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RUBBER FILLETED PROPELLER BLADE

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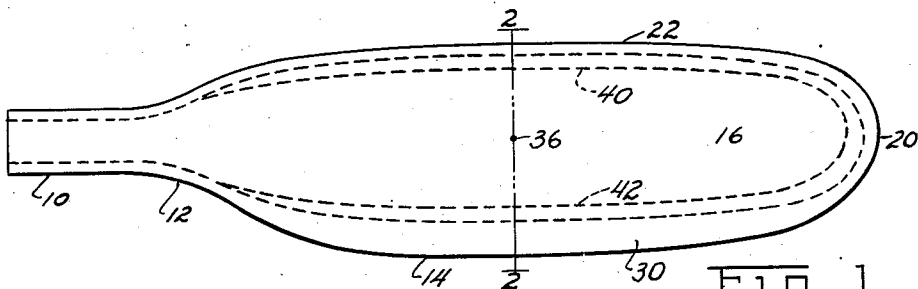


Fig. 1.

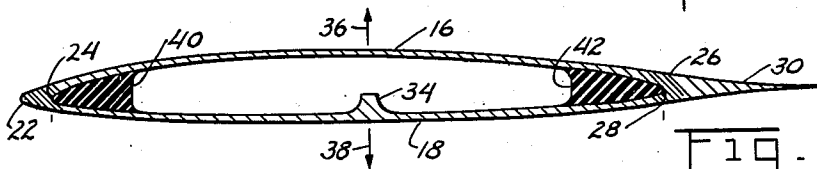


Fig. 2.

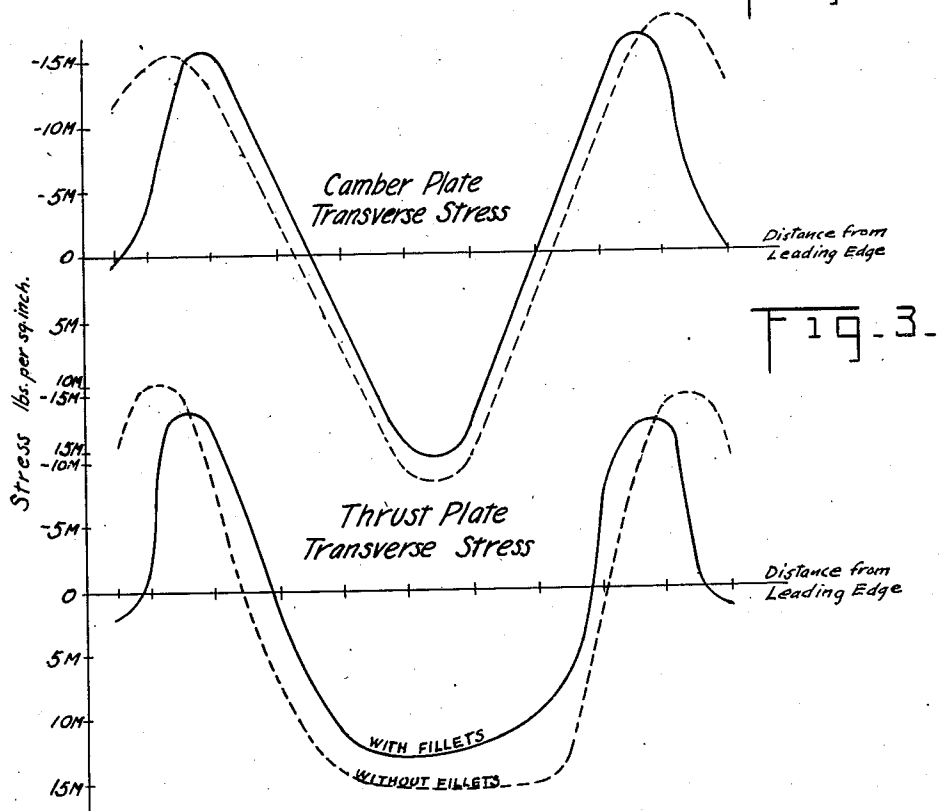


Fig. 3.

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RUBBER FILLETED PROPELLER BLADE

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3 Claims. (Cl. 170—159)

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This invention relates to means for modifying the stress distribution in structural members and is concerned particularly with the provision of elastic stress moderators which may be applied to structures in such locations as to reduce stress concentrations.

An environment for illustrating the principles of the invention has been chosen in the form of a hollow steel or metallic propeller blade and while this environment provides an excellent example for the application of the principles of the invention, the invention may have great utility in other forms of structures.

The invention will be described and considered primarily in its application to aircraft propeller blades. Such blades comprise a shank portion usually of cylindrical form from which extends a hollow paddle-like blade element comprising thrust and camber plate members united or integral at their margins to provide more or less sharp leading and trailing edges. The thrust and camber plates of propeller blades, when in operation, are subject not only to tensile stress along the blade axis, but also to forcing impulses causing the plates to vibrate with a consequent generation of stresses in the material acting transversely of the blade axis. In the usual propeller blade construction, these vibration induced stresses may have considerable magnitude at or adjacent the leading and trailing edges. Particularly in the case of blades whose camber and thrust plates are welded to one another to form leading and trailing edges, the high stress concentrations adjacent the weldments are most undesirable as continuing repetitive stresses may cause fatigue cracks and failure even though the stress levels may not be as high as those which occur at other points in the virgin metal of the plates.

This invention consists in inserting elastic yielding fillets within the relatively sharp leading and trailing edges of the propeller blades which alters the transverse stress distribution in the blade section to such degree that the stress levels in the blade materials are substantially reduced, inhibiting cracking or failure of the blade material.

An object of the invention is to provide vibration damping means in a propeller blade, while a further object is to provide yielding elastic means adjacent to points of high stress concentration in a propeller blade to modify the stress distribution and to reduce the high stresses. A further object of the invention is to provide stress modifying means in a propeller blade or structural body which will be effective without ma-

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terially increasing the weight of the blade or structure. A further object of the invention is to provide resilient fillets in a blade or structure which will have minimum bulk, and which shall be easy to apply in a fabricated blade.

Further objects of the invention will become apparent in reading the annexed detailed description in connection with the drawings. The description and drawings, however, are not to be construed as limiting the scope of the invention; the latter may be established by referring to the appended claims.

In the drawings in which similar reference characters represent similar parts,

Fig. 1 is a plan of a typical propeller blade incorporating the provisions of the invention;

Fig. 2 is an enlarged section on the line 2—2 of Fig. 1; and

Fig. 3 is a stress distribution diagram showing the pattern of transverse stresses in a propeller blade section both with and without the provisions of the invention.

In Figs. 1 and 2, the blade form is typical of hollow metal blades and is chosen for purposes of illustration only. The blade comprises a substantially hollow cylindrical shank portion 10 blending into a tapered transition portion 12, also hollow, which in turn blends into the active portion of the blade 14 which, as shown, has generally elliptic planform. Alternatively, the blade planform may be rectangular, triangular or of any other type, such blades in general being well known in the art.

The active portion of the blade comprises a camber plate 16 and a thrust plate 18 both of these plates preferably being tapered in thickness from the shank end of the blade toward the tip 20, and having transverse variations in thickness in order to provide the desired basic stress distribution across the section. As shown in Fig. 2, the blade section comprises a leading edge weldment 22 which is formed by welding the leading margins of the plates 16 and 18 to one another, the welded portion being finished externally to provide a smooth outer surface and being so treated internally as to provide a smooth rounded fillet 24. Such an internal fillet may be attained by machining the weldment and plates, or by a metallic fillet such as copper fused to the blade material. The trailing margins of the plates 16 and 18 are welded to one another in a trailing edge region, the weldment being indicated at 26. The juncture of the plates 16 and 18 in this region is also internally finished or processed to provide a smooth fillet 28. The trailing edge per se, indicated at 30, is an added metallic

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strip as shown, being joined to the weldment 26 by an additional welding step. However, the added strip may be eliminated if desired, the weldment 26 itself forming the trailing edge. If desired, a partial longitudinal rib such as 34 may be incorporated in the thrust plate 18. Such a partial rib could also be formed in the camber plate 16 or alternatively, one or more full ribs might be disposed to join the thrust and camber plates at one or more points between the leading and trailing edge of the blade. The mode of blade fabrication summarized above is mentioned merely as an example. Blades manufactured by other processes may also have the provisions of this invention applied with constructive results.

The blade section thus far described is typical of various blades known in the art. When transverse stresses are applied to a section of this sort, such stresses being produced by vibration resulting from aerodynamic or other forcing impulses, the stress level in the plates 16 and 18 adjacent the leading and trailing edges as at the weldments 22 and 28, may be of rather high order as exemplified in Fig. 2. Fig. 3 is a stress distribution diagram based upon the application of forces of finite value as represented by the vectors 36 and 38 (Fig. 2) applied to the camber and thrust plates substantially at the midpoint of the blade chord, these forces being typical as to magnitude to those encountered in normal blade operation. The chordwise abscissae in Figs. 2 and 3 are the same; accordingly the central loops below the zero stress line have their maximum value directly beneath the line of action of the forces 36 and 38. Also, the stress values are all taken on the exterior surface of the thrust and camber plates. It will be seen that the stress on the outside of the camber plate at its midpoint is tensile in character and is of the order of 17,000 p. s. i. (pounds per square inch) as shown by the dotted line. This stress diminishes on either side of the point of application of the force and then becomes compressive as the leading and trailing edges are approached. A short distance inboard of the leading edge the compressive stress reaches a maximum value of about 15,000 p. s. i. and slacks off to a value of about 12,000 p. s. i. adjacent the fillet 24. Toward the trailing edge, the compressive stress reaches a maximum value of about 18,000 p. s. i. slacking off to a value of about 13,000 p. s. i. adjacent the fillet 28. Substantially the same stress pattern exists in the thrust plate 18 as represented by the dotted line in the lower portion of Fig. 3. The flat mid portion of the lower stress curve results from the presence of the rib 34 in the center of the thrust plate.

The high stresses, of the order of 12,000 p. s. i., adjacent the leading and trailing edge fillets, are distinctly undesirable since they may cause cracking or failure in the acutely angled juncture of the thrust and camber plates.

To overcome and correct the indicated obnoxious stress distribution pattern, this invention provides a fillet 40 within the blade section and adjacent the leading edge, and a fillet 42 within the blade section and adjacent the blade trailing edge. These fillets are preferably formed of rubber having a durometer hardness between 30 and 100, typical values being 60 to 80. The fillets are bonded to the inner surfaces of the thrust and camber plates 16 and 18 and are fitted and bonded to the fillets 24 and 28 so that they will have complete intimate contact with the inner surface portions of the blade plates adjacent the

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leading and trailing edges. There are various well known methods of bonding rubber to metal and any appropriate method may be used in the application of the fillets to propeller blades or to other structures where it is desired to practice the principles of the invention. After preparation of the metal surface for bonding as by cleaning and plating, preformed fillets, uncured or partly cured, may be laid in place, and a bladder inserted in the blade and inflated to force the fillets into intimate contact with the blade, after which the assembly is heat treated to effect the bond and cure the fillets. Alternatively, solid removable forming members may be assembled in the blade, and the fillet material may be injected into the leading and trailing edge spaces, after which curing and bonding may be effected followed by removal of the forming members. The fillets 40 and 42 preferably extend lengthwise within the active portion of the propeller blade subject to high transverse stress levels, to points close to the tip 20, or extending around the tip. In Fig. 1, the fillets are shown as extending into the tapered blade portion 12, but if stress conditions are moderate at inboard stations along the blade, the fillets may be terminated farther outboard.

When the forces 36 and 38 are applied to a blade section equipped with the fillets 40 and 42, the stress distribution pattern is altered materially as will be clear by a comparison of the solid line curves (with fillets) and the dotted line curves (without fillets) shown in Fig. 3. With fillets, the stress level in the camber plate adjacent the fillets 24 and 28 is reduced substantially to zero and the value of maximum stress in the camber plate 16 is reduced by about 2000 p. s. i. with the test conditions identical to those previously described for the unfileted section. In the thrust plate, the stress level adjacent the fillets 24 and 28 is reduced to a value of about 2000 p. s. i. and the maximum stress levels are reduced by between 2000 to 3000 p. s. i. The curves of Fig. 3 represent merely one specific test loading condition for the propeller blade section with and without the rubber fillets installed but are typical of the results to be secured by various other loadings whether they be imposed synthetically in a test machine or whether they be imposed by vibration conditions occurring during normal operation of the propeller blade. It will be noted that the rubber fillets have the effect of moving the stress pattern inwardly from the edges toward the center of the blade section. Due to the small stresses in the plates at the leading and trailing edges when the rubber fillets are installed, the copper brazed fillets, or the careful finishing previously considered essential, may be dispensed with at the points 24 and 28. The weight of the rubber fillets will be little greater than the weight of the copper brazed fillets formerly considered essential.

While rubber has been indicated as a suitable material for use as fillets in a propeller blade for the purpose of reducing or redistributing the stress pattern, other yielding resilient materials may be used and the invention comprehends the use of suitable materials having yieldability, strength, modulus, hysteresis and other characteristics similar to those of rubber.

The term rubber, or material having the characteristics of rubber, as used herein is intended to mean natural or synthetic rubber, or other natural or synthetic material, whose physical and structural properties above noted are for the most part like those of natural rubber. Some syn-

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thetic or other rubber-like materials may have superior characteristics to those of natural rubber, in having smaller changes of hardness, resilience and the like to temperature changes, light and weathering. Some of the synthetic materials do not deteriorate under extraneous influences like those of natural rubber. Such improved synthetic materials are to be considered as within the scope of "materials having the characteristics of rubber" as used herein.

It has been found that fillets having a chordwise length of from 1 to 1½ inches are appropriate in propeller blade sections having a dimension of about 10 inches from the leading edge internal fillet to the trailing edge internal fillet. A similar proportionality may be applied to blades having shorter or longer chords but this proportionality is mentioned merely to assist others in practicing the invention rather than as a limitation on the size of the fillets which may be used to accomplish the purpose of the invention. The invention is, however, limited to the use of fillets at corner portions of structures where high stresses due to transverse loading may exist and is not intended to comprehend the use of a rubber or yielding elastic filling for an entire hollow section.

Though but a single embodiment of the invention has been illustrated and described, it is to be understood that changes may be made without departing from the spirit or scope thereof, as will be apparent to those skilled in the art. Reference should be had to the appended claims for a definition of the limits of the invention.

What is claimed is:

1. In a unitary hollow metallic propeller blade comprising thrust and camber components integrally united at their margins to form leading and trailing edges, said components forming the sole metallic structure of the blade, means to alter the transverse stress distribution in said components and to suppress transverse stress in the components adjacent said leading and trailing edges, comprising fillets of solid material having the characteristics of rubber and a durometer hardness of 30-100 bonded throughout a part only of their cross-sectional peripheries to the interior surfaces of said components adjacent said leading and trailing edges, said fillets extending chordwise of said blade from said edges substantially less than half the chordal dimension and said fillets extending lengthwise of the blade substantially throughout the length of said leading and trailing edges, each said fillet having a surface facing and exposed to the hollow interior of the blade.

2. In a unitary hollow metallic propeller blade comprising thrust and camber components inte-

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grally united at their margins to form leading and trailing edges, said components forming the sole metallic structure of the blade, means to alter the transverse stress distribution in said components and to suppress transverse stress in the components adjacent said leading and trailing edges, comprising fillets of solid material having the characteristics of rubber and a durometer hardness of 30-100 and a modulus of elasticity substantially less than that of the blade material bonded throughout a part only of their cross-sectional peripheries to the interior surfaces of said components adjacent said leading and trailing edges, said fillets extending chordwise of said blade from said edges substantially less than half the chordal dimension, each said fillet having a surface facing and exposed to the hollow interior of the blade.

3. In a unitary hollow metallic propeller blade comprising thrust and camber components integrally united at their margins to form leading and trailing edges, said components forming the sole metallic structure of the blade, means to alter the transverse stress distribution in said components and to suppress transverse stress in the components adjacent said leading and trailing edges, comprising fillets of solid material having the characteristics of rubber and a durometer hardness of 30-100 and a modulus of elasticity substantially less than that of the blade material bonded throughout a part only of their cross-sectional peripheries to the interior surfaces of said components adjacent said leading and trailing edges, said fillets extending lengthwise of said blade substantially throughout the length of said leading and trailing edges, each said fillet having a surface facing and exposed to the hollow interior of the blade.

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