Oct. 28, 1952 C. A. LIEDHOLM 2,615,520

REINFORCED PROPELLER BLADE

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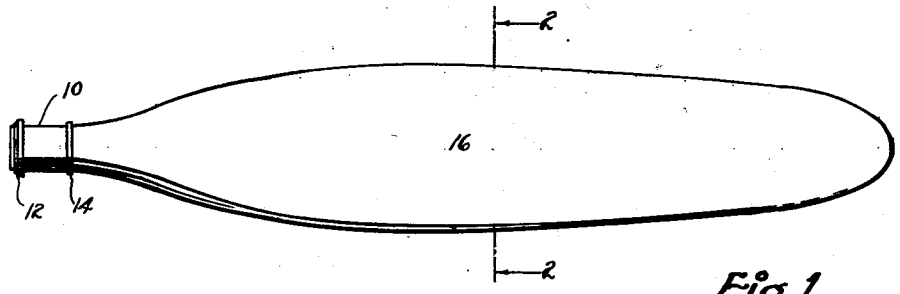


Fig. 1

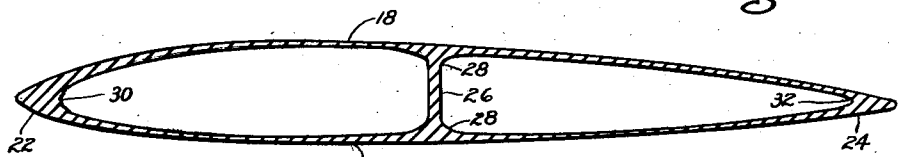


Fig. 2

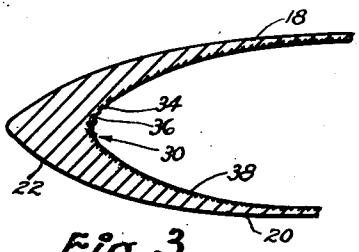


Fig. 3

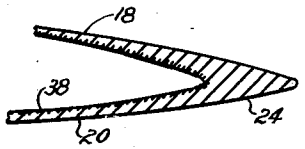


Fig. 4

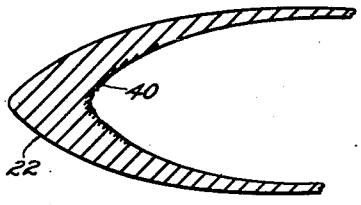


Fig. 5

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REINFORCED PROPELLER BLADE

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1 Claim. (Cl. 170—159)

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This invention relates to propeller blades and is concerned particularly with a means for and method of increasing the strength of hollow steel propeller blades for the purpose of making them more resistant to vibratory stresses.

In hollow steel propeller blades a limit in operating stress levels is frequently established by cracking and failure at certain zones in hollow steel blade structures, such failures being due in part to high localized stresses induced by vibration, and in part to the inevitable microscopic or macroscopic checks and cracks which may appear anywhere in the mass of the steel of which the blade is formed. Such failures are further contributed to by imperfections in the welding of blade components to one another, which allow scattered zones where localized stresses may be high enough to cause local failures and to thereby initiate cracks which may grow to serious proportions as the blade continues to operate at high stress levels. These faults and cracks may occur despite precision techniques in the fabrication of blades and despite zealous and careful inspection of all surfaces of the propeller blade. It will be realized that the problem is of rather critical nature since blades operate at high stress levels, and the mass of material of which they are composed is held to the minimum to reduce the weight of the blade.

Inspection of the exterior of a fabricated propeller blade, prior to final surface finishing, is comparatively simple—magnetic, macroscopic and visual inspection can be made with little difficulty. Few blade failures result from flaws having their inception at the blade outer surface. The interior surfaces of hollow steel propeller blades, however, are much more difficult to inspect since remote inspection techniques must be practiced with the aid of optical and other instruments which may be inserted into the hollow of the blade from the butt end. I have found that most failures of propeller blades occur from interior inceptions, which are contributed to by inspection difficulties mentioned above and to difficulties attendant to fine surface finishing of the interior surfaces of propeller blades.

I have further found that precompression of the interior surface material of a hollow steel propeller blade is extraordinarily effective in raising tolerable operating stress level and in reducing the likelihood of failure in propeller blades.

Objects of this invention are to increase the

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resistance of hollow steel propeller blades to failures due to vibratory stresses and to other stresses which may be imposed thereon, and to effect such resistance to failure by internally precompressing either all or part of the interior surface of a hollow steel propeller blade and increasing its strength and fatigue resistance by a suitable metallurgical technique such as by nitriding.

Further objects of the invention will become apparent from the following description and claim, and from the drawings. The drawings and the description associated therewith, however, are not to be construed as limiting the scope of the invention since various other means for accomplishing objectives of the invention will become apparent to those skilled in the art.

In the drawings in which similar reference characters represent similar parts, Fig. 1 is a planiform elevation of a hollow steel propeller blade;

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

Fig. 3 is an enlarged fragmentary section of a blade leading edge portion incorporating the provisions of the invention;

Fig. 4 is a section similar to Fig. 3 at the blade trailing edge; and

Fig. 5 is an enlarged fragmentary section of a blade leading edge portion showing an alternative mode of practicing the invention.

The propeller blade to which the invention is applicable is represented in its entirety in Fig. 1 and comprises a tubular shank portion 10 provided if desired with a flange 12 utilized in connection with retention of the propeller blade in a propeller hub. The blade also may be provided if desired with an annular cuff ring 14 which provides an abutment against which a blade embracing cuff may be secured against displacement under the influence of centrifugal force. These elements 12 and 14 do not form a part of the invention and are illustrated merely as examples of a particular blade organization. The effective portion of the blade aerodynamically, comprises a large paddle shaped member 16 constituted by a camber plate 18 and a thrust plate 20, the two plates preferably being tapered in thickness longitudinally of the blade and having varying thickness at any particular profile of the blade to provide for proper stress distribution. The plates adjacent the leading edge 22 and adjacent the trailing edge 24 are ordinarily thickened and are integrally united with one another through the medium of welds. Further, and particularly where blades are large and

wide, the blade may be centrally reinforced by a rib **26** extending longitudinally and centrally of the blade and secured as by welding to thickened portions **28** of the camber and thrust plates. Frequently, the rib **26** is formed in part on each blade plate and the two parts are united along the blade neutral axis to comprise the entire rib. As inferred, a rib such as **26** may or may not be necessary in the blade, depending upon its size and design requirements.

In that type of blade wherein separate camber and thrust plates are preformed and are subsequently united at their leading and trailing edges, the weld at said edges is applied from the outside of the blade and a fillet **30** is formed within the leading edge, a similar fillet **32** being formed internally of the blade adjacent the trailing edge. The interior surface of the welded fillet is ordinarily more or less non-uniform in its surface finish and unless it be finished smoothly as by filing or grinding, high and low points and other faults may exist on the fillet as shown at **34** and **36** in Fig. 3, which under blade operating conditions form points of high stress concentration which may lead to fatigue failure. The procedures for securing a fine finish in blade fillets are rather costly and time consuming but up to this time are fully justifiable in view of the improved fatigue resistance of the blade which is produced. The fillets however, are not the only points at which failures may initiate, and in certain types of blades, due to the pattern of stress distribution occasioned by the blade design and by the vibratory stresses and steady state stresses imposed upon the blade in operation, failures can occur at other parts of the blade surface. An analogous situation as to failures may also exist in blades where welds are made in other blade zones than the leading and trailing edges.

I have found that by superficially increasing the strength of and precompressing the interior surface of a propeller blade to the proper depth, the effect of localized faults in the blade surface is minimized and that the fatigue resistance of a propeller blade can be raised to levels heretofore not obtainable. A preferred method of securing the precompression indicated at **38** is to nitride the interior surfaces of the propeller blade. This may be easily accomplished by following the usual nitriding procedure, namely and in general, the soaking of the blade for an appropriate length of time at about 975° F. while nitrogen carrying gas such as ammonia is passed over the surface to be nitrided. This forms iron nitride in the steel, increasing its strength and hardness and causing a slight growth of the material. This growth causes precompression of the material since it is constrained by the enveloping unnitrided blade material. In the case of the hollow blade, this technique is extremely simple in its accomplishment since the blade proper may be soaked at the proper temperature in a non-oxidizing atmosphere and ammonia gas may be passed into the blade hollow through an appropriate gas connection associated with the butt of the propeller blade. A nitrided case having great fatigue strength and hardness develops over the inner surface of the propeller blade to a depth of from .005 to .030 inch depending upon the time of soaking, the inner margins of the case blending gradually into the parent metal.

In some types of propeller blades, nitriding of the entire interior surface of the blade may be unnecessary, in which case those portions of the blade surface where nitriding is not desired may be coated with an appropriate plating which prevents nitriding. The nitriding may be localized at such zones, for instance, as the fillets at the inside of the leading edge and the trailing edge of the blades as noted in Fig. 5 at **40**.

The best depth of the precompressed or nitrided layer varies with blades of different design. It should be a depth to allow substantially the same high operating stress levels to be maintained both in the outer and inner surfaces of the blade material, such stress levels being the maximum to allow freedom from blade failure. Expressed in another way, the depth of the nitrided layer should be such that failures of the blade due to stress overload, normally applied to test samples, should start from the inner surface and from the outer surface with substantially equal frequency. When such a condition prevails, the safe operating stress level of the blade is at a maximum and is materially greater than that attainable with untreated blades, or with over- or under-treated blades. Even so, moderately over- or under-treated blades should be better than untreated blades.

A considerable amount of testing has been accomplished on propeller blades, otherwise identical, some having nitrided inner surfaces and others being unnitrided. Actual nitrided blade samples under enforced test conditions have failed in a stress range of the order of a minimum of 40,000 pounds per square inch whereas the un-nitrided samples have failed at stresses of the order of a minimum of 23,000 pounds per square inch, the latter failures having started from the blade interior surfaces.

While nitriding of the steel of the propeller blade is preferred as a means for internal surface precompressing and, incidentally, hardening and strengthening, other means may be employed for increasing the prestress, hardness and strength of the material, such as case carburizing and cold working. It is appreciated that the prior art has taught the treatment of propeller blades to differentiate strength and hardness in the wall of the blade but in all instances of which applicant has knowledge, emphasis in the art has been placed upon increasing the strength and hardness of the exterior surfaces of the blades either by electro-deposition of hard metal, cold working, surface carburization or nitriding. The primary purpose of external strengthening and hardening was to increase propeller blade resistance to abrasion and external erosion and naturally to increase the strength of the blade in general. However, such prior art expedients while constructive for improving abrasion resistance, do not provide a solution for the underlying problems of reinforcing blades against vibration induced stress or of equalizing failure inceptions between the outside and inside blade surfaces. Nor do the prior teachings provide means to overcome imperfections in the interior of the blades where surface finishing and inspection is extremely difficult.

The phenomenon of increasing fatigue strength of propeller blades by nitriding or other modes of internal hardening is believed to consist in the proposition that the treated surfaces are placed in a state of controlled compressive stress which delays fault inception where the surface finish may be imperfect. It is known that the technique of nitriding causes a growth of the material of the order of a few per cent whereby the nitrided layers are inevitably compressed and the metal

layers adjacent thereto are correspondingly placed in tension. The controlled compressive stress at the interior blade surface, by actual test materially increases the fatigue strength of the propeller blades despite minor defects which may occur on the interior surfaces of the blade or on the interior surfaces of the relatively unfinished fillets or welds which occur at various parts of the blade. When techniques such as cold work or other hardening processes are used on the interior surfaces of the propeller blade, it is considered that such techniques should properly include the creation of a state of precompression on the inner blade surfaces.

Though two embodiments illustrating the invention have been shown and described, it is to be understood that the invention may be applied in other and various forms. Changes may be made in the arrangements, without departing from the spirit of the invention. Reference should be had to the appended claim for definitions of the limits of the invention.

What is claimed is:

A hollow steel propeller blade comprising an integral, substantially homogeneous shell of airfoil profile having thickened leading and trailing edge portions and relatively thinner shell portions therebetween, said thinner shell portions extending across the blade chord from a short distance rearward of the leading edge to a short distance forward of the trailing edge, the interior surface layers of said leading and trailing edge portions

deviating from the homogeneity of the rest of the blade and being nitrided to a depth of from .005" to .030", to precompress said surface layers, and to increase the strength and hardness thereof better to resist the action of operating stresses thereat, said nitrided surface layers terminating where the thickened leading and trailing edge blade portions blend in thickness to said thin shell portions.

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