changes and modifications may be made in the arrangement and construction of the various parts without departing from the scope of this novel concept.

What it is desired to obtain by Letters Patent is:

1. In a hollow metal propeller blade having a substantially tubular metal core member forming the load carrying portion of said blade, means for mounting said blade comprising mounting elements formed integrally with the inboard end of said core, said core comprising substantially flattened surfaces located outboard of said mounting elements and extending substantially to the tip thereof, a shell of airfoil shape surrounding said core and comprising a continuous sheet surrounding said core and having its major edges connected together to form the trailing edge of said blade, means for bonding said shell to said core along said flattened surfaces, and means for reducing the deflection tendencies of said blade and increasing the bonded area between said core and shell comprising a bulbed portion of said core adjacent the inboard end of the blade and intermediate the ends thereof, said bulbed portion having a cross-sectional configuration whereby the circumference of said tubular core member is gradually increased relative to the chordwise dimension of the shell in an outboard direction from said mounting elements and subsequently decreased a substantially like amount at a distance outboard along the span of said blade.

2. A propeller blade according to claim 1 wherein the outboard edges of said shell are in juxtaposed relation along a continuous chordwise line and bonded together to form the tip of said blade.

CHARLES M. KEARNS, JR.
GLEN T. LAMPTON.

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