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S. G. BART

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RUBBER-BACKED PROPELLER

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Fig. 1.

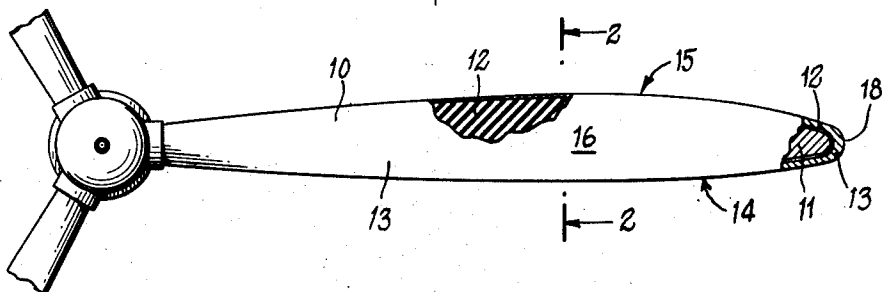


Fig. 2.

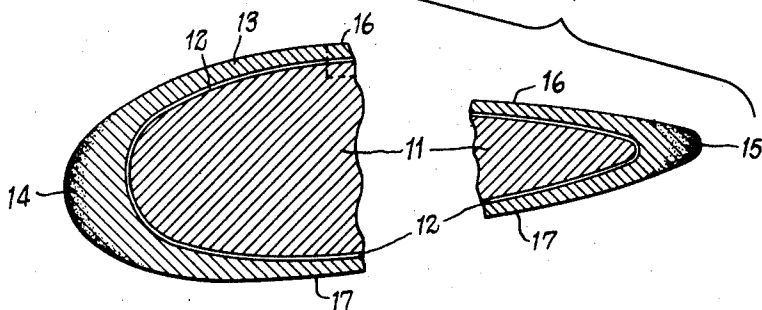
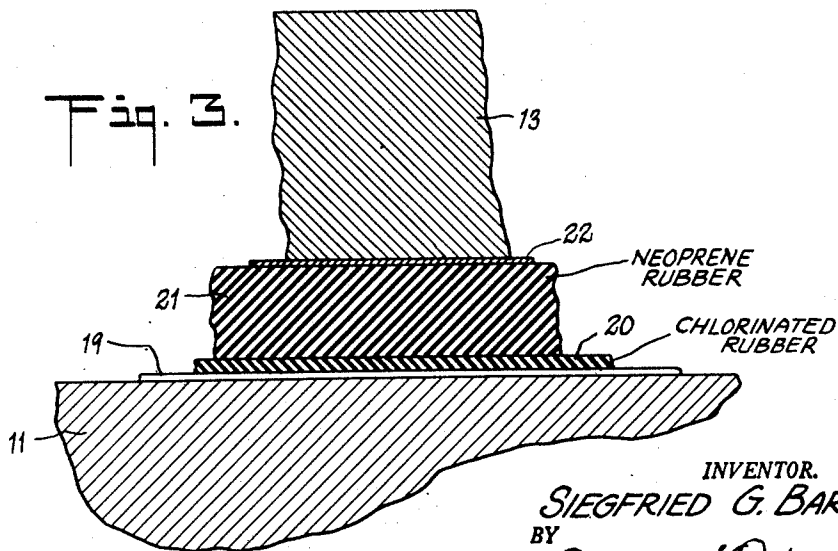


Fig. 3.



INVENTOR.  
SIEGFRIED G. BART  
BY  
Warren S. Oston  
ATTORNEY

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## RUBBER-BACKED PROPELLER

Siegfried G. Bart, Essex Fells, N. J.

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4 Claims. (Cl. 170-159)

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The invention relates in general to a multi-layered, sandwich material of the type in which a layer of metal is deposited electrolytically on a layer of rubber for use wherever such multi-layered materials are suitable, and specifically relates to a rubber-backed aeroplane propeller blade and similar aerofoils. This application constitutes a division of my pending application entitled, "Rubber Bonding Process," Serial No. 183,595, filed September 7, 1950.

The primary object of the invention is to provide an improved form of aerofoil in which the outer shell-forming surface of the electrolytically deposited covering will remain permanently bonded to the underlying rubber or at least bonded for a much longer period than has been possible prior to the production of articles manufactured by the method disclosed in the above-identified parent application.

Among the other objects of the invention is to produce an aeroplane propeller blade which will be light in weight, whose outer surface will meet aerodynamic requirement of a smooth, continuous, uninterrupted outer metallic skin, and to provide a cushioning effect to the outer skin and to form the propeller as an integral one-piece article.

It has been known to form the outer, air-beating surfaces of propellers at least in part of sheet steel laid on wood and of chromium plating on steel, but it is difficult to shape the steel exactly to the aerodynamic configuration now demanded of propeller blade designs and under severe operating conditions chromium plating on steel has a tendency to develop minute cracks and eventually disintegrates in service.

Depositing nickel electrolytically, especially when deposited on rubber as herein featured, provides a one-piece outer layer or skin to the propeller blade which does not need to be preformed as in the case of the steel facings and does not crack or chip as does the chromium and, on the contrary, provides a smooth hard surface, particularly at its leading edge and wherever else there is required a surface highly resistant to the abrading and erosive effect of water, sand and other solids often present in the air.

While aeroplane propellers are usually considered to be rigid bodies actually they are preferably required to have some small degree of flexibility in certain parts and relative rigidity in other parts. For instance, the leading and trailing edges, as well as the tips, are usually required to be rigid, more or less, while parts therebetween forming the camber surfaces should possess at

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least a slight degree of flexure. Also, in aeroplane propeller blades and similar aerofoils there is greater wear, especially at the leading edge and tip and, accordingly, the present disclosure features a peculiar apportioning of the electro-metal which forms the outer skin to provide for relatively thick cross section of material and for greater density of material and thus for a greater hardness of material at the leading and trailing edges and at the tips, and a relatively thin and more flexible cross section of material in that part of the skin which forms the camber portions of the blade.

Briefly, this is attained by using a stress-free nickel and by building up and thus thickening the nickel deposited on the narrow edges forming the leading and trailing edges and on the converging surfaces outlining the tips of the blade.

Various objects of the invention will be obvious from a consideration of the accompanying drawings in which:

Fig. 1 is a view in plan of an aeroplane propeller blade of conventional design forming a preferred embodiment of the invention, a portion of the outer metal shell being removed to show the underlying rubber-containing layer and a portion of the metal tip is shown in section in the plane of the blade;

Fig. 2 is a transverse sectional view taken on the line 2-2 of Fig. 1, somewhat enlarged, with the mid-portion broken away to save space and with the layers shown approximately in their relative dimensions; and

Fig. 3 is a very much enlarged sectional showing on a scale of about 1 to 5000 of the several layers of material including the two initial layers of rubber which eventually become the single layer of rubber, in the blocked-off portion outlined by dotted lines at the upper central portion of the finished blade, as shown in Fig. 2.

The finished blade 10 as shown in Fig. 1 is of conventional design and as shown in Fig. 2 includes an inner core 11 forming the base on which a rubber backing layer 12 is formed as herein featured, and on which rubber layer an outer layer or shell 13 of electrolytically deposited nickel is formed. The blade when completely formed is provided with a relatively thick leading edge 14 rounding in a vertical plane as shown in Fig. 2 on a relatively large radius and a relatively thin trailing edge 15 similarly rounding on a relatively small radius. Between the leading and trailing edges the blade provides an upper camber-forming surface 16 and a lower camber-forming surface 17 merging at their ends into a

tip 18 as is usual in propeller blades. The inner core or base 11 in this case is preformed of forged or cast aluminum and of such size and contour so that when the different layers are added thereto as hereinafter described there will be produced the finished blade with its desired size, configuration and structural strength to respond to approved aerodynamic requirements of such blades. While forged aluminum has been selected because of its light weight, cheapness and other desirable properties, it is suggested that the core may be made of other metals, or may even be made of wood or plastics.

In practicing the method herein featured it is necessary that the exposed surface of the aluminum core must be cleared of all adhering grease and other foreign matter. To obtain the necessary cleanliness it is suggested that the core surface be anodized as by treating it in an acid bath of an electrolytic cell with the current reversed.

A thin layer of plastic bonding material 19, of which several suitable types are on the market and most of them containing a phenol-formaldehyde base, is applied to the cleaned surface of the aluminum core. Such a bonding product manufactured for this purpose by U. S. Stoneware Co., of Tallmadge, Ohio, under the trade-name "Reonite," has been used with success. The bonding material is applied in several coats and permitted to dry between succeeding coats. The core so coated is baked with infrared heat in an oven for about one hour and at a temperature of about 150 degrees F., and then removed from the oven. This plastic layer 19 provided a protective coating to the aluminum and adheres well to the same.

Three or four coats of chlorinated or bonding rubber cement free of sulphur and with a suitable solvent are then sprayed onto the plastic bonding material so baked on the core with about fifteen minutes of air drying between the application of each coat to remove the solvent and to leave a thin, rubber-containing, base-coating bonding layer 20 of chlorinated rubber, in the illustrated case having a thickness of about 0.0005 of an inch.

Seven to twenty coats of neoprene (polychloroprene) rubber cement which does not require any sulphur for curing are then sprayed on the bonding layer 20 with air drying between succeeding coats to form a relatively thick cushioning neoprene rubber cement layer 21, in the illustrated case having a thickness of about 0.004 of an inch. Neoprene rubber cement as it appears on the market contains, in addition to its rubber content, carbon black, zinc oxide, magnesia and certain other ingredients in small proportions.

In those cases where the neoprene rubber cement or equivalent cushion-forming, rubber-like material will adhere to whatever material may be used to form the core 11, the bonding layer 20 may be omitted.

This neoprene rubber cement so used contains an accelerator such as magnesium oxide (MgO—magnesia)—which is present in about two per cent and is operative to facilitate the aging of the rubber and to toughen the neoprene to a rubber-like mass within the relatively short period of heating time employed in practicing the curing steps herein featured. The two layers of rubber thus eventually forming the all-rubber backing layer 12 are then given a preliminary, that is, an incomplete or partial curing by baking the core so rubber-coated in an oven

for about two and one-half hours at a temperature of about 150 degrees F. On removal from the oven and thus while the rubber is hot and tacky, at least, on its exposed surface, a layer 22 of graphite is dusted onto the surface of the rubber to form a continuous layer of a cathode-forming material. While graphite is suggested, other cathode-forming conductive materials such as powdered metal may be used.

It is suggested that, in place of dusting the graphite onto the surface to form the layer 22, the graphite be added to the last coat of the sprayed layer 21 mixed into the same preferably in amounts of two to ten percent of graphite to the rubber in this last coating. This, of course, eliminates layer 22 as a distinctive all-graphite layer.

The rubber-coated core so dusted with graphite or faced with a thin graphite-containing film is positioned within the electrolyte of an electrolytic cell containing nickel and the cell caused to function conventionally so that eventually the rubber-coated core 11 is enclosed in a one-piece, continuous skin or shell 13 of electrolytic nickel deposited by means of a current of high depositing density and otherwise following conventional practices in this respect. In order that the deposited nickel layer be free of stress and form the same as bright nickel, an additional agent such as saccharine is added to the electrolyte of the Watts type to make of it a modified Watts solution. While nickel is suggested as the preferred metal to form the outer shell 13, it is suggested that the shell may be formed of two electro-metals, for instance, an inner layer of copper and an outer layer of nickel, or it may be formed of a metal harder than nickel, such as tungsten, titanium, molybdenum, or alloys which can be plated. It is suggested that the outer shell 13 be electroformed iron with a chromium plate.

It is a distinctive feature of this disclosure that the electrolytic bath be maintained at a temperature ranging between 125 degrees and 165 degrees F., preferably nearer 150 than 125 degrees F., for ten to twenty hours while depositing its nickel. This final heat treatment in the bath has the effect of completing the curing of the neoprene rubber cement and apparently effects a curing of the chlorinated rubber, for the entire layer 12 appears to have its strength improved by the curing process herein featured. During the metal-depositing step the bath is heated as by means of steam pipes and care is exercised to keep the bath not materially greater than 150 degrees F., for a temperature materially greater than 150 degrees F. tends to destroy the adhesive qualities of the rubber and if more than 150 degrees F. is used the time the rubber is exposed to such temperature should be quite brief.

The resulting, completely cured rubber layer 12 thus formed by the amalgamation of the rubber-containing layers 19 and 20 forms a tough, resilient rubber bond with an improved adhesion to both the aluminum core and the resulting outer nickel shell over anything which has been found heretofore. Neoprene rubber cement does not adhere well to the plastic layer 19 and this is the reason for using the chlorinated layer 20 therebetween. As the plastic bonding material 19 adheres to the basic aluminum core 11, as the first layer of chlorinated rubber adheres to the bonding material 19, as each layer of rubber is bonded to the next preceding layer, and as the final electro-metal is bonded to the neoprene rubber cement it follows that each superposed layer is

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bonded to the layer next beneath it and thus the rubber completely fills the space between the inner core and the outer shell and there is formed, in effect, a one-piece laminated sandwich material. Over an extensive period of use even under conditions where there was much vibration of the resulting product, for instance, in the propeller, the nickel covering adhered tenaciously to the rubber and no blisters or raised spots formed.

The nickel skin covering 13 formed as herein featured in forming the propeller is neither homogeneous nor of equal cross section of material in its several parts. By reason of the narrowed edges provided by the sharply rounded leading edge 14 and the even more sharply rounded trailing edge 15 there will be a tendency of the bath in its normal operation to form a denser deposit of nickel on the narrow edges than on the more flat camber-forming surfaces 16 and 17. Also, by arranging a selective deposition of the anodes in the bath relative to the cathode surfaces and following known controls in this respect, there is presented first by the graphite-coated surface, and subsequently by the successive deposits of the nickel and, if necessary by the use of selective masking processes, a deposition of the nickel which can be regulated to obtain a relatively thin cross section of material at the camber-forming surfaces and a very much increased cross section of material in those parts which form the leading and trailing edges and the tip.

In one embodiment of the invention the nickel skin 13 of the camber-forming parts 16 and 17 was formed to a depth of about eight to ten-thousandths of an inch. Despite the fact that the skin is formed of nickel, its extreme thinness tends to give a certain degree of ductility and flexibility to the blade considered as a whole, and particularly in its mid-width portion, which thus provides a hinge effect along the longitudinal medial plane of the blade midway between the leading and trailing edges. On the contrary, the body of nickel which forms the leading edge 14 is quite thick, massive, rigid and harder than the body of nickel which defines the upper and lower camber-forming parts. The body forming the shell 13 has a thickness in the line of thrust of the propeller blade of from ten to eighty-thousandths of an inch, depending on the use to which the propeller blade is to be put, and in any case merging from its thick leading edge with progressive reduction in thickness smoothly into the camber-forming parts at top and bottom of the blade. A maximum thickness of nickel at the leading edge of about forty-thousandths of an inch is found to be ideal for propellers and for similar forms of aerofoils.

While the abrasive wear on the trailing edge is not as great as on the leading edge of propellers, it is suggested that the nickel in the part which forms the trailing edge likewise be made thicker, more rigid, denser and thus harder along the line of thrust than in the camber-forming parts, and likewise merge with gradually reduced cross section of metal into the thin, camber-forming parts. In the illustrated case the maximum thickness of nickel at the trailing edge is slightly less than is the thickness of metal in the leading edge.

In general, the propeller blade presents an external, continuous, air-engaging surface formed of a skin of tough, strain-free nickel free of projections of any kind and which skin as it is deposited electrolytically can be made to give an air-beating surface which can be formed accurately to the minute dimensions of aerodynamic

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specifications. Being of electrolytically formed nickel the exposed surface has the resistance to wear which characterizes hard bright nickel and in the part thereof most likely to wear in time, such as the edges and tips, even the hard nickel is made more dense, thus harder and thus more resistant to wear than the other parts, such as the camber-forming surfaces where at least a slight degree of flexibility is desired. Propeller blades formed as herein featured have a materially longer life and have other aerodynamic advantages over all known forms of similar types of propeller blades.

I claim:

1. An aeroplane propeller blade comprising a preformed relatively rigid core provided with a leading edge, a trailing edge and with upper and lower camber surfaces therebetween, said core at a mid-length portion thereof encircled by two superposed layers of material, that is, an inner layer of a rubber-like material and a thin outer layer of metal, said rubber-like material functioning as a resilient bond between the preformed rigid core and the thin outer layer of metal, the thickness of the rubber-like material being of the order of four thousandths of an inch and substantially uniform in cross section, the thickness of the layer of metal gradually and progressively increasing from about eight to ten-thousandths of an inch in the camber-forming portions to about forty-thousandths of an inch in the edge-forming portions and said layer of metal presenting a continuous unbroken and smooth surface in its air-beating portions.

2. A substantially rigid aeroplane propeller blade having a slight degree of flexibility along its longitudinal medial plane, said blade including an inner, preformed, relatively rigid core functioning to give configuration and strength to the blade, an intermediate layer of a rubber-like cushioning material enclosing the core and an outer skin of strain-free metal enclosing the layer of cushioning material, presenting a continuous unbroken surface to the air-beating portions of the blade and defining the leading edge, the trailing edge and the tip of the blade and between the leading and trailing edges forming the upper and lower camber portions of the blade, said outer metal skin being of relatively thin cross section of material in its camber-forming portion to provide for flexibility and thus to provide for a hinge effect along the medial plane of the blade, and said metal skin in the parts forming the leading and trailing edges and the tip having a cross section of material greater than the portions which form the camber portions, thus providing more rigidity in the edges and tip than in the camber portions, thereby to provide a relatively thin and more flexible cross section of material in that portion of the skin which forms the camber portions of the blade than in the edge and tip forming portions.

3. The blade defined in claim 2 and in which the portion of the metal skin forming one of the edges has a greater density and a greater hardness of metal than the metal skin which forms the camber portions of the blade.

4. A substantially rigid aeroplane propeller blade including an inner preformed metallic core functioning to give configuration and strength to the blade as a whole, an intermediate layer of a cushioning material enclosing the core and an outer skin of electro-metal enclosing the layer of cushioning material, a thin layer of a plastic bonding material between the cushioning layer

and the metallic core, said layer of cushioning material formed of an inner, relatively thin layer of cured chlorinated rubber free of sulphur and an outer thicker layer of neoprene rubber cement, and a layer of a cathode-forming material between the neoprene rubber cement and the outer skin of electro-metal.

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