June 11, 1935. D. A. DICKEY 2,004,102

HOLLOW STEEL PROPELLER CONSTRUCTION

Filed Feb. 24, 1932 2 Sheets-Sheet 1

FIG. 1

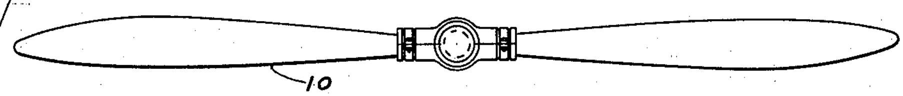


FIG. 2

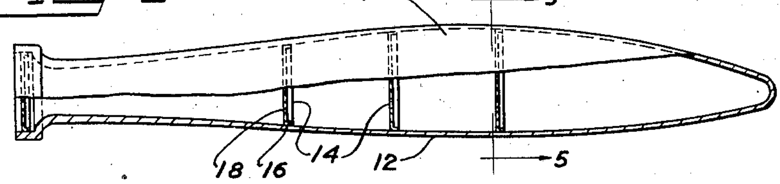


FIG. 3

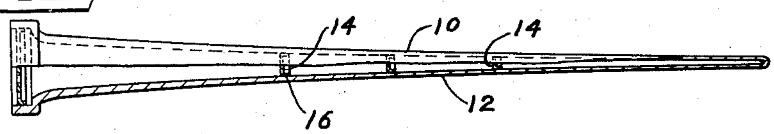


FIG. 4

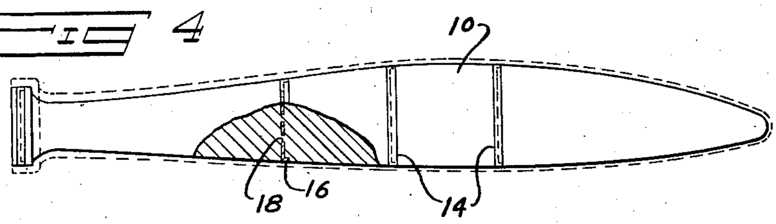


FIG. 5

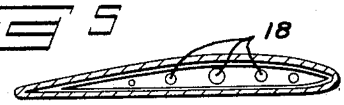
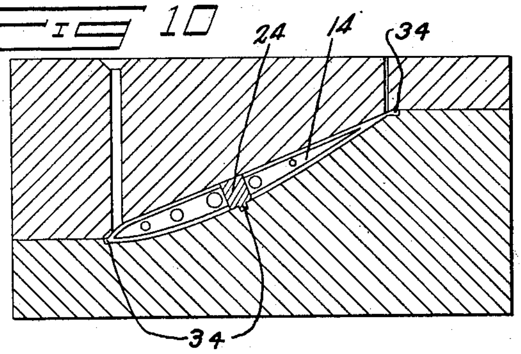


FIG. 10



INVENTOR
DANIEL A. DICKEY.
BY *Francis H. Vanderwerker* and *Wade Koontz*
ATTORNEYS

June 11, 1935. D. A. DICKEY 2,004,102

HOLLOW STEEL PROPELLER CONSTRUCTION

Filed Feb. 24, 1932 2 Sheets-Sheet 2

FIG 6

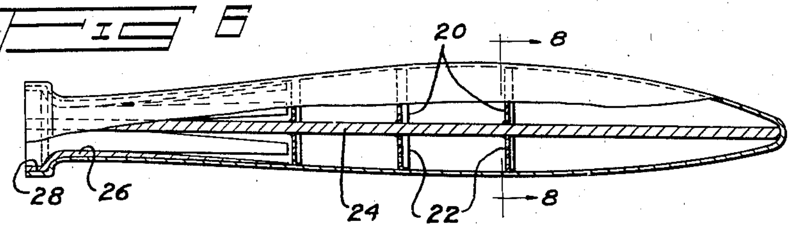


FIG 7

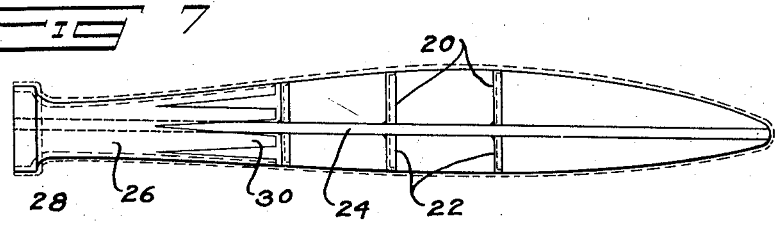


FIG 8

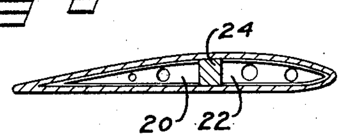
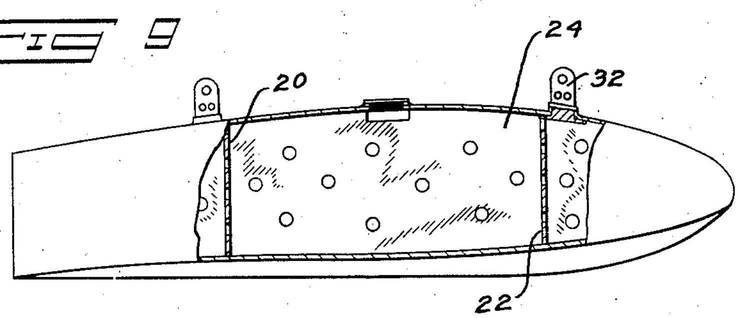


FIG 9



INVENTOR
DANIEL A. DICKEY.
BY *Francis H. Vanderwerker* and *Clade Koontz*
ATTORNEYS

Patented June 11, 1935

2,004,102

UNITED STATES PATENT OFFICE

2,004,102

HOLLOW STEEL PROPELLER CONSTRUCTION

Daniel A. Dickey, Dayton, Ohio

Application February 24, 1932, Serial No. 594,935

9 Claims. (Cl. 170—159)

(Granted under the act of March 3, 1883, as amended April 30, 1928; 370 O. G. 757)

The invention described herein may be manufactured and used by or for the Government for governmental purposes, without the payment to me of any royalty thereon.

This invention relates to a novel method of and means for producing hollow articles of manufacture and by which structural members, that serve as supporting and/or attaching means for the hollow article, are incorporated therein and constitute a part thereof. My invention is particularly applicable to and in the manufacture of devices that are subject to severe stresses and strains, but which are designed to have the least possible weight per unit of strength. Especially is my invention useful in the manufacture of hollow metal propellers and hollow metal floats for use in connection with aircraft.

In the construction of hollow propellers of large size or of short propellers of wide and thick cross-section, some type of internal support against collapse is necessary if undue weight of outer shell is to be avoided. The area or external surface of a propeller blade must be large enough to develop the necessary air loads. Due to the cantilever nature of a propeller blade and to the action of centrifugal force the total loading of the cross-sections of a blade are progressively accumulative from the tip to the root. A blade covering too weak to carry more than sectionalized loads may be employed if an internal structure is supplied to carry the accumulated loads. Coverings that can readily be applied to surfaces of complex curvature are, as a rule, too weak to carry economically (from the standpoint of weight) accumulated loads, whereas coverings favorable in strength to carry accumulated loads are very difficult to form to a complex curvature. In the latter case the forms of the surfaces must be compromised in design to favor the application of the covering. By the utilization of an internal structure or framework designed to carry the accumulated loads, the surface loads may be carried sectionally by the covering which may be of a material with good forming properties but of less pronounced strength.

It is well known that by the process of electrolytical deposition of metal, such as iron, shells or sheets can be produced of the following characteristics:

a. Iron of high purity and of evident non-corrosive properties;

b. Surfaces of any produced complexity of curvature—such as required in propeller blades;

c. Controllable to any gradation of thickness—a matter of extreme importance in the production of parts for use in airplanes;

d. The deposit will adhere to certain other materials with a tenacity of bond equivalent in strength to that of the deposited material itself.

In accordance with my invention, a suitable core material and a structural part of the article to be manufactured are either permanently or temporarily secured together to constitute a composite core structure of suitable configuration about which a metallic material, such as iron, is chemically or electrolytically deposited and to a certain extent to produce or develop a hollow metal article in which the deposited material constitutes a shell or covering that is of sufficient strength to carry the surface loads to which the article may be subject and unites with the structural part in such manner that accumulated loads of the article are transmitted to the structural part.

I have shown and described my invention, by way of one example, as applied to a propeller preferably of the type having separate blades, each independently attached to a hub through the medium of a stalk on the said blade, which engages a socket in the hub.

In accordance with one embodiment of my invention, I produce a novel propeller by providing a composite core structure of suitable configuration to the development of a propeller blade and consisting preferably of a low-melting-alloy, and a plurality of spaced transversely disposed structural parts of the propeller to which the alloy is caused to adhere by appropriate means and with which it is so arranged as to expose a portion of the structural part without the surface of the alloy so that by the electrodeposition of a metal to the composite core structure a propeller shell or covering is formed about the core, which covering, by means of the manner of application and the relative arrangement of the alloy and part, becomes suitably jointed with the structural part or framework. My invention contemplates the complete removal of the low-melting-alloy and to this end suitable provision is made, such as openings within the structural part or framework, to allow the escape of the alloy or other suitable readily removable material from within the blade and through the open end thereof. In the forming of the composite structure the alloy material is caused to flow in and fill the openings of the structural part and in this manner effect a bonding therebetween. The structural parts are preferably so designed and so disposed that the peripheral surface merges with the surface of the alloy to produce a surface corresponding in contour to the desired contour of the blade.

In another novel construction of propeller of this type, the blade is formed with a longitudinal structural member and transverse members constituting the framework, by my novel method of first, producing a composite core structure of the low-melting-alloy and the structural members or framework and, thereafter, simultaneously forming a shell about the core by the electrodeposition of a metallic material and bonding the deposit to the structural member to thereby consolidate them. The composite core structure in this instance is formed by securing said longitudinal member between pairs of aligned transverse web members and filling the interstices between the longitudinal and transverse members with a low-melting-alloy. The structural members are arranged within the core structure, that is of a desired blade conformation, in such manner as to be capable of uniting or consolidating with the material as it is being electrodeposited about the core to produce a stiff internally braced blade, which in addition to possessing the inherent characteristics of an electrodeposited material, will rigidly resist compression as well as tension stresses and particularly torsion stresses.

Other novel features of my invention will become apparent from the detailed description and I will now proceed to describe the several forms or embodiments of my invention, which are illustrated in the drawings forming a part of this application.

In the drawings:

Fig. 1 is a diagrammatic illustration of a propeller embodying my invention;

Fig. 2 is a part sectional plan view of a blade detached from the propeller shown in Fig. 1;

Fig. 3 is a part sectional front elevational edge view of the blade shown in Fig. 2;

Fig. 4 is a plan view of a propeller blade core showing parts of the core in section and the propeller blade shell in phantom;

Fig. 5 is a cross-sectional view taken on the line **5—5** of Fig. 2;

Fig. 6 is a plan view similar to Fig. 2 showing a further embodiment of my invention;

Fig. 7 is a plan view of the core that is used in the construction of the blade shown in Fig. 6, showing the shell of the blade in phantom;

Fig. 8 is a cross-sectional view taken on the line **8—8** of Fig. 6;

Fig. 9 is a part sectional, side elevational view of a flotation device in which my invention is embodied; and

Fig. 10 is a cross-sectional view of a mold showing lugs on members and recesses in the mold.

Similar reference characters will be used to designate similar parts throughout the several views of the drawings.

In Figs. 2 to 4 inclusive I have shown a hollow metal propeller blade **10**, that comprises essentially a shell or covering **12** and a plurality of spaced web members **14**, that are vertically disposed transversely with respect to the longitudinal axis of the propeller. Each web is laterally shaped from strips of flat thin material, such as sheet iron, to provide a flange **16** about the peripheral edge and to present a contour or outline corresponding to the desired cross-sectional outline of the blade at the point where the web is located. The webs are designed of sufficient strength that when incorporated within the shell of the blade, they will resist distortion in any crosswise direction. Openings **18** are provided in the webs and serve a three-fold purpose, one of which is to lighten the structure; the remaining two will become apparent as the description proceeds.

The shell or covering **12** has a varying thickness in cross-section throughout the entire length of the blade, each section being of such thickness and form as to be commensurate with the magnitude and character of the load imposed thereon. The shell is formed about the webs and secured thereto in a manner to provide a plurality of cells whereby to sectionalize the load of the shell so that the load on the shell area of each cell is transmitted to its corresponding cell framework as hereinafter described.

Figs. 6, 7 and 8 show a variation from the construction shown in Figs. 2 to 4, in that each transverse web member **14** is made of two parts **20** and **22**, between which is disposed a longitudinal member **24** of graduated areas in cross-section, that is preferably formed from a bar of metal such as iron into a shape corresponding to the desired longitudinal cross-sectional outline of the blade at the point where the longitudinal member assumes its position within the blade. There is also provided a tapered sleeve **26** having at its outer end an annular shoulder **28** and at its inner end a series of fingers **30**.

The outer end of the sleeve serves to provide additional strength to the stock end of the blade and lends itself to the provision of means for attaching to the hub. The fingers on the inner end of the sleeve afford greater ease of forming this portion of the sleeve to a contour corresponding to that of the shell and provide a gradual blending of the strength of the stock end into the adjacent portion of the blade.

In this embodiment the wall thickness of the shell is substantially uniform throughout its entire length. The internal bracing structure, consisting of the inner sleeve and the longitudinal and transverse members, cooperates with the shell in such a manner that accumulated loads are transmitted mainly through the bracing structures.

A further variation of my invention is shown in connection with a flotation device for an aircraft as shown in Fig. 9, and it differs from the other above embodiments in that the shell or covering for the flotation device completely encloses and unites with the structural members that provide an internal bracing medium to prevent the collapsing of the walls of the covering and also in that it embraces the incorporation of another type of structural element, such as attaching fittings **32**. These fittings protrude upwardly from the shell and are rigidly bonded therewith in a manner similar to and simultaneously with the bonding of the covering to the longitudinal structural member **24** and the transverse structural members **20** and **22**. The fittings are preferably attached rigidly to the longitudinal member and project upwardly therefrom.

In accordance with a preferred method of manufacturing the above described embodiments, a composite core structure is formed by providing a metallic mold, with smooth internal surfaces, in which to cast the composite core. The mold is provided with means, such as recesses or dowels, by which to secure members that are to form a part of the composite core. Referring to Fig. 10 by way of example, these members shall be the longitudinal member 24 and the transverse members 14. Each of these members is provided with several protruding lugs 34, which, by being engaged in the recesses provided therefor in the mold, hold the members accurately in place. After the members are placed and the mold has been closed, the molten metal, preferably an alloy with a relatively low melting point—such as 80 parts tin, 80 parts bismuth, and 120 parts lead, with a melting point of about 132° C.—is forced into the mold. After solidification, the core is removed from the mold and the lugs, which in this case protrude beyond the main surface of the core, are ground away and polished until the core surface is regular and smooth. The entire core surface is then suitably cleaned for the electrodeposition of the metal shell.

This core is then suspended as the cathode in a heated bath containing about 40 oz. ferrous chloride ($FeCl_2 4H_2O$) and from 15 oz. to 45 oz. calcium chloride ($CaCl_2$) per gallon of solution, the remainder of the solution being water excepting a slight amount of free hydrochloric acid (HCl), giving a pH of about 2. The temperature of the bath is about 90° C. In the same bath and surrounded by porous filtering diaphragms are iron anodes of rather high degree of purity, 99.85% Fe. With a current density on the cathode—the core—of from 50 to 65 amperes per square foot the iron from the anodes is built up on the cathode, the thickness and distribution of thickness being controlled by means well known to the art. The quality of the deposit is improved by agitation, such as moving the cathode up and down, throughout the period of deposition.

When the deposit has attained the desired thickness, the core with its deposited shell is removed from the bath, cleaned, and heated to a temperature sufficient to melt the alloy of the core, which is permitted to drain out through the holes provided, in part, for this purpose. This leaves the hollow article, in this example a propeller blade, with the internal members or framework that had previously constituted a part of the core, now forming a part of the finished article through the bonding (or union) of the deposited material to the exposed parts of the members. It is to be noted that the melting temperature of the alloy is low enough to have no detrimental effect upon the deposited shell and the internal members.

From this point on the blade may be subjected to processes of heat-treating and machining as are pertinent to the desired refinement of the article. Plating with nickel, chromium, or other finishes may be effected before or after the removal of the core.

It is desired to be understood that the propellers and flotation device shown and described constitute but a few of many embodiments of my invention, and is not to be taken as definitive or for any other purpose than that of illustration. It is also desired to be understood that while I described in the method of producing a hollow article, an entirely metal core, a part of which is removable, it will be obvious to those skilled in the art that non-conducting materials may be used in conjunction with the structural members to form the composite core structure, in which case the surface of the non-conducting material is suitably prepared in a well-known manner for the electrodeposition of the shell. It is obvious that my invention and its various features may be embodied in various other forms and constructions and my invention is to be understood as limited only to such features or structures as are clearly defined in the appended claims.

I claim:

1. A propeller blade comprising, a shell having a relatively thin wall cross-section and an open framework, said shell and framework being continuously consolidated at all points of contact to provide a cellular structure substantially throughout the width and length of a portion of said blade, the areas of consolidation between said shell and framework being such that substantially the entire load on the shell area of each cell is imposed upon its corresponding framework.

2. A propeller blade comprising, a metal shell having a relatively thin wall cross-section throughout substantially the length thereof and an open framework, said metal shell and framework being consolidated to provide a cellular structure substantially throughout the width and length of a major portion of said blade, the shell of each cell being continuously consolidated along the perimeter of its corresponding framework so as to effect an efficient distribution of the load thereon.

3. A propeller blade comprising, a metal shell of relatively low strength quality and having its wall cross-section relatively thin substantially throughout the length thereof, and an open framework, said shell and framework being consolidated to provide a cellular structure substantially throughout the width and length of a major portion of said blade, the shell of each cell being continuously consolidated along the perimeter of its corresponding framework so as to effect an efficient distribution of the load thereon.

4. A propeller blade comprising, a metal shell of relatively low strength quality, and having its wall cross-section of uniform thickness throughout substantially the length thereof and an open framework of relatively high strength quality, said shell and framework being continuously consolidated at all points of contact to provide a cellular structure substantially throughout the width and length of a major portion of said blade, the areas of consolidation between said shell and framework being such that substantially the entire load on the shell area of each cell is imposed upon its corresponding framework.

5. A propeller blade comprising, a metal shell having a relatively thin wall cross-section throughout substantially the length thereof and an open framework, including a longitudinal spar extending from tip to root of said blade and a plurality of transverse spars disposed in spaced relation along the length of said longitudinal spar, each of said transverse spars forming with said longitudinal spar the cross-sectional outline of said blade, said shell and framework being consolidated to provide a cellular structure substantially throughout the width and length of a major portion of said blade, the shell of each cell being continuously consolidated along the perimeter of its corresponding framework so that substantially the entire load on the shell area of each cell is imposed upon the efficiently distributed over its corresponding framework.

6. A propeller comprising, a blade in which a metal shell is electrolytically deposited on and continuously consolidated with an open metal framework that constitutes the form for the cross-sectional outline of said blade to provide

therewith a cellular blade structure substantially throughout the length and width of said blade; the areas of consolidation between the shell and frame portions of each cell being such that substantially the entire load on the shell area of each cell is imposed upon its corresponding framework.

7. A propeller comprising, a blade having a shell made of an electrodeposited material and an open framework including a longitudinal metal spar member of graduated area in cross-section and transverse metal members extending from the sides of said spar, said shell and said framework being consolidated to provide a cellular structure in which a plurality of cells are disposed on opposite sides of said longitudinal spar member, each cell having its frame and shell portions consolidated over a sufficient area such as to effect an efficient distribution of the load of the shell area within each cell to its corresponding framework to thereby sectionalize the load on the shell substantially throughout its entire area.

8. An article of manufacture comprising, a thin metal shell of relatively low strength quality and an open framework having an outline corresponding to that of the manufactured article disposed within said shell, said framework being consolidated with said shell to provide a plurality of cells, each cell being consolidated with its corresponding framework over a sufficient area respectively so as to effect an efficient distribution of the load thereon.

9. An article of manufacture comprising, an open framework, a thin metal shell of relatively low strength quality electro-deposited on said framework, said framework being continuously consolidated with said shell at all points to provide a plurality of cells, each cell being consolidated with its corresponding framework over a sufficient area respectively so as to effect an efficient distribution of the load thereon.

DANIEL A. DICKEY.