

Feb. 5, 1946.

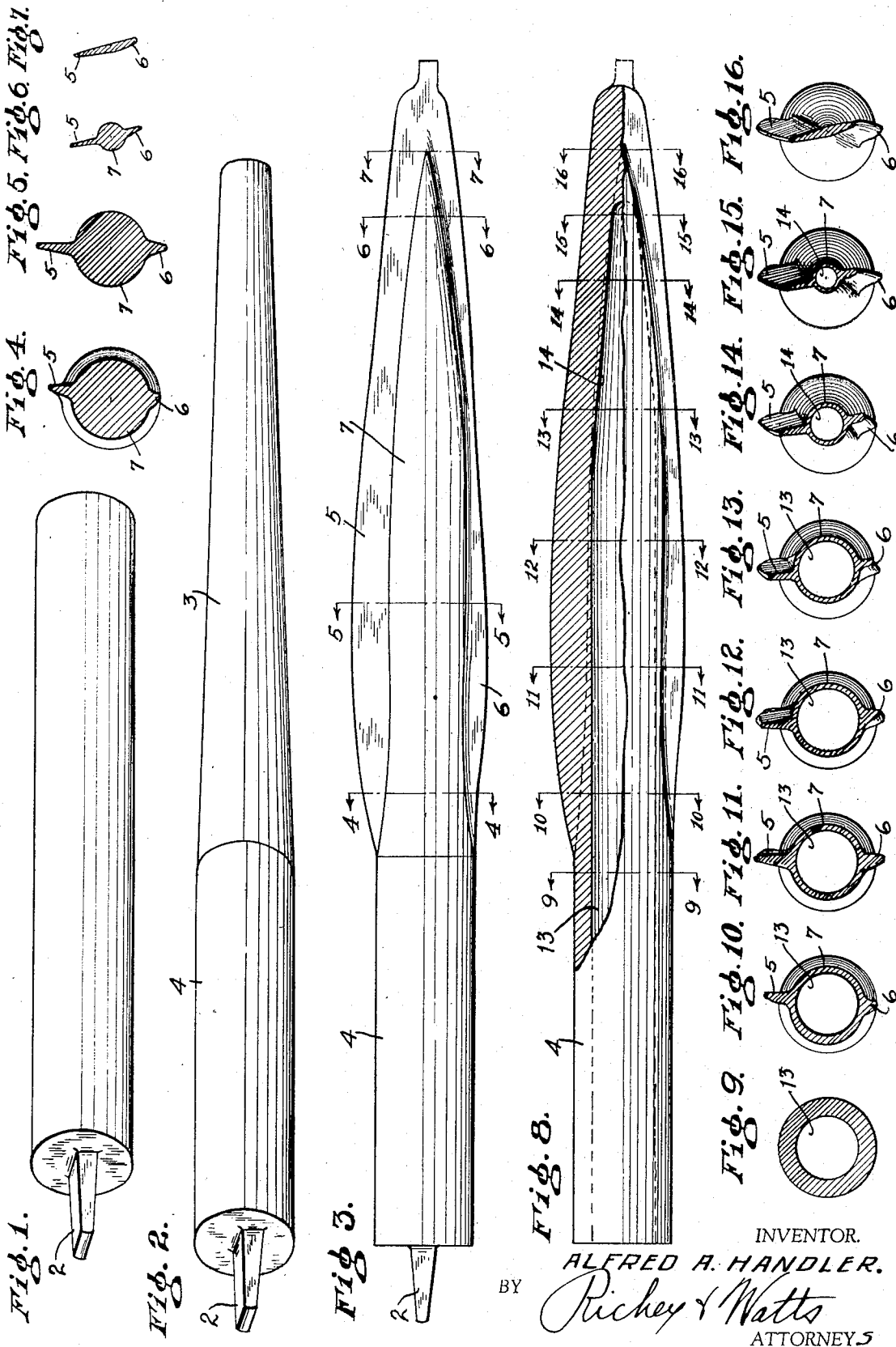
A. A. HANDLER

2,394,445

PROCESS OF MAKING HOLLOW PROPELLERS

Filed July 18, 1938

3 Sheets-Sheet 1



INVENTOR.

ALFRED A. HANDLER.

BY

Richey & Watts

ATTORNEYS

Feb. 5, 1946.

A. A. HANDLER

2,394,445

PROCESS OF MAKING HOLLOW PROPELLERS

Filed July 18, 1938

3 Sheets-Sheet 2

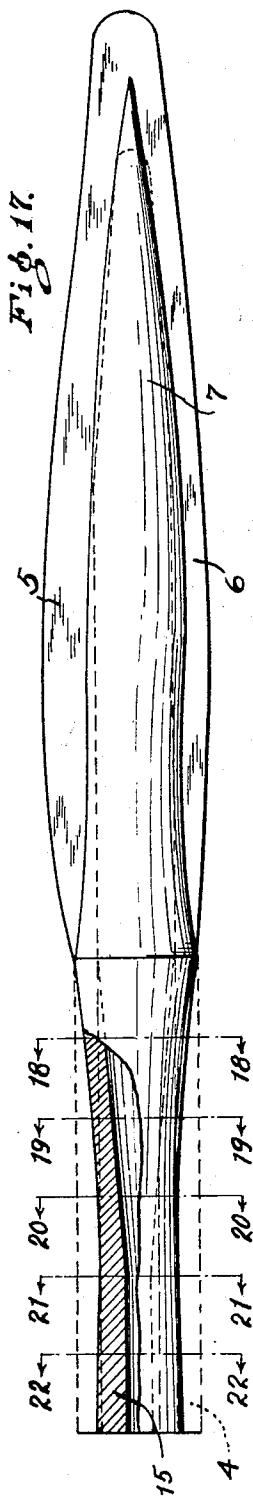
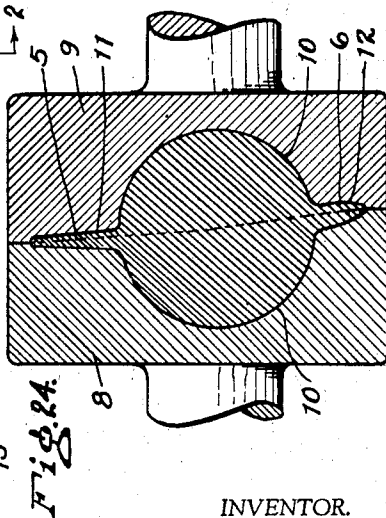
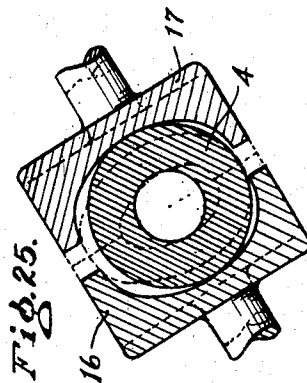
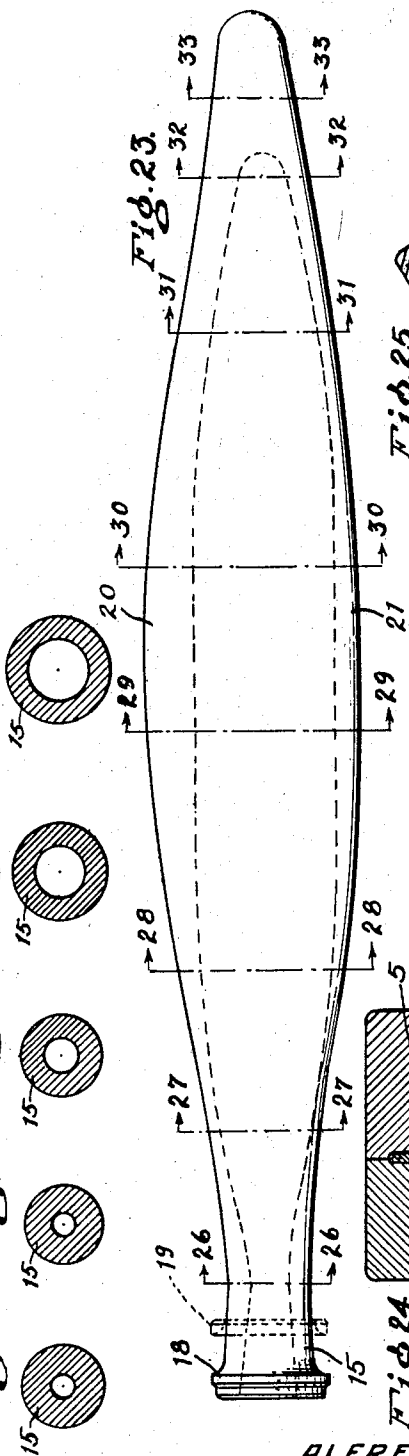


Fig. 22. Fig. 21. Fig. 20. Fig. 19. Fig. 18.



INVENTOR.
ALFRED A. HANDLER.
BY *Rickey & Watts*
ATTORNEYS

Feb. 5, 1946.

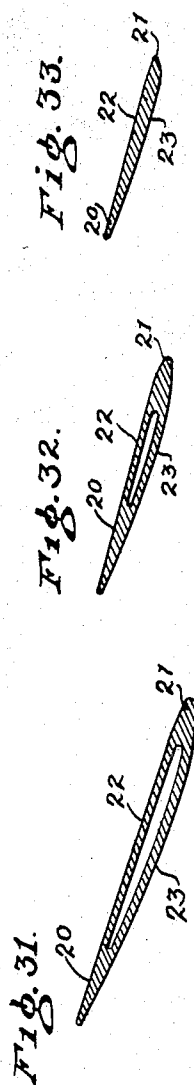
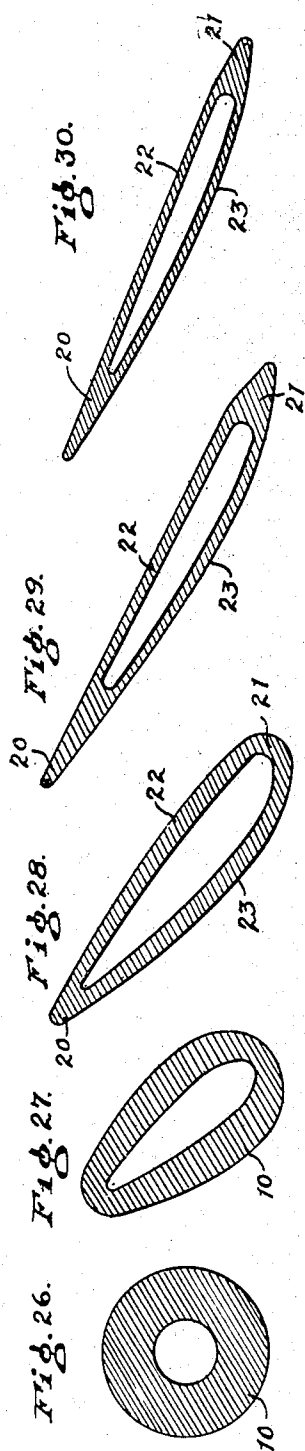
A. A. HANDLER

2,394,445

PROCESS OF MAKING HOLLOW PROPELLERS

Filed July 18, 1938

3 Sheets-Sheet 3



INVENTOR.
ALFRED A. HANDLER.
BY *Richey & Watts*
ATTORNEYS.

UNITED STATES PATENT OFFICE

2,394,445

PROCESS OF MAKING HOLLOW
PROPELLERS

Alfred A. Handler, Cleveland, Ohio, assignor to
Aluminum Company of America, Pittsburgh,
Pa., a corporation of Pennsylvania

Application July 18, 1938, Serial No. 219,711

17 Claims. (Cl. 29—156.8)

This invention relates to the art of metal working, and more particularly to a process of forging airplane propeller blades, and the blades produced thereby.

Many airplane 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 airplane, 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 in accordance with my prior Patents Nos. 1,957,499, 2,044,293, 2,044,294 and 2,044,295. These blades have been used in large quantities and have proven extremely reliable. Many efforts have been made, however, to further reduce the weight of 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.

The present invention has as its principal object the reduction of the weight of metal propeller blades in proportion to their size while maintaining the necessary strength, durability, fatigue resistance and uniformity.

The principal feature of the present invention consists broadly of forming a hollow 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 forging or pressing the blank to blade form with one or two thick portions of the wall of the blank forming one or both edges of the blade. Preferably the thick wall portions are formed by forging laterally projecting fins along opposite sides of the blank, after which the main body of the blank is hollowed out in any suitable manner, and the blank is finally pressed or forged to final form, the internal hole being flattened out to conform substantially to the external contour of the finished blade forging. It will be understood, however, that the invention in its broader aspects is not concerned with the particular way of making the hollow blank. During the final pressing or flattening the metal in the laterally projecting fins or thick wall portions is pressed into the desired shape of the leading and trailing edges of the blade, and provides a

greater volume of metal at the edges than at the flat faces of the blade.

During the flattening operation the metal immediately adjacent the internal hole in the blade is bent through relatively gradual and easy curves, since the opening does not extend to the edges of the blade. As a consequence, the stresses imposed on the metal are maintained substantially uniform around the blade, and at all points are maintained well within the allowable limits of working stresses.

Non-uniform working or stressing of the metal in the fabrication of the blade is undesirable even when the maximum stresses are maintained within the allowable limits of the metal being worked, since any working of the metal tends to refine the grain size in proportion to the amount of working. After the completion of the working operation, the blades made of light metal alloys are subjected to suitable heat treatments, during which the refined grains tend to grow. The grain growth is greatest in regions in the metal of the greatest grain size contrast, since apparently larger grains tend to assimilate, and grow at the expense of, the smaller grains. Accordingly, the more uniform the amount of working to which the metal is subjected, the less the grain size contrast, and the less grain growth will occur in the finished forging. Where excessive grain size contrast exists, as at the junction of zones in the metal which have received substantially different amounts of working, the more rapid grain growth produces an area of excessively large grains which constitute an area of weakness in the finished blade.

All of these defects resulting from unequal or non-uniform working of the metal in different parts of the blade are avoided or minimized in the present invention by maintaining the internal openings spaced a greater distance from the outside edge of the metal at the parts which are to form the edges of the blade so that the working of the metal in the flattening of the blank is substantially uniform around the internal opening.

The present invention also includes a number of other fabricating steps which are more particularly useful in connection with the principal feature of this invention, but which are also useful separately or in other processes of making propellers or similar articles. The blank is preferably formed from a billet which has been rolled or extruded, which is first tapered towards the end which will eventually be the tip end of the propeller blade. In this tapering at least a portion of the billet

is worked into 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 the 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 unworked 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, either by machining or mechanical deformation. Preferably however it is performed by rolling in accordance with the process disclosed and claimed in my prior Patent No. 2,044,293.

Another feature of the present invention is the production of the non-uniform wall thickness of the hollow blank from a billet tapered in this manner. The tapered billet is mechanically deformed so as to provide ears or fins disposed longitudinally along the tapered portion and projecting laterally therefrom, which will ultimately become the leading and trailing edges of the propeller blade, and an internal opening is formed throughout the major portion of the length of the blank, either by piercing or boring, or a suitable combination of such operations, which is preferably substantially circular in cross section and tapers towards the tip end of the blank. The non-circular external contour and the round opening combine to provide the non-uniform walls so that the blade may be formed without excessive stress on the metal.

Another feature of this invention, which is useful generally in propeller manufacture, is the formation of the shank end of the blade. The shank end of the hollow blank is made of greater diameter than is necessary or desirable with the particular blade size so that the internal opening 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 were left unworked by the 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, either before or after the final shaping of the blank, a flange is upset on the shank end.

My invention also includes the novel blade structure and the novel shank structure produced by these various operations. These and other features and advantages of the present invention will be more apparent from the following detailed description of a preferred process and product.

In the accompanying drawings which illustrate a preferred embodiment of my invention:

Figure 1 is a perspective view of a billet;

Figure 2 is a similar view of a blank after the initial tapering or coning operation;

Figure 3 is a plan view of the blank after the formation of laterally projecting ears or fins;

Figures 4, 5, 6 and 7 are cross sections taken on

the lines 4—4, 5—5, 6—6, and 7—7, respectively, of Figure 3;

Figure 8 is a view partly in plan and partly in longitudinal section of the blank after the internal opening has been formed;

Figures 9 to 16, inclusive, are cross sections taken on the lines 9—9 to 16—16, respectively, of Figure 8;

Figure 17 is a view partly in plan and partly in longitudinal section of the blank after the shank portion has been swaged;

Figures 18, 19, 20, 21 and 22 are cross sections taken on the lines 18—18, 19—19, 20—20, 21—21 and 22—22, respectively, of Figure 17;

Figure 23 is a plan view of the rough finished blade;

Figure 24 is a diagrammatic view showing the manner of forming the laterally projecting ears or fins;

Figure 25 is a diagrammatic view showing the manner of swaging the shank of the blank;

Figures 26 to 33, inclusive, are cross sections taken on the lines 26—26 to 33—33, inclusive, respectively of Figure 23.

Referring to the drawings the specific embodiment of my invention illustrated herein preferably starts with a rolled or extruded billet of aluminum alloy, such as illustrated in Figure 1. As shown this billet is substantially circular in cross section, although it will be understood as the description proceeds that it may be elliptical or other shape. For convenience in handling during the initial operations the billet may be provided with a tong hold 2 as shown in Figure 1.

The major portion of the billet remote from the tong hold 2 is tapered or coned in the manner illustrated in Figure 2 to elongate the billet substantially to the desired blade length and provide suitable cross sections of metal for the formation of the blade at different points throughout its length. The blank then consists of the tapered or coned portion 3 and the portion 4 which remains substantially unchanged. Preferably this operation is carried out by rolling as disclosed in my prior Patent No. 2,044,293, although it may also be accomplished in a number of other ways. Such rolling preferably includes a series of one-way rolling passes extending toward the tip end between rolls suitably contoured to apply a progressively increasing force on the blank and gradually shape it into the desired conical or tapered form. Reference is made to my said Patent No. 2,044,293 for a more complete disclosure of the rolling operation. Where the billet is initially extruded or rolled and the tapering or coning operation as shown in Figure 2 is carried out by rolling as disclosed in said patent, the longitudinal flow lines of the billet are gathered or bunched without interrupting their continuity so that the flow lines of the blank as shown in Figure 2 conform to the contour of the blank and provide the maximum strength.

The blank as illustrated in Figure 2 is then formed with longitudinally extending laterally projecting fins 5 and 6 by hammer forging, pressing, rolling or in any other suitable manner. Preferably the fins are arranged to spiral a slight amount about the blank as indicated in Figures 4 to 7 inclusive in a rough approximation of the relative spiraling or pitch of the finished blade. As shown the fin 5 is designed to form the trailing edge of the blade and the fin 6 is designed to form the leading edge. Preferably as shown the fin 5 is made of a slightly greater lateral extent and a slightly less thickness than the fin 6 to

provide the necessary metal and arrangement thereof to form the leading and trailing edges in the finished blade shown. It will be understood, of course, that the relative positions and dimensions of the fins 5 and 6 will vary with the blade design. The fins 5 and 6 are worked out laterally from the tapered portion 3 of the blank shown in Figure 2, leaving a central roughly conical portion 7. When the blank 2 is made in accordance with the preferred process as explained above, the longitudinal flow lines of the conical portion 3 are simply spread out laterally without being broken or seriously distorted in the formation of the fins 5 and 6.

I prefer to form these fins by hammering or pressing with dies such as illustrated diagrammatically in Figure 24. As shown, mating dies 8 and 9 are provided with recesses 10 smaller than the corresponding diameter of the coned portion 3 of the blank. The dies are also formed with recesses 11 and 12 shaped to form the fins 5 and 6, so that metal spread laterally from the portion 3 of the blank is forged or pressed into the fins.

The blank as shown in Figure 3 is then formed with an internal opening. In the embodiment shown this is accomplished by boring a substantially cylindrical hole 13 from the hub end of the blank through the greater portion of the length of the blank and terminating in a substantially conical hole 14 which stops short of the tip end of the blade as shown in Figure 8. It will be understood, however, that the internal opening may be made in any suitable manner. For example, the blank may be made smaller in dimensions than illustrated in Figure 3 and the hole may be formed at least partially by piercing as disclosed in my prior Patent No. 1,957,499 with the remainder of the hole, if necessary, finished by boring or in any other suitable way.

At the conclusion of this operation the blank has the form illustrated in Figures 8 to 16, inclusive, with the hollow substantially cylindrical portion 4 and the hollow conical portion 7 carrying the fins 5 and 6.

In the preferred embodiment of this invention the shank end of the blank is next swaged or otherwise worked from the substantially cylindrical hollow portion 4 to the shank 15 illustrated in Figure 17. This operation is preferably accomplished by swaging as illustrated diagrammatically in Figure 25. As shown a pair of mating dies 16 and 17 are provided with oval apertures designed to receive and forge the hollow portion 4 into an oval shape in one direction. The blank is then turned 90° and again struck by the dies 16 and 17 forcing it to an oval form in the opposite direction. This operation is continued with one or more sets of dies until the walls of the hollow cylindrical portion 4 are reduced substantially to the diameter and thickness of the shank 15 as illustrated in Figures 17 to 22, inclusive. Other working operations, such as rolling, may be substituted for the swaging, if desired.

It will be apparent that this operation permits the forming of a straight hole extending into the blank from the hub end which is larger in diameter than the hole in the finished shank. This permits the removal of the maximum amount of metal from the blade portion without destroying the desired proportions of the finished blade and without sacrificing the strength of the shank. At the same time, this operation thoroughly works and refines the metal of the shank and hub portions, which were unworked in the blade forming

steps, making the grain refinement and working of the metal more uniform throughout the finished blade.

Preferably the shank end 15 of the blade is then machined inside and out to desired rough finish dimensions and in this operation any inaccuracies in the contour and thickness of the shank end produced by the swaging operation are removed. In the embodiment illustrated the shank end 15 is then upset to form a flange 18 and where desired a bearing ring 19 may be secured upon the shank by the upset flange 18 in accordance with the process disclosed in my prior Patent No. 1,995,451. It will be understood that the flange may be upset either before or after the final forging of the blade.

The entire blank as illustrated in Figure 17 is then placed in pressing or forging dies and is flattened through the blade portion substantially to the contour illustrated in Figures 23 and 26 to 33, inclusive. During the flattening operation the fins 5 and 6 formed by the blade portion are pressed into the trailing and leading edges 20 and 21, respectively, of the blade. The hollow shank portion 15 is partially flattened as illustrated in Figures 27 and 28 and the edges thereof merged smoothly into the edges 20 and 21 formed from the fins 5 and 6. In the same operation the blank is preferably given the desired twist or pitch and in the design of blade shown one side is flattened to form the flat side 22 of the blade and the opposite side is suitably shaped to form the contour face 23 of the blade.

It will be apparent that in the swaging operation to form the shank end 15 the longitudinal fiber structure or flow lines of the hollow cylindrical portion 4 are simply bunched or pressed so that they remain in substantial conformity with the contour of the finished shank portion 15. Likewise, in the final pressing or forging of the blank to shape, the metal of the hollow shank portion 15 and the hollow conical portion 7 is simply bent into the desired contour and at no point is the metal bent through a sufficiently sharp angle to unduly stress the metal. The sharper portions of the edges of the blade at the leading and trailing edges 20 and 21 are formed from the solid fins 5 and 6 so that it is unnecessary to bend the hollow blank portion through the sharp angles required to form these edges. Accordingly in this operation the metallic structure produced in the blade by the previous forging operations is not injured.

In the final forging or pressing the blank is preferably forged slightly smaller with the consequent formation of a small flash around the leading and trailing edges of the blade. By reason of the arrangement of the metal into the proper position and with the proper cross-sectional area of metal to form the finished contour at each point throughout the length of the blade, the flash is substantially uniform in depth at all points and is maintained of extremely small dimensions in order to avoid any possible interference with the metallic structure developed by the previous operations.

In the carrying out of the final forging or pressing of the blade a deformable material, when desired, may be maintained in the internal opening to exert a pressure against the walls of the opening and prevent any tendency of collapse. Sand or similar material may be employed and removed after this operation has been completed. Likewise the internal opening may be filled with compressed air or gas to exert a pressure against the

walls of the internal opening. I have found, however, that this forging or pressing operation may be successfully carried out on most designs of blades without any core material within the internal opening and with the same open to atmosphere. Possibility of collapse of the walls of the blade is greatly reduced, if not entirely eliminated, by the formation of the fins 5 and 6 prior to the flattening operation.

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

The finished blade shown in Figure 23 has the usual propeller blade shape with the substantially cylindrical shank portion 15 merging into the blade portion, the latter having the relatively flat sides or faces 22 and 23 and the leading and trailing edges 21 and 20 respectively which diverge from the shank to an intermediate point and converge to the tip end of the blade. As will be apparent from Figures 23, 28 to 32, inclusive, the walls of the blade are substantially thicker at the leading and trailing edges than at the side faces by reason of the formation of these edges from the fins 5 and 6. It will likewise be apparent that when the blade portion is flattened in the final forging operation the perimeter of the hole in the blade portion remains substantially constant except as it may be diminished by any slight thickening of the walls and consequent flowing of the metal into the hole in the final forging operation, whereas the perimeter of the hole in the shank portion is substantially reduced by reduction of the shank portion in the swaging operation or the like.

While I find this invention to be most useful in the manufacture of blades from aluminum alloy or other light metal alloy, it is also readily adaptable to other metals. For example, blades may be made of iron, steel, copper and its alloys, such as brass and bronze, and nickel alloys. In fact any metal that can be forged or rolled may be worked into blades by this process.

Although I have described a specific example of my invention it will be understood that many variations and rearrangements of the steps may be resorted to without departing from the scope of the invention. For example, the various operations for forming the hollow blank of non-uniform wall thickness may be combined or rearranged in any desired way. Similarly the various novel features of the invention, while most valuable when used together, are also useful separately and in other combinations. Accordingly I do not wish to be limited except by the following claims.

I claim:

1. The process of making a propeller blade comprising forging at least a portion of the length of a solid billet into a substantially conical form tapering toward the tip end of the blank, forging a radially projecting fin through at least a portion of the length of the blank, forming an internal opening substantially round in cross section in the blank and flattening the blank by a pressure operation so that said radially projecting fin is formed into one of the edges of the blade.

2. The process of making a propeller blade comprising forging at least a portion of the length

of a solid billet into a substantially conical shape tapering toward the tip end of the blank, forging a pair of radially projecting fins through at least a portion of the length of the blank, forming an internal opening substantially round in cross section in the blank and flattening the blank by a pressure operation so that said radially projecting fins are formed into the edges of the blade.

3. The process of making a propeller blade comprising forging at least a part of the length of a solid billet into a roughly conical shape tapering toward the tip end of the blank, forging a radially projecting fin upon the blank extending from the tip end through a portion of the length, forming an internal opening in the blank extending from the hub end through at least a portion of the length of the blank and tapering in diameter toward the tip end of the blank and flattening the blank by a pressure operation so that said fin is formed into one of the edges of the blank.

4. The process of making a propeller blade comprising rolling a solid billet of metal to form a substantially conical portion tapering toward the tip end of the blade, forming a blind opening extending inwardly from the hub end of the blade through substantially the entire conical portion and by a forging operation flattening the hollow blank so formed to press the hollow conical portion into blade shape.

5. The process of making a propeller blade comprising forging one end of a solid cylindrical metal billet into a substantially conical form tapering toward the tip end of the blank, forging the blank to form a fin extending longitudinally along the conical portion and having a cross-sectional contour approximating the cross-sectional contour of an edge of the finished blade, forming an internal opening substantially circular in cross-section through at least a part of the length of the conical portion of said blank on which said fin is formed, to produce a blank having a hollow, finned portion with the metal distributed in successive transverse sections in amounts substantially proportional to the metal distribution in the corresponding portions of the finished blade, and flattening said blank through at least said hollow, finned portion to flatten said circular opening without completely closing the same, and to bring the exterior surfaces of the hollow finned portion substantially into alignment with the surfaces of said fin.

6. The process of making a propeller blade comprising forging one end of a solid cylindrical metal billet into a substantially conical form tapering toward the tip end of the blank, forging the blank to form a fin extending longitudinally along the conical portion and having a cross-sectional contour approximating the cross-sectional contour of an edge of the finished blade, forming a blind internal opening substantially circular in cross-section extending from the hub end of said blank into the conical portion on which said fin is formed, to produce a blank having a hollow, finned portion with the metal distributed in successive transverse sections in amounts substantially proportional to the metal distribution in the corresponding portions of the finished blade, and flattening said blank through at least said hollow finned portion to flatten said circular opening without completely closing the same, and to bring the exterior surfaces of the hollow finned portion substantially into alignment with the surfaces of said fin.

7. The process of making a propeller blade comprising forging one end of a solid cylindrical metal billet into a substantially conical form tapering toward the tip end of the blank, forging the blank to form a fin extending longitudinally along opposite sides of the conical portion and around the tip end of the blank and having a cross-sectional contour approximating the cross-sectional contour of the edges and tip of the finished blade, forming a blind internal opening substantially circular in cross-section extending from the hub end of said blank into the conical portion on which said fin is formed, to produce a blank having a hollow, finned portion with the metal distributed in successive transverse sections in amounts substantially proportional to the metal distribution in the corresponding portions of the finished blade, and flattening said blank through at least said hollow, finned portion to flatten said circular opening without completely closing the same, and to bring the exterior surfaces of the hollow finned portion substantially into alinement with the surfaces of said fin.

8. The process of making a propeller blade comprising rolling one end of a solid cylindrical metal billet having longitudinal flow lines into a substantially conical form tapering toward the tip end of the blank so as to gather said longitudinal flow lines into conical shape, forging the blank to work out a fin extending longitudinally along the conical portion and having longitudinal flow lines and a cross-sectional contour approximating the cross-sectional contour of an edge of the finished blade, forming an internal opening substantially circular in cross-section through at least a part of the length of the conical portion of said blank on which said fin is formed, to produce a blank having a hollow, finned portion with the metal distributed in successive transverse sections in amounts substantially proportional to the metal distribution in the corresponding portions of the finished blade, and flattening said blank through at least said hollow, finned portion to flatten said circular opening without completely closing the same, and to bring the exterior surfaces of the hollow finned portion substantially into alinement with the surfaces of said fin while maintaining a longitudinal flow line structure in said fin and said flattened hollow portion.

9. The process of making a propeller blade comprising forging one end of a solid cylindrical metal billet into a substantially conical form tapering toward the tip end of the blank, forging the blank to form a fin extending longitudinally along the conical portion and having a cross-sectional contour approximating the cross-sectional contour of an edge of the finished blade, forming an internal opening substantially circular in cross-section and tapering in diameter toward the tip end of the blank through at least a part of the length of the conical portion of said blank on which said fin is formed, to produce a blank having a hollow, finned portion with the metal distributed in successive transverse sections in amounts substantially proportional to the metal distribution in the corresponding portions of the finished blade, and flattening said blank through at least said hollow, finned portion to flatten said circular opening without completely closing the same, and to bring the exterior surfaces of the hollow finned portion substantially into alinement with the surfaces of said fin.

10. The process of making a propeller blade comprising forging one end of a solid cylindrical metal billet into a substantially conical form

tapering toward the tip end of the blank, forging the blank to form a fin extending longitudinally along the conical portion and having a cross-sectional contour approximating the cross-section of an edge of the finished blade while maintaining the body of said conical portion substantially circular in sectional contour, forming an internal opening substantially circular in cross-section through at least a part of the length of the conical portion of said blank on which said fin is formed, to produce a blank having a hollow, finned portion with the metal distributed in successive transverse sections in amounts substantially proportional to the metal distribution in the corresponding portions of the finished blade, and flattening said blank through at least said hollow, finned portion to flatten said circular opening without completely closing the same, and to bring the exterior surfaces of the hollow finned portion substantially into alinement with the surfaces of said fin.

11. The process of making a propeller blade comprising forging a solid elongated metal blank to form a fin extending longitudinally therealong and having a cross-sectional contour approximating the cross-sectional contour of an edge of the finished blade, forming an internal opening substantially circular in cross-section through at least a part of the length of said blank on which said fin is formed, and flattening said blank through at least said hollow, finned portion to flatten said circular opening without completely closing the same, and to bring the exterior surfaces of the hollow finned portion substantially into alinement with the surfaces of said fin.

12. The process of making a propeller blade comprising forging a solid elongated metal blank having a body portion and a thickened portion extending longitudinally along one side of the body portion and projecting therefrom in a radial direction, forming a longitudinal opening in said body portion through at least a part of the length thereof on which said thickened portion is formed, said opening being of such diameter as to leave the wall of said body portion on each side of said solid thickened portion with a radial thickness less than the circumferential length of the junction of said solid thickened portion with said body portion, and forging said thickened portion into one of the edges of the finished blade and bending the walls of said body portion toward each other to flatten said opening without completely closing the same and to bring the exterior surfaces of said walls substantially into alinement with the surfaces of said edge.

13. The process of making a hollow propeller blade comprising forging one end of a solid metal billet into a substantially conical form tapering toward the tip end of the blank, forging the blank to form a solid thickened portion projecting in a radial direction from the conical portion and extending longitudinally along opposite sides of the conical portion and around the tip end of the blank, forming an opening extending longitudinally into the blank from the hub end thereof and through at least a part of the finned length and terminating short of the tip end, said opening having a diameter exceeding the thickness of said thickened portion and tapering in diameter toward the tip end of the blank, and flattening said blank through at least said hollow finned portion to form said thickened portion into the edges and tip of the propeller blade, and to bring the exterior surfaces of said hollow portion sub-

stantially into alignment with the surfaces of said edges and tip.

14. The process of making a propeller blade comprising forging one end of a solid cylindrical metal billet into a substantially conical form tapering toward the tip end of the blank, forging the blank to form a solid thickened portion extending longitudinally along the conical portion and projecting therefrom in a radial direction, forming an internal opening substantially circular in cross section through at least a part of the length of the conical portion of said blank on which said thickened portion is formed, to produce a blank having a hollow portion with a solid projection with the metal distributed in successive transverse sections in amounts substantially proportional to the metal distribution in the corresponding portions of the finished blade and flattening said blank to form said thickened portion into one of the edges of the finished blade and bending the walls of said hollow portion toward each other to flatten said opening without completely closing the same and to bring the exterior surfaces of said walls substantially into alignment with the surfaces of said edge.

15. The process of making a propeller blade comprising forging one end of a solid cylindrical metal billet into a substantially conical form tapering toward the tip end of the blank, forging the blank to form a solid thickened portion extending longitudinally along the conical portion and projecting therefrom in a radial direction, forming a blind internal opening substantially circular in cross section extending from the hub end of said blank into the conical portion on which said thickened portion is formed, to produce a blank having a hollow portion with a solid projection with the metal distributed in successive transverse sections in amounts substantially proportional to the metal distribution in the corresponding portions of the finished blade and flattening said blank to form said thickened portion into one of the edges of the finished blade and bending the walls of said hollow portion toward each other to flatten said opening without completely closing the same and to bring the exterior surfaces of said walls substantially into alignment with the surfaces of said edge.

16. The process of making a propeller blade comprising forging a tapering portion on one

end of a solid metal billet, forging the blank to form a fin extending longitudinally along the tapering portion and having a cross-sectional contour approximating the cross-sectional contour of an edge of the finished blade, forming a longitudinally extending internal opening through at least a part of the length of the tapering portion of said blank on which said fin is formed, said opening being of such size in cross-section as to leave the walls of said blank on opposite sides of said fin with a radial thickness less than the circumferential length of the junction of said fin with said blank, to produce a blank having a hollow, finned portion with the metal distributed in successive transverse sections in amounts substantially proportional to the metal distribution in the corresponding portions of the finished blade, and flattening said blank through at least said hollow, finned portion to flatten said internal opening without completely closing the same, and to bring the exterior surfaces of the hollow finned portions substantially into alignment with the surfaces of said fin.

17. The process of making a propeller blade comprising forging a tapering portion on one end of a solid metal billet, forging the blank to form a fin extending longitudinally along opposite sides of the tapering portion and around the tip end of the blank and having a cross-sectional contour approximating the cross-sectional contour of the edges and tip of the finished blade, forming a longitudinally extending blind internal opening through at least a part of the length of the tapering portion of said blank on which said fin is formed, said opening being of such size in cross-section as to leave the walls of said blank on opposite sides of said fin with a radial thickness less than the circumferential length of the junction of said fin with said blank, to produce a blank having a hollow, finned portion with the metal distributed in successive transverse sections in amounts substantially proportional to the metal distribution in the corresponding portions of the finished blade, and flattening said blank through at least said hollow, finned portion to flatten said internal opening without completely closing the same, and to bring the exterior surfaces of the hollow finned portions substantially into alignment with the surfaces of said fin.

ALFRED A. HANDLER.