

Feb. 23, 1943.

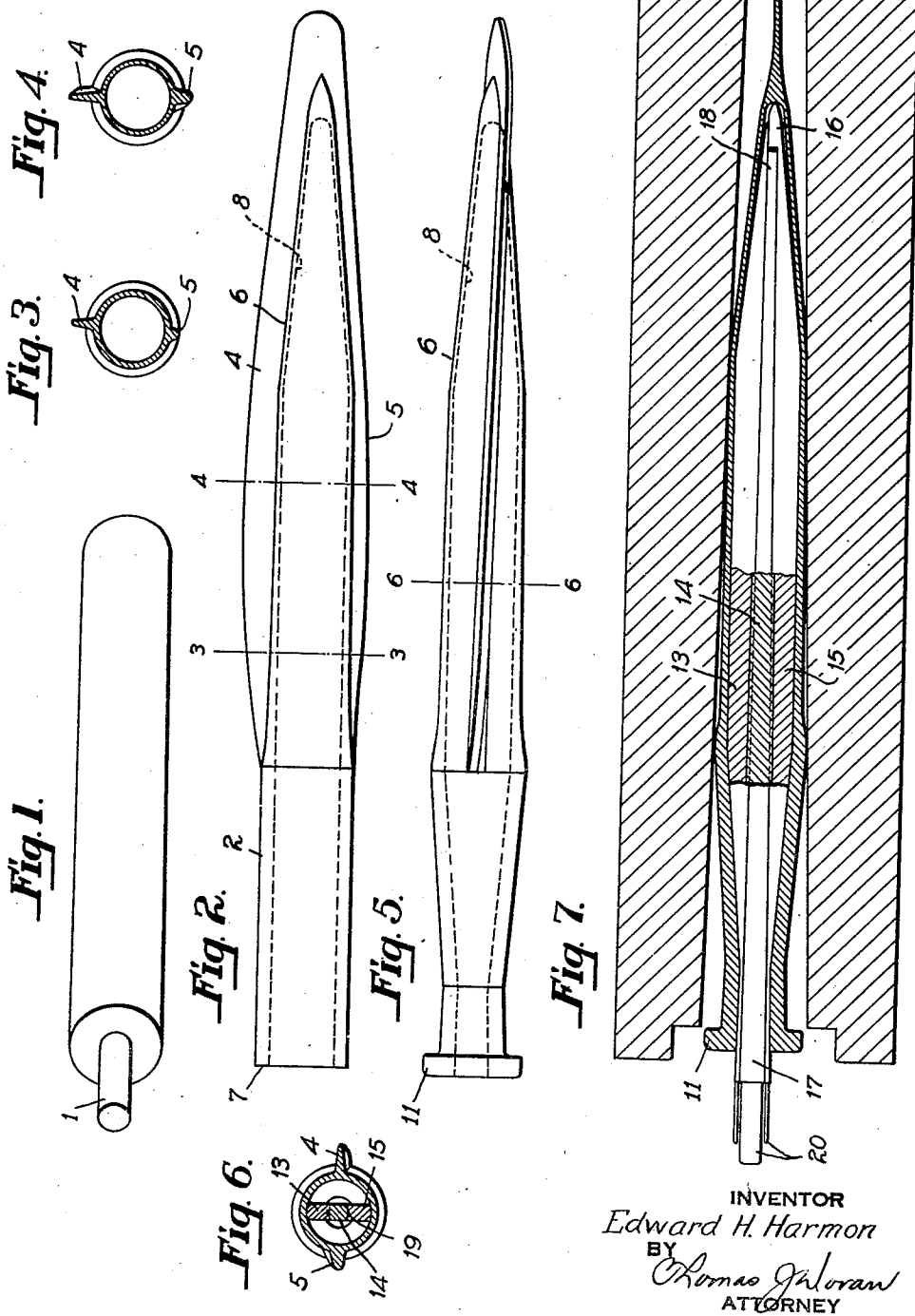
E. H. HARMON

2,312,094

METHOD OF MAKING HOLLOW PROPELLERS

Filed July 25, 1939

2 Sheets-Sheet 1



Feb. 23, 1943.

E. H. HARMON

2,312,094

METHOD OF MAKING HOLLOW PROPELLERS

Filed July 25, 1939

2 Sheets-Sheet 2

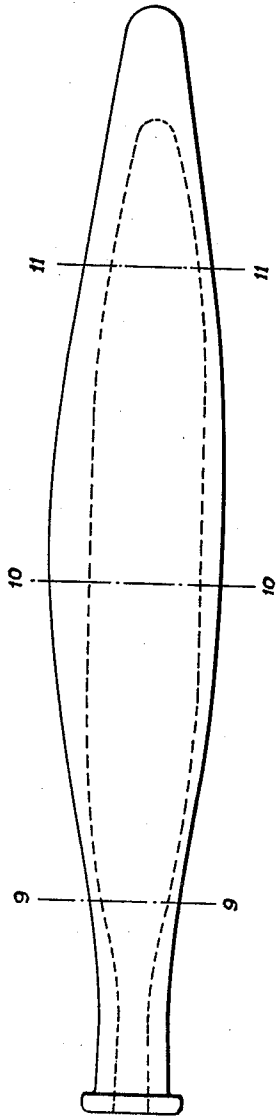


Fig. 8.

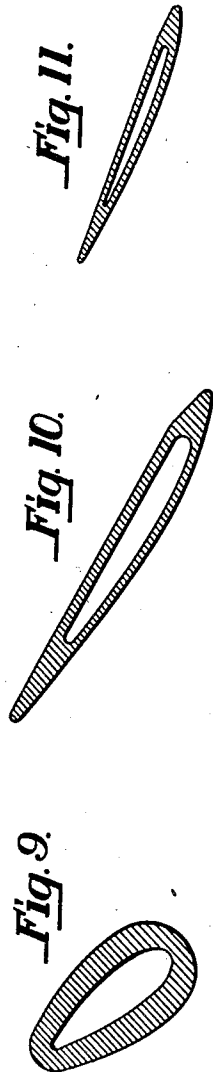


Fig. 9.

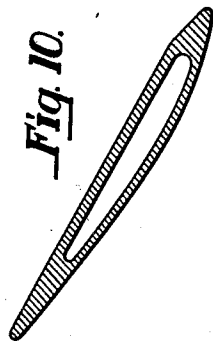


Fig. 10.

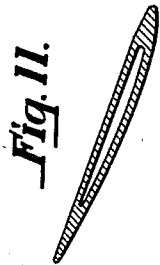
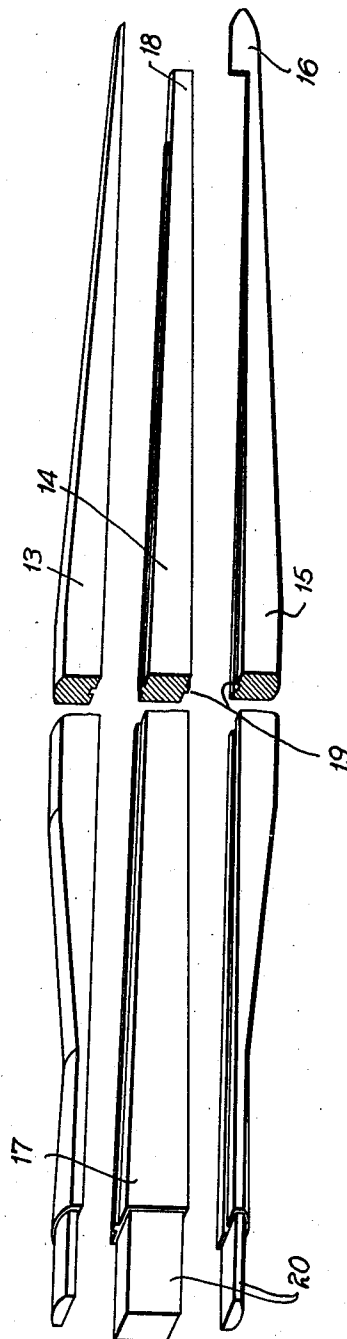


Fig. 11.

Fig. 12.



INVENTOR
Edward H. Harmon
BY
Thomas J. Moran
ATTORNEY

UNITED STATES PATENT OFFICE

2,312,094

METHOD OF MAKING HOLLOW PROPELLERS

Edward H. Harmon, Lakewood, Ohio, assignor to
Aluminum Company of America, Pittsburgh,
Pa., a corporation of Pennsylvania

Application July 25, 1939, Serial No. 286,396

1 Claim. (Cl. 29—156.8)

This invention relates to a method of forming hollow metallic articles and more particularly to a method of forming hollow metallic propeller blades for aircraft.

Many aircraft propeller blades have heretofore been made of aluminum or other light metal alloy stock. Light metal alloys are particularly well suited for such propellers because they provide the necessary strength and airfoil section with a minimum weight, which is desirable not only from the standpoint of total weight of the aircraft, but also in reducing the centrifugal loads.

The most successful metal airplane propeller blades heretofore made have been those made of light metal alloys and fabricated by means of apparatus and methods such as those disclosed in U. S. Patents Nos. 1,957,499, 2,044,293, 2,044,294, and 2,044,295. Many efforts have been made, however, to further reduce the weight of the propeller blades in proportion to their length and airfoil section without sacrificing the necessary strength to carry the various centrifugal, thrust and vibratory loads to which the blades are subjected.

A reduction of the weight of metal propeller blades in proportion to their size, while maintaining the necessary strength, durability, fatigue resistance and uniformity has been accomplished by designing and making blades in accordance with the following method. This method consists in forming a blank tapering generally from the end which is to form the hub to the end which is to form the tip of the blade, and with sufficient cross-sectional area at each point in its length to provide the necessary metal for the finished blade and with non-uniform wall thickness, and then forging or pressing the blank to blade form, with laterally projecting fins along opposite sides of the blank. After the preliminary forging steps described, the main body of the blank is hollowed out in any desirable form, the internal hole being subsequently partially flattened out to conform substantially to the external contour of the finished blade forging.

However, some difficulty has been experienced in the fabrication of sound propellers by this method because of the inadequacy of support of the interior walls of the hollow blank when in the process of being formed into propeller shape. If the thin walls of the blank are not properly supported when the pressure of the forming tool is applied, there is a tendency for the walls to collapse or otherwise not conform to the contour of the dies. A number of methods of giving internal support to the walls of hollow propeller blanks have been proposed in the art at various times, but none has proved entirely satisfactory.

The principal object of the present invention is to provide a method of forming hollow metallic articles from hollow blanks, in which internal

support is given to the walls of the hollow blank by a mandrel during the forming operation. Another object of my invention is to provide a method of giving internal support to the walls of a hollow propeller blank by a mandrel during the forming operation, thereby causing the wall to conform to the contour of forming dies.

In connection with my invention a blank is preferably formed from a billet which has been rolled or extruded. The blank is first tapered towards the end which will eventually be the tip end of the propeller blade. In this tapering operation at least a portion of the billet is given a roughly conical shape, with the small end at the end which will form the tip of the blade and with sufficient cross section of metal throughout the length of the tapered portion to form the corresponding cross section of the finished blade. Preferably a substantial length of the billet is left in its original shape in this operation, and this portion ultimately becomes the shank and hub end of the blade. The tapering operation may be performed in any way so far as the present invention is concerned, but preferably by mechanical deformation in accordance with the process disclosed and claimed in U. S. Patent No. 2,044,293.

The tapered billet is next mechanically deformed so as to provide ears or fins disposed longitudinally along the tapered portion, which fins ultimately become the leading and trailing edges of the propeller blade. An internal hole or recess is formed throughout the major portion of the length of the blank, either by piercing or boring, or suitable combination of such operations, which hole is preferably substantially circular in cross section and tapers towards the tip end of the blank. The non-circular external contour of the blank and the circular hole combine to provide nonuniform walls in the blank.

The shank end of the hollow blank may be made of greater diameter than is ultimately necessary or desirable with the particular blade size so that the above-mentioned hole may be made of uniform diameter through the shank and into the blade portion. The shank end of the blank is then swaged or otherwise worked to reduce its diameter and increase the wall thickness while maintaining approximately a circular cross section. The shank end is thereby brought to the desired size with respect to the blade portion while retaining sufficient wall thickness to adequately carry the centrifugal and bending loads to which it is subjected. This operation also works the shank and hub portions of the blank which would be left unworked by the later forming steps, thereby making the amount of working more uniform throughout. The swaged shank end of the blank is preferably machined inside and out to bring it substantially to the rough

finished dimensions and true up the outside and inside surfaces which may be distorted by the swaging operation. Preferably before the final shaping of the blank, a flange is upset on the shank end.

The final rough shaping of the propeller blade may be carried out by any suitable method of working, as, for instance, forging, rolling, pressing, or swaging.

The principal feature of my invention resides in the manner by which the internal walls of the hollow propeller blank are supported during the forming operations. A mandrel of a relatively low melting point metal is inserted in the hollow propeller blank in such a manner that it contacts opposite internal walls in the plane of movement of the deforming means, thereby forming a partition-like support extending the entire length of the hole in the blank. Since the opening through the shank into the hole is ordinarily somewhat smaller than the portion of the hole in the blade portion of the blank, the mandrel is composed of a number of parts which may be inserted into the hole separately through the shank opening. The mandrel may be of any metal having a melting point lower than the metal of the blank and sufficient strength to give adequate support to the walls of the blank, yet having sufficient ductility to permit deformation beneath the forming dies. When the mandrel is inserted in its proper place in the hole, it forms a partition extending the full length of the hole but leaves a precalculated unoccupied area on either side which will be substantially taken up during the subsequent forming operation. The mandrel, while in this position, forms a rigid core which gives sufficient resistance to the pressure of the forming dies to prevent the blank walls from collapsing or otherwise not conforming to the contour of the dies. As the forming operation proceeds, the mandrel, while continuing to give support to the internal walls of the propeller blank, is deformed and compressed until the unoccupied area within the blank is substantially or entirely removed. The cubic content of the metal comprising the mandrel is calculated to substantially occupy the hole in the propeller blade after the desired amount of deformation. After the blank has been compressed about the mandrel to the desired form, then the blade is wrought to a roughly final contour, the metal which comprised the mandrel is removed preferably by melting it out by heating, and the blade may then be trimmed and machined to final dimensions.

My invention may be more clearly understood by referring to the accompanying drawings which illustrate diagrammatically the various steps comprising one mode by which my invention may be practiced.

Fig. 1 is a perspective view of a billet suitable for use in forming a propeller blade;

Fig. 2 is a plan view of the blank after the formation of laterally projecting ears or fins thereon and with the central bore formed thereon;

Figs. 3 and 4 are cross sections taken on the lines 3—3 and 4—4 respectively of Fig. 2;

Fig. 5 is a side view of the blank after working the shank of the blank and forming a hub thereon;

Fig. 6 is a cross section taken on line 6—6 of Fig. 5 showing the mandrel giving a partition-like support to the walls of the blank;

Fig. 7 is a vertical section taken centrally and

longitudinally of a pair of dies and a propeller blank, showing the mandrel in position for the forming operation;

Fig. 8 is a plan view of the rough finished blade;

Figs. 9 to 11 inclusive, are cross sections taken on the lines 9—9 to 11—11 inclusive, respectively, of Fig. 8 showing the cross-sectional form of the rough finished blade;

Fig. 12 is a perspective view of a multi-piece mandrel suitable for use in my invention, showing the various sections separated.

Referring to the drawings, the specific embodiment of my invention illustrated herein starts with a rolled or extruded billet of aluminum alloy, as illustrated in Fig. 1. This billet is preferably substantially circular in cross section, although it will be understood that it may be elliptical or of other shape. For convenience in handling during the initial operations, the billet may be provided with a tong hold 1.

The major portion of the billet remote from the tong hold 1 is first tapered or coned to elongate the billet substantially to the desired blade length and provide suitable cross section of metal for the formation of the blade at different points throughout its length. The blank then consists of a tapered or coned portion and a shank portion which remains substantially unchanged and which may be seen at 2 in Fig. 2. Preferably this operation is carried out by rolling, as disclosed in Patent No. 2,044,293, although it may also be accomplished in other ways.

The blank, tapered or coned as described above, is then provided with longitudinally extending, laterally projecting fins 4 and 5 by hammer forging, pressing, rolling, or in any other suitable manner. The fins may be arranged to spiral a desired amount about the blank as indicated in Figs. 3, 4 and 5 in a rough approximation of the relative spiraling or pitch of the finished blade. The fin 4 is designed to form the trailing edge of the blade, and the fin 5 is designed to form the leading edge, the fins being formed along substantially diametrically opposite sides of the roughly conical portion 6. Preferably, the fin 4 is made of a slightly greater width and a slightly less thickness than the fin 5 to provide the necessary metal and arrangement thereof to form respectively the trailing and leading edges in the finished blade.

The blank is then provided with an internal hole or recess, as shown in Fig. 2. This is preferably accomplished by boring a cylindrical hole from the hub end 7 of the blank through the greater portion of the length of the blank and terminating in a substantially conical portion 8 which stops short of the tip end of the blade as shown. It will be understood, however, that the internal opening may be made in any suitable manner.

The shank 2 of the blank is next swaged or otherwise worked from the substantially cylindrical hollow form shown in Fig. 2 to the form illustrated in Fig. 5.

The shank is then machined inside and out to desired rough finish dimensions. The end of the shank is preferably upset at this stage of the process to form a flange 11 on the hub end.

At the conclusion of the swaging and upsetting operation the blank has the form illustrated in Fig. 5. The blank is now ready for the particular application of my invention. A multi-piece mandrel designed to conform to the longitudinal contour of the internal walls of the blank when assembled, as shown in Fig. 7, is inserted in the

hole in the hollow blank. As illustrated in preferred form in Fig. 12, the mandrel consists of three separate sections, 13, 14, 15, although a larger or smaller number of sections may serve equally as well providing the sections are so designed as to permit them to be inserted through the shank opening, which is preferably made smaller than the central portion of the hole. The section 15 of the mandrel is inserted in the blank through the shank opening—the curved portion following the longitudinal contour of the internal wall and extending nearly the full length of the hole. The small area in the tip of the blank is nearly filled by a tip portion 16 on the end of the section 15 of the mandrel.

After section 15 is inserted in its proper place, the section 13 is inserted in the same relative position along the opposite internal wall. The central section 14 of the mandrel is then inserted between them. The central section is formed slightly wedge-shaped, tapering generally from the hub end 17 to the tip end 18, and when it is driven into its proper relationship with the other sections, the mandrel is held in rigid relationship against opposite sides of the hole. The sections of the mandrel may be tongued or grooved, as shown at 19 in Figs. 6 and 12. The tongue of one section fitting in the groove of the adjacent section serves as a guide while inserting the sections in the hole, causing each section to be aligned on a common plane with the adjacent sections, and as a result of more rigid support is provided for the walls. The mandrel sections are provided with tong holds so to facilitate handling thereof.

The mandrel may be of any metal, having a melting point sufficiently below the melting point of the metal comprising the propeller blade to permit melting of the mandrel at the completion of the operation without injury to the propeller blade, yet high enough to remain solid during the forming operation. It should be characterized by sufficient strength under compression to give adequate support to the internal walls of the blank at working temperatures, and sufficient ductility to permit deformation beneath the forming dies. For example, when the blank is of aluminum or an aluminum base alloy, a lead or lead alloy mandrel is satisfactory.

After the mandrel is inserted and wedged in the proper position in the blank, the blank is inserted between forming dies, with the supported sides of the blank in a position to contact the forming dies in the plane of the applied pressure. As the forming dies are closed and the blank is shaped, the mandrel likewise gradually flattens and spreads, contacting a greater area of the internal walls of the blank, and consequently the area of the internal wall supported by the mandrel is increased. At the end of the operation the hole is completely filled by the metal which originally comprised the mandrel. When the blank is first placed between the dies it contacts the dies along a narrow strip extending longitudinally on opposite sides of the blank, but as the forming operation progresses greater area is contacted until at the finish of the forming operation the entire main body portion of the blade is in contact with the encompassing dies. The cubic content of the mandrel can be made equal to the cubic content of the hole of

the finished blade by controlling the original dimensions of the mandrel.

When the forming operation is completed, the blade containing the deformed mandrel is removed from between the dies and heated to a temperature sufficiently high to melt the low melting point metal which originally comprised the mandrel, but not to a temperature high enough to injure the metal comprising the blade. The blade is held at this temperature sufficiently long to permit all the low melting point metal to melt and run from the blade.

No particular limitation is hereby placed on the method of working the hollow blank into propeller blade shape. By using the mandrel herein described, any one of a number of commonly employed methods of propeller fabrication can be used for the forming of the hollow propeller blade, as, for instance, forging, pressing, or rolling operations.

Following the operations described, the blade may be completed in any desired way, usually by trimming, sizing, and heat treating. The blade is then given any desired finishing operation, such as machining, grinding, and polishing to bring it to the exact dimensions and surface characteristics desired.

While I find this invention to be most useful in the manufacture of propeller blades from aluminum alloy or other light metal alloys, it is also readily adaptable to the manufacture of blades from other metals. The mandrel used in forming the blades should be of a metal having a melting point below the melting point of the blade yet above the working temperature. For example, a mandrel of copper may be employed in making blades of iron or steel; an aluminum mandrel may be employed in making blades of copper and its alloys, such as brass and bronze; and an iron or copper mandrel may be employed in making hollow blades of nickel. In fact any metal that can be forged or rolled may be used for the blank.

Although I have described a specific example of my invention it will be understood that many variations may be made in the process disclosed above without departing from the scope of the invention or the appended claim.

I claim:

In the process of producing hollow metallic aircraft propeller blades, the steps comprising forming a hole in an elongated metal blank, inserting into said hole a multiple-piece metal mandrel having a melting point lower than that of the blank, said mandrel having opposing sides wedged against opposite surfaces of said blank and forming a centrally disposed longitudinal partition in said blank having a cubic content smaller than the cubic content of said hole, deforming said blank into propeller blade shape and reducing the cubic content of said hole by exerting pressure against the portions of the blank supported by said mandrel until said mandrel fills said hole, said mandrel being adapted to deform under the deforming pressure at least as readily as said blank, whereby said mandrel yieldingly opposes the deforming pressure throughout the deforming of the blank and is work-formed thereby, and thereafter removing said mandrel metal from said blank.

EDWARD H. HARMON.