June 6, 1939. M. SCHOLZ ET AL 2,161,533

MEANS FOR PROTECTING WOODEN PROPELLERS

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Fig.1

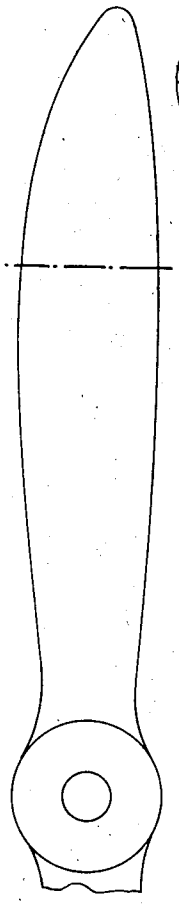


Fig.2

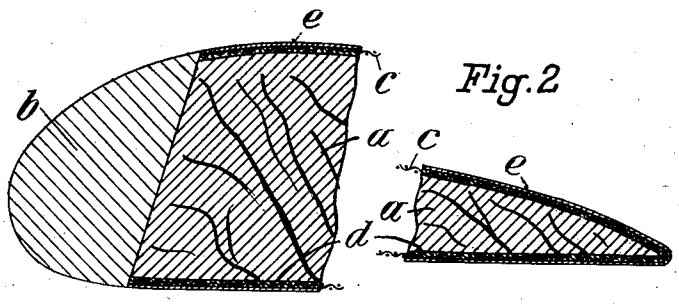


Fig.3

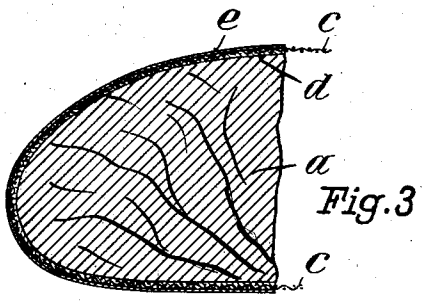


Fig.4

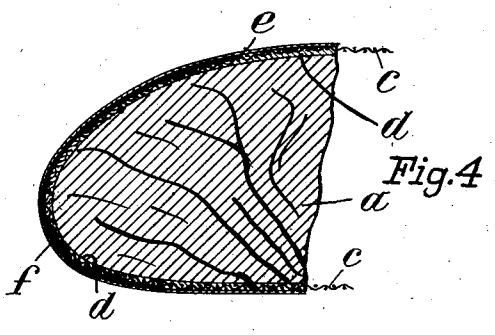


Fig.6

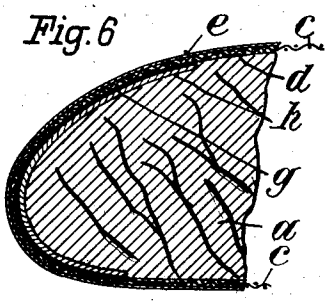
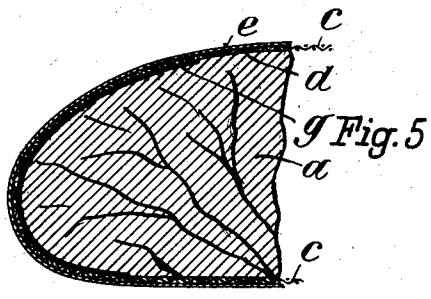


Fig.5



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MEANS FOR PROTECTING WOODEN PROPELLERS

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Fig. 7

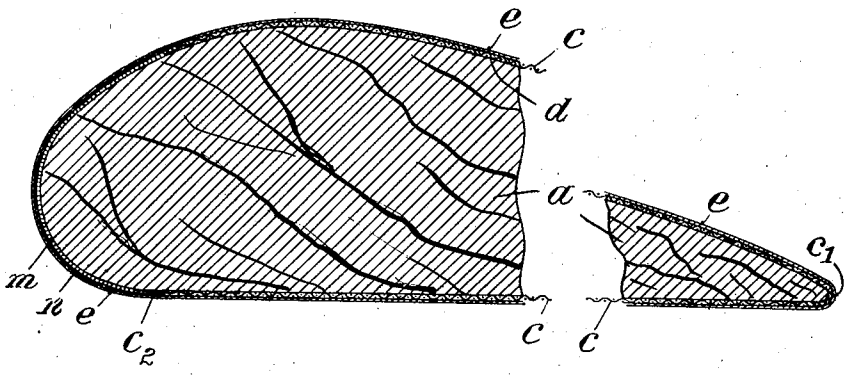


Fig. 8

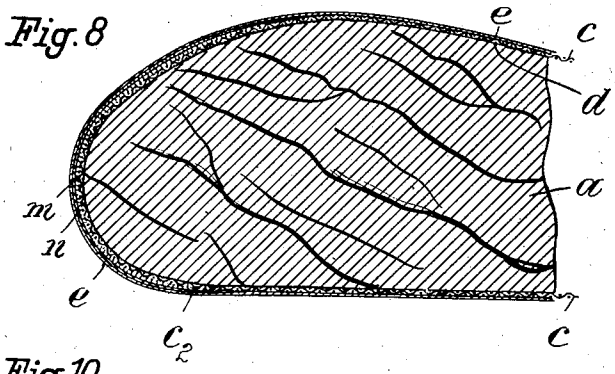


Fig. 10

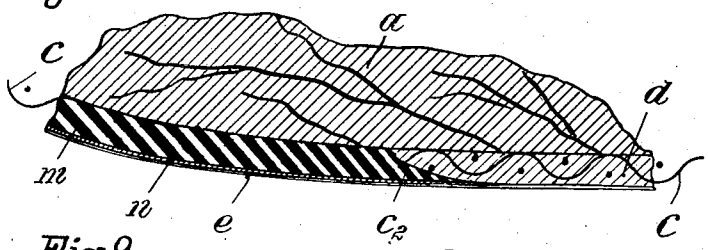


Fig. 9

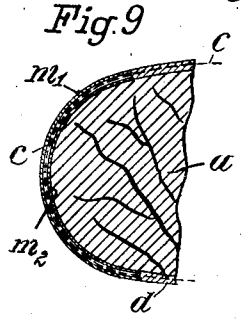
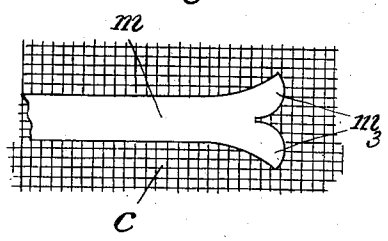


Fig. 11



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UNITED STATES PATENT OFFICE

2,161,533

MEANS FOR PROTECTING WOODEN PROPELLERS

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Application February 1, 1937, Serial No. 123,540
In Germany February 1, 1936

8 Claims. (Cl. 170—159)

The present invention relates to the art of protecting parts of aircraft made of wood or other light structured material and more especially to the art of protecting the blades of wooden propellers. It is known to protect propeller blades by a protective covering against damage by splashes of sand, hail, gravel and water and against the influence of atmospherics, etc. Particular attention has been paid to the protection of the leading edge of propeller blades. It has been proposed for instance to protect the leading edge of propeller blades by soldering a sheet metal covering onto a wire gauze which covers a larger portion of the blade than the leading edge and by fastening said gauze on the blade by means of an adhesive. The adhesive hitherto used for this purpose however has the disadvantage that it does not fasten the wire gauze directly to the wood of the blade, since the wood has first to be provided with a foundation of adhesive which enables the wire gauze to be glued on. Moreover the adhesive used in this connection becomes hard when it solidifies. In consequence thereof it cannot follow the movements of the wood during operation of the propeller, but cracks or peels off and thus renders the leading edge protective covering liable to become detached. In order to counteract this disadvantage the wire gauze is further secured on the blade wood by means of nails or studs and the latter are likely to damage the blade. Such damage is particularly noticeable in another type of protective covering, in which a wire gauze surrounds the whole propeller blade and such gauze is attached to the blade wood by means of nails or by sewing on the gauze with wire thread.

According to the invention the protective metal covering, such as wire gauze, is directly attached to the wood of a wooden propeller blade or other part of such propeller without the use of screws, nails, rivets or the like, by means of an adhesive which retains its elasticity and which completely fills the meshes or other openings of the protective metal covering, the adhesive being subsequently covered with a glazing, for instance a glazing of selfhardening synthetic resin. Parts of aircraft are thus obtained, in which the wood or the like, the protective metal covering imbedded in the adhesive, the adhesive and the glazing form an organically connected indivisible whole, the surface of which is sufficiently hard and which is nevertheless able to follow the movements of the wood without cracking or tearing off owing to the permanent elasticity of the adhesive.

As an adhesive which remains elastic and which is capable of being coated with a glazing, a mixture is used which consists of synthetic resins which are capable of being hardened and are preferably in a semi-hardened condition, such as the condensation products of phenol, urea, acetone or their homologues or substitution products and aldehydes, especially formaldehyde, or their polymers, with a saturated solution in alcohol of boric acid in the form of boric acid anhydride or ortho-, meta- or tetra-boric acid. To this mixture there is preferably added a non-volatile, liquid or dissolved softening agent such as the polymerization products of vinyl acid esters especially acrylicacidmethylester or vinylacetates. A rapid hardening is achieved if a known hardening agent for synthetic resins such as an alkyl sulfate, an alkyl chloride, hydroxylamine-hydrochloride or benzene trichloride, preferably in alcoholic solution, is added shortly before the adhesive is used. Solutions of this kind possess an extraordinarily strong adhesive power, they harden slowly to a horn-like consistency and remain transparent. By the addition of a sufficient amount of the above mentioned softening agents the tenacity and elasticity of the adhesive can be increased within certain limits.

In some cases it is advantageous to press the wire gauze into the wood or other structural material and then to cover the whole with the adhesive and the glazing. In the construction of aircraft, for instance, this mode of procedure leads to economy of weight.

Several modes of execution of the invention, as applied to wooden propellers, are shown by way of example in the accompanying drawings in which

Figure 1 represents a side view of a wooden propeller.

Figures 2–9 are blade sections on a somewhat larger scale, the said sections being somewhat distorted, and

Figures 10 and 11 represent details of the invention.

According to Fig. 2 the wooden propeller *a* is provided at its leading edge with a protective metal band *b*. Apart from this edge the front and rear surfaces of the propeller are covered with a wire gauze *c*, which is directly fastened to the wood *a* by means of an adhesive *d* which has permanently elastic properties. The layer of adhesive completely fills the meshes of the wire gauze *c*. The smooth but not hard surface so obtained is covered with a glazing *e* of selfhardening synthetic resin.

According to Fig. 3 the propeller blade *a* is covered on its entire surface with a wire gauze *c*, which is secured to the blade by means of a permanently elastic adhesive *d*, whereupon the whole is covered with a hard grazing *e*. No protective strip for the leading edge is used in this case.

If desired the protective covering of the leading edge may be reinforced as shown in the construction of Fig. 4. In this case the wire gauze *c* which is imbedded in the adhesive *d* is freed from adhesive at its surface, for instance by grinding with emery. It is then roughened and subsequently provided electrolytically or by spraying with a layer of copper or other metal *f*. Owing to the elastic nature of the adhesive contained in the meshes of the wire gauze *c* the layer of copper or other metal is also elastically connected with the wood *a*, so that a loosening of the protective metal covering need not be feared. In this arrangement *e* indicates the glazing as in the preceding modes of construction.

In the construction of Fig. 5 the leading edge of a propeller blade *a* is first provided with a strip of sheet metal *g* which is directly glued onto the blade by means of an adhesive *d* of permanent elasticity. This strip of metal *g* is then covered with a wire gauze *c* in such a manner that the gauze exceeds the area of strip *g* to a sufficient extent or surrounds the whole of the airscrew blade. The wire gauze is directly glued on by means of a layer of the adhesive *d* and the metal strip *g* is soldered onto the wire gauze where it is in contact with the latter. The whole covering and any parts of the wooden blade which are not protected are then coated with a glazing *e* which is capable of hardening. In order to obtain a surface with a high gloss it is advantageous to polish the glazing used in the above modes of construction and then to apply a further diluted coating of a self-hardening glazing of synthetic resin.

According to the construction of Fig. 6 the strip of sheet metal *g* is first fastened under pressure and at a raised temperature to a sheet of wood *h* and the protective covering so obtained is then attached to the wooden blade. The further protective covering in the form of a wire gauze is then fastened to the blade in the manner described above. By means of the wire gauze *c* the strip of metal *g* is firmly secured on the wooden propeller blade, so that strip *g* cannot become detached.

The application of the wire gauze protection can be carried out in a single operation.

In the protection of wooden propeller blades or other parts of wooden propellers according to the invention it is of particular importance that the surface of the wooden blade is not connected with the wire gauze by means of a flat surface, but forms a lattice-like connection with the individual wires, and that the intervening layer of elastic adhesive forms a cushion, which resiliently transmits the elastic changes of form of the wooden blade caused by vibrations during the operation of the propeller, to the individual flexible wires of the gauze without detrimental effect on the latter. The metal layer *f* does not interfere with the elastic properties of the wire gauze after the latter has been glued on. When the wire gauze is partly ground off in order to apply a layer of metal, interrupted latticelike metal lines are produced at the protruding parts of the wire gauze, on which the metal is deposited and so forms the covering layer of metal. The wires which adjoin the points of intersection have, owing to their elasticity, a cushion-like effect, so that the wooden blade is connected with the thin layer of metal on the outside by two cushioning layers consisting of the adhesive on the one hand and the wire gauze on the other. Besides the layer of metal may also possess a certain amount of elasticity. By thus avoiding a flat connection between the metal layer on the exterior and the surface of the wooden blade any loosening of the layer of metal or bursting (due to fatigue of the metal) in consequence of the vibrations and movements of the airscrew propeller is avoided.

The transparency of the adhesive has the advantage of making it easily possible to examine the condition of the metal reinforcing and the wood of the propeller, which is particularly important in military aircraft. The adhesive has the further advantage that after the completion of the hardening it will not take up moisture at all or only to a very slight extent, that is, it is moisture repellent.

Steel wire gauze is the preferred embodiment of foraminous, flat reinforcing metal.

The forward edge of the blade, instead of being made of metal may also consist of a yieldable material which has the advantage that hard bodies striking the forward edge are resiliently thrown off and that, furthermore, the masses and, therefore, the centrifugal forces remain smaller. Rubber, especially artificial rubber, which is less sensitive to operating liquids such as mineral oils, gasoline, or the like, which, however, is extremely difficult to cement, is a particularly suitable elastic material for the purpose.

The artificial rubber which is resistant to the usual operating liquids is fastened to the wood of the propeller by gluing it on directly by means of the elastic adhesive referred to above, which is used in a non-hardened condition and to which carbon tetrachloride is added. The latter produces a small amount of swelling of the said artificial rubber which is useful in producing a satisfactory adhesion. Instead of carbon tetrachloride other chlorinated aliphatic compounds may be used, for instance ethylene chloride and similar compounds, especially compounds which are capable of swelling the said artificial rubber. The swelling agents for natural rubber cannot be used for this purpose.

A suitable composition consists for instance of 100 cc. of a dilute solution of the above mentioned synthetic resin to which alcoholic boric acid is added and further 5 cc. of a 1% solution of one of the above mentioned hardening agents and 30 cc. of carbon tetrachloride. When the solution of synthetic resin is mixed with carbon tetrachloride the mixture sometimes becomes turbid, but such turbidity disappears when the alcoholic solution of the catalytic agent (e. g. alkyl sulfate, alkyl chloride) is added, so that the adhesive finally forms a clear solution. The synthetic resin solution may contain a single synthetic resin or it may consist of a mixture of several of the synthetic resins above referred to. If it is intended to produce a comparatively soft product, which does not substantially differ from the properties of rubber, softening agents are added to the mixture in sufficient quantities.

When using these softening agents it is known to be of importance that they possess as high a boiling point as possible so that they do not evaporate to any extent, and further that they do not gradually crystallize. If desired inorganic pig-

ments may be added to the adhesive, but such addition is not indispensable.

As softening agents there may also be added to the adhesive natural drying oils such as linseed oil, also tricresyl phosphate, diphenyl chlorinated in the nucleus which is resistant to alkali and acids, further the so called T-oil which consists of synthetic hydrocarbons of high molecular weight. Finally there may be used as softening agents the so called "Alkydales" which consist of resins containing phthalic acid.

In order to accelerate the hardening very dilute alcoholic solutions of hydrochloric acid may also be used, also alcoholic solutions of sulfurous acid, dilute ethyl sulfate and the like. Substances are preferably used which liberate acid by cleavage and the acid of which is volatile so that it gradually disappears by evaporation when the hardening has taken place. The softening agents are used in quantities which vary between 20 and 70%.

The adhesive of the present invention produces a very strong adhesion between such artificial rubber and artificial rubber and between other structural materials, especially wood. Such adhesion is both durable and resistant to mineral oils. The adhesive has the further advantage that it is resistant to heat up to temperatures of 200° C. and over.

The gluing is carried out by applying the solution of the adhesive to the surfaces to be glued together. It is then allowed to evaporate at room temperature until it is found that dust no longer adheres to the coated surfaces. The surfaces are then joined together at room temperature and kept under pressure for about 12 hours. Complete adhesion is effected at normal temperature in about 6 days, but at a raised temperature, for instance at 70° C., complete adhesion takes place in about 6 hours. It is of importance that the surfaces to be glued together are previously thoroughly degreased, which can conveniently be effected by means of carbon tetrachloride.

In order to protect the protective covering made of such artificial rubber, or if desired of natural rubber, against the influence of the sun, the rubber covering is coated with an aluminium lacquer after it has been attached to the wood of the blade by means of the above mentioned adhesives. In order to obtain a smooth outer layer it is further coated with a layer of cellulose lacquer.

In the constructions of Figures 7 to 11 *a* indicates the wood of the propeller and *c* is preferably a fine meshed tissue of very thin high grade steel wire having a diameter of for instance 0.01 mm. This tissue *c* covers the front and rear faces of the blade and at the rear edge *c'* of the blade it is mechanically connected for instance by soldering. The wire tissue *c* is firmly secured on the wood *a* by completely imbedding it in a layer *d* of the above mentioned adhesive of permanent elasticity. The layer *e* consists of a glazing of self hardening synthetic resin or of cellulose lacquer or the like.

According to Fig. 7 the layer of adhesive *d* and the metal covering *c* on the front and rear faces of the blade terminate in the direction of the leading edge at c^2, the metal being suitably secured to the wood at this point for instance by pressing the metal tissue or wires into the wood. The leading edge is covered with a layer *m*, of rubber of preferably artificial nature resistant to operating liquids, which is directly glued onto the wood of the blade by means of one of the above mentioned adhesives. The rubber layer *m*, which corresponds to the profile of the blade, tapers off laterally and covers the adhesive layer *d* which also tapers off, so that the joints between the two layers are completely covered up, as shown in Fig. 10. Thereupon the rubber is ground off to produce the exact profile and it is then covered with a layer *n* of aluminium lacquer. The final outer layer consists of a glazing *e*.

In the constructions of Figures 8 to 11 the protective metal covering *c* also surrounds the front edge of the blade and passes through the rubber layer *m*. The imbedding of the metal tissue *c* in the layer of adhesive *d* also terminates at c^2.

According to Figs. 8 and 10 the coating of adhesive is applied to the blade wood *a* by means of the protective metal covering. The application of the rubber layer *m* is effected by applying the rubber from the outside to the metal tissue and then pressing it strongly against the wood for instance by winding cloth over the parts to be connected or by applying rubber bands. The winding of cloth over the parts to be connected may also be used for securing the necessary pressure in the construction of Fig. 7. By exercising strong pressure the rubber *m* is pressed through the meshes of the thin metal tissue to the wood, so that the latter becomes strongly attached and constitutes a carrier. The adhesive glues the rubber firmly onto the protective metal covering *c*.

In the construction of Fig. 9 the wire tissue *c* is first firmly imbedded in the rubber *m* by placing it beneath the outer rubber layer m^1 or between two rubber layers m^1, m^2, the adhesion between the rubber and the metal or between rubber, metal and rubber being secured by gluing. The imbedding of the wire tissue between the two rubber layers may also be effected by vulcanisation. The protective tissue prepared in this manner is then stretched over the wooden blade and the parts of the tissue which are not provided with rubber are imbedded in the adhesive *d*, the gluing of the rubber layer *m* with the wood *a* being, if desired, dispensed with. In the constructions of Figs. 8–10 the rubber layer is also ground off and covered with a layer of aluminium lacquer *n*. Finally the exterior is coated with a glazing *e*.

The last mode of execution enables the protective tissue *c* provided with the edge protection of rubber to be kept in store. Fig. 11 represents part of a tissue which is ready for use. The strip *m* for protecting the edge of the blade ends in a flap m^3, which is intended to cover the point of the blade.

By using thin high grade steel wire it is possible to produce an exceedingly thin and light protective covering and nevertheless to increase the resistance of the blade wood against splitting or chipping. At the same time the protective effect generally of the protective covering is increased.

What we claim and desire to secure by Letters Patent of the United States is:

1. A wooden propeller blade which is covered throughout on at least its trailing edge and its opposite faces with perforated flat reinforcement metal, the metal being cemented directly to the wood of the blade by means of an adhesive of permanent elasticity, said adhesive consisting of a mixture of preferably already partially-hardened dissolved hardenable artificial resin with a saturated solution of boric acid in alcohol, and the surface of the adhesive lying above the

reinforcing metal being provided with a hard layer of glazing.

2. A wooden propeller blade which is covered throughout on at least its trailing edge and its opposite faces with perforated flat reinforcement metal, the metal being cemented directly to the wood of the blade by means of an adhesive of permanent elasticity, said adhesive consisting of a mixture of preferably already partially-hardened dissolved hardenable artificial resin with a saturated solution of boric acid in alcohol, said adhesive containing also a softening agent selected from the group consisting of polymerization products of vinyl acid esters and containing an alkyl sulfate as a hardening agent of the artificial resin, the surface of the adhesive lying above the reinforcing metal being provided with a hard layer of glazing.

3. A wooden propeller blade which is covered throughout on at least its trailing edge and its opposite faces with perforated flat reinforcement metal, the metal being cemented directly to the wood of the blade by means of an adhesive of permanent elasticity, said adhesive consisting of a mixture of preferably already partially-hardened dissolved hardenable artificial resin with a saturated solution of boric acid in alcohol, the surface of the adhesive lying above the reinforcing metal being provided with a hard, smooth, layer of glazing, consisting of a diluted self-hardening artificial resin glaze, which acquires a high lustre when hardened.

4. A wooden propeller blade which is covered throughout on at least its trailing edge and its opposite faces with perforated flat reinforcement metal, the metal being secured to the wood in part by being embedded in the wood of the blade and in part by being cemented directly to the wood of the blade by means of an adhesive of permanent elasticity, said adhesive consisting of a mixture of preferably already partially-hardened dissolved hardenable artificial resin with a saturated solution of boric acid in alcohol, the surface of the adhesive lying above the reinforcing metal being provided with a hard layer of glazing.

5. A wooden propeller blade which is covered throughout on both the leading edge and the trailing edge and on its opposite faces with perforated flat reinforcement metal, the metal being cemented directly to the wood of the blade by means of an adhesive of permanent elasticity, said adhesive consisting of a mixture of preferably already partially-hardened dissolved hardenable artificial resin with a saturated solution of boric acid in alcohol, the surface of the adhesive lying above the reinforcing metal being provided with a hard layer of glazing, and an additional protective body of sheet metal interposed between the reinforcement and the body of the blade at the said leading edge, said additional protective body of sheet metal being cemented securely to the body of the blade.

6. A wooden propeller blade which is covered throughout on both the leading edge and the trailing edge and on its opposite faces with a narrow-meshed fabric made of high quality thin steel wire, the said metal fabric being cemented directly to the wood of the blade by means of an adhesive of permanent elasticity, said adhesive consisting of a mixture of preferably already partially-hardened dissolved hardenable artificial resin with a saturated solution of boric acid in alcohol, the surface of the adhesive lying above the reinforcing metal fabric being provided with a hard layer of glazing.

7. A wooden propeller blade which is covered at least on its two faces and on its trailing edge with thin steel wire gauze, the gauze being cemented directly to the wood of the blade by means of an adhesive, which is permanently elastic, transparent and water-repellent and whose surface lying over the metal is provided with a hard glazed layer.

8. A wooden propeller blade which is covered at least on its two faces and on its trailing edge with thin steel wire gauze, the gauze being cemented to the wood of the blade by means of an adhesive, which is permanently elastic, transparent and water-repellent and whose surface lying over the metal is provided with a hard glazed layer, the leading edge of the blade of the propeller having a covering of artificial rubber, resistant to oil and gasoline, also cemented to the wood by means of such adhesive.

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