

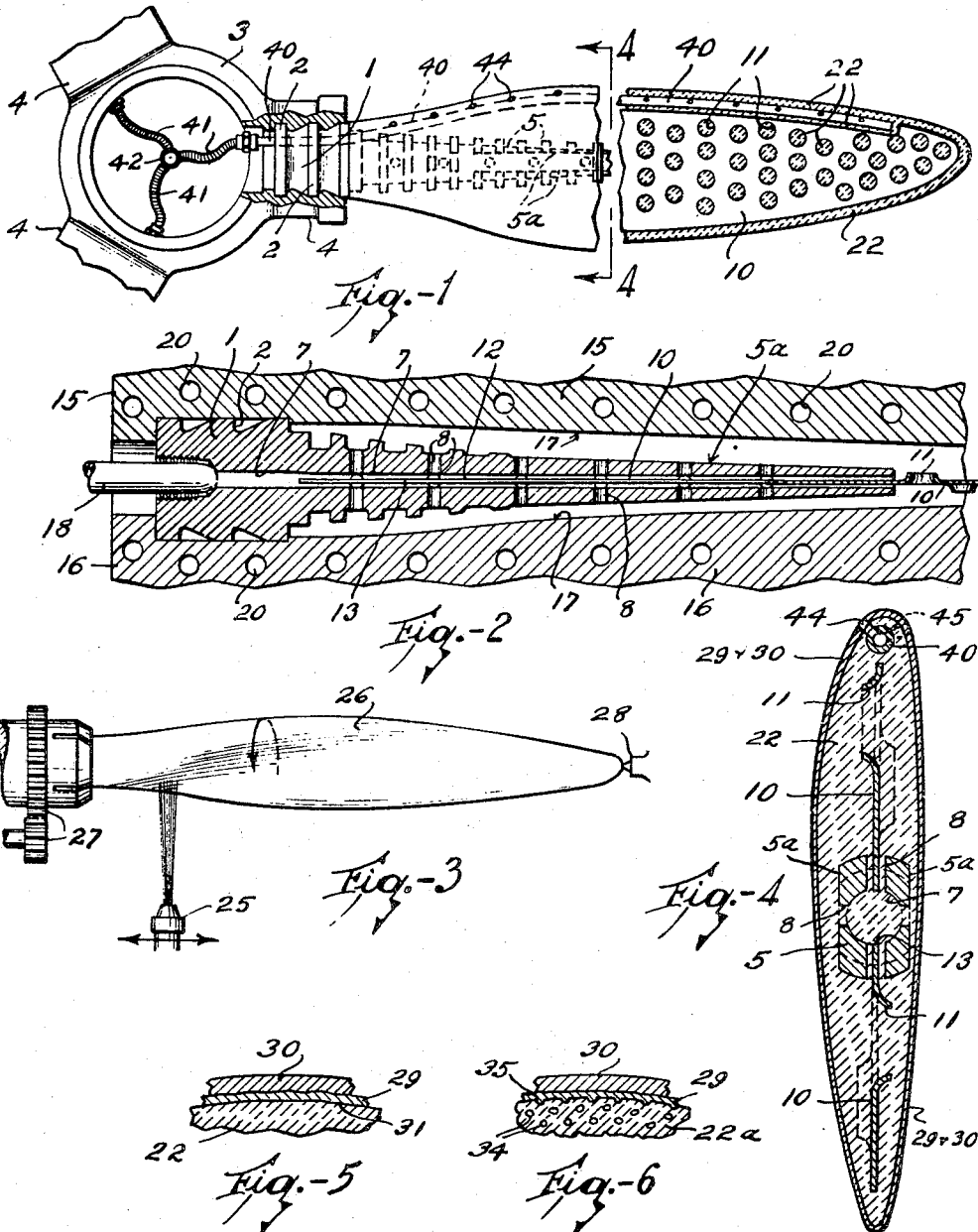
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PROPELLER BLADE

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PROPELLER BLADE

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This invention relates to a propeller blade particularly for aircraft and a new method of making such blade.

One object of the invention is to provide a propeller blade which can be made without any great amount of hand work and have strength, flexibility and other desirable characteristics comparable to, if not excelling, the higher grades of laminated wooden propellers and all-metal propellers while at the same time being moisture and impact resistant and of light weight.

A further object is to provide an improved method of making metallically armored propeller blades.

A specific object is to provide a propeller blade having an adequately reinforced core including high strength plastic material and an armor sheath partially or wholly covering the same of sufficient tensile strength and impact resistance to prevent chipping and abrading of the propeller surface as by projectiles, particularly at low temperatures.

A further object is to provide a metallically armored propeller in which the armor is completely bonded to the core, whereby adequately to resist all tendency to peeling off, whether by impact or temperature effects or otherwise.

Another object is to provide an improved propeller blade made partially from plastic material with an improved reinforcing core formed substantially as an integral part of a shank piece or butt of the blade suitable for mounting in a metal hub provided with means for turning the blade about its longitudinal axis for pitch adjustment, feathering and the like.

Another object is to provide a de-icing means for propeller blades which means is operative efficiently to de-ice all the blade surfaces on which ice is likely to accumulate.

Further objects include the provision of a propeller blade having adequate tensile, compressive, twist resisting and impact resisting strength, notwithstanding relatively light weight and resistance to the effects of temperature change and relative humidity or even immersion in water for long periods.

Further objects and features of the invention will become apparent from the following description and by reference to the accompanying drawing, in which

Fig. 1 is a front view of one blade of a propeller and a more or less diagrammatic representation of a hub on which the blade may be mounted;

Fig. 2 is a sectional view showing, by way of example, a mold in which part of the core por-

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tion of the blade can be formed, said view showing, in place in the mold, a metal shank or butt piece and inner reinforcing element rigid therewith;

Fig. 3 is a diagrammatic representation showing the manner of applying armoring metal to the completed core;

Fig. 4 is a relatively enlarged fragmentary cross sectional view showing particularly the relationship of the de-icing fluid tube and discharge nozzle jets therefor at one edge portion of the blade;

Fig. 5 is a greatly enlarged (e. g. magnified) typical section of the completed blade near its surface; and

Fig. 6 is a view similar to Fig. 5 showing a modification in a plastic portion of the blade core or body.

Several prior proposals for the use of inorganic plastics as materials for propeller blades have been made, and it has also been proposed to provide metal sheathing or armor for propeller blades made at least partially from plastics and for other non-metallic materials, as cores. Paper and fabric reinforced plastic cores of synthetic resin such as heretofore proposed require a great deal of labor to form them; and under the extremely high bending and twisting strains to which propellers for aircraft are subjected as well as impact forces, the laminations are apt to separate and the resinous material, being brittle, is apt to fracture and become chipped or shattered. It has, in practice, usually been necessary to encase propellers made largely or wholly from organic plastics with a built-up partial or complete armor of metal or "dope"-impregnated fabric in order to prevent contact of the plastic materials with moisture as well as in order to protect the plastic against being chipped or fractured by flying missiles such as small stones and, in case of fighting craft, flak. The difference in twisting and bending resistance or elasticity between the different materials heretofore used and the differential of expansion and contraction under heat between said different materials are common causes for short life on part of composite propeller blades including such plastic materials as heretofore used or proposed.

In the present arrangement I have sought to reduce all the differentials which commonly account for deterioration and partial or complete destruction of composite blades by using a plastic material for the core which has great toughness, hardness comparable to metal, practically no tendency to cold flow at moderately high tem-

peratures or to fracture by impact or strain at sub-zero temperatures and which has little, if any, tendency to separate locally from the metallic armor or other metal portions during subsection to rapid temperature changes and extremely high bending and twisting strains. The unitary character of the blade is preserved in part by a metallic armor of composite nature, one component of which is selected for desirable bonding characteristics with the plastic as well as protection of the latter during application thereto and another component being selected principally with a view to greater surface strength and abrasion resistance. The above are only the salient features of the present method and propeller blade construction produced thereby. Others will be brought out later herein.

Referring further to the drawing, Fig. 1 shows a left hand portion of a blade in side elevation and a right hand portion in substantially central principal plane section along the major surface of a reinforcing sheet and central core piece supporting the sheet. The blade has a shank or butt portion 1 suitably formed, for example, generally cylindrically, and with flange projections as at 2 which, in the form shown, are buttress "thread" effects for mounting the propeller in a suitable hub. A hub is diagrammatically indicated at 3 with a tubular extension 4 adapted to receive the projections 2 and which may include provision for turning the entire blade about its longitudinal axis into high and low pitch, feathering and/or reverse positions. Reference is directed to my copending application, Serial No. 498,492 filed July 13, 1943, for a suitable hub construction providing for variable pitch as to the blades of which there may be any suitable number and arrangement and for one manner of supplying de-icing fluid to the blades. The ribs 2 on the butt portion 1 are, in actual practice, supported in split mounting sleeve members such as shown for example in my copending application Serial No. 476,398, filed February 19, 1943. For simplicity, the butt portion 1, as herein shown, is embraced by metal of the associated hub extension 4 as though tunable for pitch adjustment therein.

The shank piece or butt 1 has extending therefrom a longitudinal reinforce bar 5 which may be made separately from the butt piece 2 or integral therewith. The reinforce bar 5 is preferably generally tapered or of gradually reduced section toward the tip portion of the blade to reduce the tendency for crystallization and consequent fracture and also because it is necessary to reduce the section at least in one central plane of the blade as the blade thickness itself is reduced outwardly toward the tip. Opposite sides of a portion of the reinforce bar 5 are faced off as at 5a, as brought out by comparison of Figs. 1, 2 and 4.

In order to form a firm and permanent interlock with the plastic core the reinforce bar 5 may have a plurality of parallel circumferentially extending ribs 6 distributed at intervals therealong, or the reinforce bar may have any other sort of surface effects which will interlock with plastic material molded about the bar.

If the plastic material which continuously surrounds the reinforce 5 and determines the shape of the blade is to be formed by injection molding as against "transfer," "compression" or other molding methods any of which could be practiced instead, then the butt piece and reinforce bar 5 will have a central longitudinal bore

as at 7 in which event the reinforce will have cross passages as at 8 to enable injection of the plastic through the central bore and flow thereof outwardly into a mold through such passages 8 in appropriate directions.

In addition to the reinforce 5, I preferably employ also a plate-like reinforce and plastic-interlocking element such as shown at 10. The element 10 is preferably in the form of a sheet metal blank of the general shape of the main face portions of the blade but somewhat smaller and having a fairly large number of passages 11 therethrough. The passages are shown as comprising alternately oppositely necked or flanged openings through which the plastic material at one side of the sheet 10 is adequately integrally bonded at intervals with the plastic on the other side of the sheet. The flanges present greater interlock or shoulder surfaces to the plastic than would plain punched openings. The sheet 10 may be anchored to the reinforce 5 and/or to the butt piece 2, a convenient manner of fastening the sheet comprising slotting the reinforce bar 5 longitudinally as at 12, slipping the sheet into the slot and then brazing or welding the sheet to the reinforce at the lateral limits of the slot. The sheet material is cut away centrally of the reinforce bar as at 13 so as not to obstruct the inlet duct 7 for the plastic.

Assuming the composite shank and reinforcing structure above described is secured between two appropriately heated mold members or dies such as 15 and 16 which are separable substantially along a plane parallel to the principal plane of the blade when formed, the plastic may be injected into the main mold cavity 17 as through a nozzle 18 brought into sealing contact with an end wall of the butt piece 1 at the central hole 7 of the butt piece. Suitable mold heating and cooling means may include conduit passages formed in the mold as at 20 for receiving alternately steam and water or other heating and cooling media; and such passages are appropriately spaced, proportioned and positioned so that the heat is properly distributed as required to cause the plastic entirely to fill the cavity 17 under pressure before any partial solidification takes place. Appropriate vents may be provided for discharging excess plastic as at the tip-forming portion of the mold. The solidified plastic is indicated in Figs. 1, 4 and 5 at 22.

The method outlined above for incorporating the plastic with the central reinforce and butt piece structure is especially suited to the plastic materials cellulose acetate and cellulose acetate butyrate which are preferred largely because of their high tensile and flexural strength, impact resistance, hardness, lack of brittleness and small tendency to elongate or "cold flow" under moderately high temperatures and to fracture under low temperatures. The above, of course, are only a few of the well known desirable characteristics of the thermoplastic materials mentioned. Other plastics having similar properties may be considered operative equivalents and within the scope of this patent. Thermosetting materials can, of course, be used and the molding methods would vary as best fits the particular plastic selected, whether thermosetting or thermoplastic.

A propeller blade form when ejected from the mold, such as shown in Fig. 2, is then encased preferably in a complete envelope of metal. In order to avoid joints in covering a preformed blade body made of wood or the like with metal, it has been proposed to treat such body with elec-

trically conductive substance and then apply the metal electrolytically. Electrolytically deposited metal has very little tensile strength and is, moreover, quite brittle; but the principal disadvantage of its use as propeller blade armor or sheathing is that it is practically impossible to secure a strong bond between metal so deposited and a non-metallic core. I have found that by spray-coating metal directly onto the exterior surfaces of the plastic materials, good bonding and adequate strength capabilities are secured. While metal spray coating, if not carefully done, can result in metal deposits of uneven thickness being applied as well as considerable roughness of surface, the bond is adequate so that any roughness and excessive thickness can readily be removed by well known machining or grinding operations or by hand as with files, abrasives and in other ways.

One manner of handling the core in spray coating is suggested in Fig. 3 wherein the spray nozzle for the metal is indicated at 25 and the completed molding at 26. The molding is mainly supported as by the shank piece 2 for rotation as by automatically variable speed gearing mechanism suggested, diagrammatically only, at 27. Additional support is indicated at 28. Suitable means is also provided gradually progressively and automatically to change the zone of operation of the metal spray in respect to the blade surface either by shifting the blade or the nozzle continuously and in a direction parallel to the longitudinal axis of the blade at the required speed, as determined by the thickness of coating desired. Mechanisms for accomplishing such motions as referred to above are well known in the machine tool arts, hence need no specific showing here.

The blade core is spray coated locally, progressively by successive steps, on both sides at nearly the same time during turning of the blade at appropriate varying speeds as different surface portions are presented to the nozzle. Thereby the tendency for the blade to be warped (as would be the case if one side were completely coated and then the other side) is greatly reduced and a more uniform and smoother coating can be obtained.

For the first coating which is applied directly onto the plastic and preferably by the use of a fairly low melting point metal such as aluminum, the nozzle is positioned much farther away from the molding than in the case of the second coating since, in the first operation, it is desirable to prevent scorching or melting of the core by the hot metal although sporadic softening of the plastic surfaces takes place and slight penetration necessary for firm bonding of the first coating of metal therewith; and, in the second operation, detrimental effects of heat are prevented by the insulative action of the underlying or first metal coating.

Incidentally, if the spray coating is done against the revolving and progressively relatively advanced molding (e. g. moving the spray gun for relative advancing) the application is in a more or less spiral path about the blade so that if there is any "joint" effect where one spraying operation overlaps metal deposited by the preceding operation, the "joint" will extend around the blade in a direction at right angles to the longitudinal axis thereof rather than lengthwise of the blade at any point. Thus if the spraying operation starts at the tip the subsequent spray applications have a scale-like effect, overlapping each

other toward the tip for greatest resistance to becoming detached by centrifugal and abrasive forces during propeller operation.

The blade core is first given a complete and fairly light coating as of aluminum or other low melting point metal (see Fig. 5 at 29). The lower melting point metals have less tendency to scorch the plastic although some of the particles embed themselves in the surface of the plastic and enhance the bonding. The first coat 29 forms a protective layer upon which higher melting point metal, for example, steel, can be spray coated as at 30 or possibly in some other manner, e. g. by electroplating in case the low melting point metal of the first coat is adapted to be coated electrolytically. The bond 31 between the first coating 29 and the plastic 22 may be enhanced by having the surface of the plastic somewhat rough. Roughness or "tooth effect" can be secured either by a rough finish on the mold cavities or by sand blasting or etching of the plastic after molding (not illustrated.)

Another manner of enhancing the bond and, by the same means, reducing the density hence total weight of the plastic component is suggested in Fig. 6 wherein the plastic body 22a is shown as provided with innumerable small cavities 34, formed as by introduction and dispersion of gas-forming materials into the plastic stock, some of which cavities break through to the surface as at 35 and thereby form tooth effects for mechanical bonding with the initial metal coating 29 in cases in which there is more thermal expansion differential than in the preferred selection of materials described above.

I have found that if the first coat is aluminum and the second coat steel, the composite armor is adequate to serve all the functions normally served by sheet metal armor such as already known in the propeller art, and it has the special advantages, namely full bonding over the entire coextensive surfaces; there are no joints, and the metal can be increased in thickness as at the leading edge of the blade, as suggested by Fig. 4, or at any such other portions as may be found to be subjected to especially heavy duty.

Tube effects in propeller blades and cuffs for blades are already known, which tube effects are designed to distribute de-icing fluid to the blades during rotation. So far as I know, however, it has not been considered desirable to provide for distribution of such fluid from inside the blade proper to the outlying surface portions of the blades. The theory has been that a limited distribution near the hub will effect distribution of de-icing fluid to the entire blade due to centrifugal force acting on the fluid. That is not adequate however because before the fluid can travel outwardly much beyond the point of discharge, the blade surfaces outwardly from the point of discharge move forwardly out of range of the fluid. My solution is to carry the fluid outwardly inside the blade to various points for uniform distribution to the surfaces needing de-icing. Conduction is through a single tube along the leading edge which tube has nozzle apertures, for example, of graduated size (reduced size outwardly toward the blade tip), to compensate in part for the greater pressures acting on the fluid in the outlying regions. However, the apertures can be all the same size, as shown, if sufficient positive pressure is applied to the fluid to effect discharge thereof and an adequate supply is delivered to the tube.

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The de-icer fluid tube shown at 40 extends through an eccentric bore in the butt piece 1 for connection as by flexible tubing 41 with a supply line which, for example only, is shown centrally of the hub 3 diagrammatically at 42. The coupling and supply arrangement for the de-icer fluid tube from a pressure supply source is more completely shown and is claimed in my co-pending application Serial No. 498,492 mentioned above.

The tube 40 leads from the butt piece 1, to which it may be secured as by solder, along the leading edge portion of the plastic body material 22 in which it becomes embedded as will be apparent. The tube is closed at its outer end and is coextensive with as much of the length of the blade as may be found to be subject to deposits of ice and sleet. After the blade is completely formed as heretofore described, a series of small openings are drilled through the metallic armor into the tube as indicated at 44, Fig. 4, so that the openings constitute ejector nozzles for distributing alcohol or other de-icing fluid along the camber surface portions of the blade. The actual effect of discharging such de-icing fluid from the blade as by suitable pressure applied to the tube 40 is to volatilize the fluid in the zone of operation of the blades and the resulting mist of de-icer fluid accomplishes the de-icing regardless of the particular region of the blade from which the fluid is discharged and onto what surface the fluid tends to flow. Unless, however, the fluid is discharged for a considerable distance along the blade, it is practically impossible due to the rapid forward motion of the ship for outlying portions of the blade to come into contact with any de-icer fluid. A smaller number of holes are drilled into the tube as at 45, Fig. 4, from the pressure side of the blade adjacent the leading edge. For example, there may be one hole 45 for each three holes 44.

I claim:

1. A propeller blade comprising a central hollow metallic reinforcing bar supported on a butt piece at one end and tapered outwardly to a tip portion at the opposite end, a perforated sheet metal reinforcing element mounted on said bar, extending beyond said tip portion and laterally of the blade, a molded core of organic plastic material surrounding said bar and element and locked thereto by interlocking engagement with the perforations of said element and with the interior of said bar, and a protective metallic armor bonded directly to said plastic core.

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2. A propeller blade comprising a central slotted metallic reinforcing bar tapering outwardly to a tip portion at one end, a perforated sheet metal reinforcing element mounted in the slot in said bar, extending longitudinally of said bar and laterally of the blade, a molded core of organic plastic material surrounding said bar and element and locked thereto by interlocking engagement with the perforations of said element and with the slot in said bar, and a protective metallic armor bonded directly to said plastic core.

3. A propeller blade comprising a central slotted metallic reinforcing bar shaped at one end to form a butt piece and tapering outwardly at the other end to form a tip portion, a perforated sheet metal reinforcing element mounted in the slot in said bar, extending longitudinally of said bar and laterally of the blade, a molded core of organic plastic material surrounding said bar and element and locked thereto by interlocking engagement with the perforations of said element and with the slot in said bar, and a protective metallic armor bonded directly to said plastic core.

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