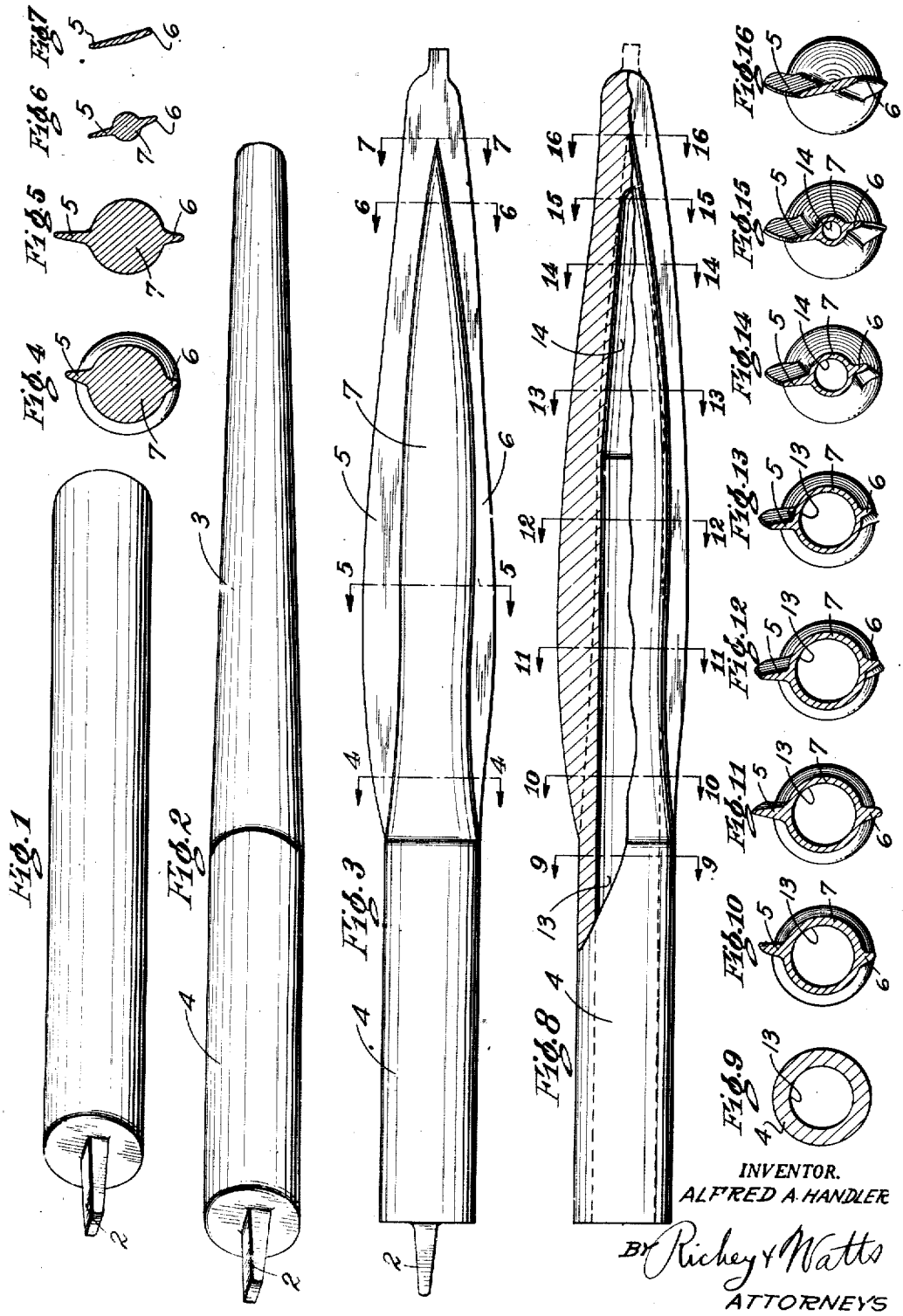
Feb. 5, 1946. A. A. HANDLER 2,394,446

PROPELLER

Original Filed July 18, 1938 3 Sheets-Sheet 1

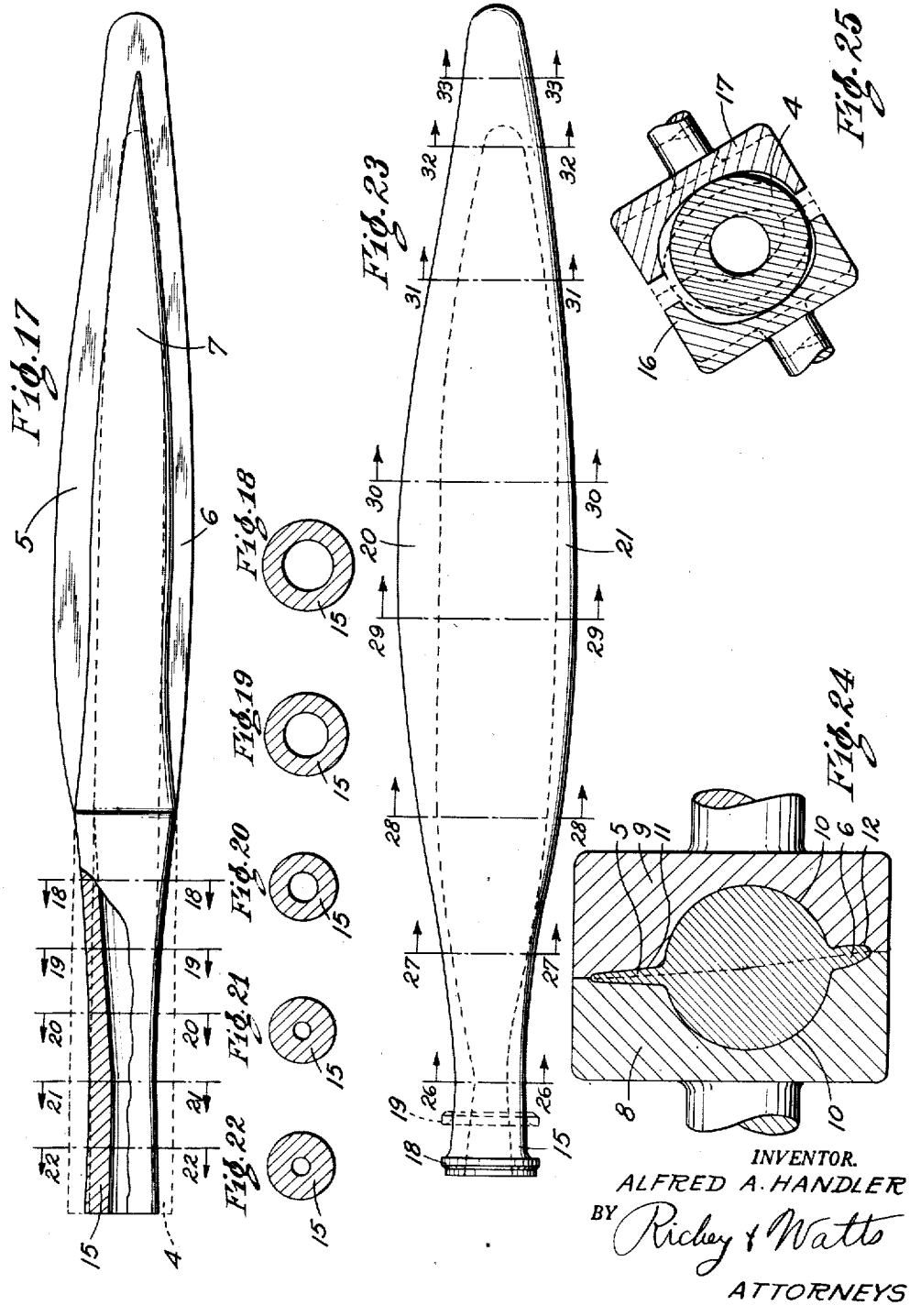


INVENTOR.
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Feb. 5, 1946. A. A. HANDLER 2,394,446

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Original Filed July 18, 1938 3 Sheets-Sheet 2



Feb. 5, 1946. A. A. HANDLER 2,394,446

PROPELLER

Original Filed July 18, 1938 3 Sheets-Sheet 3

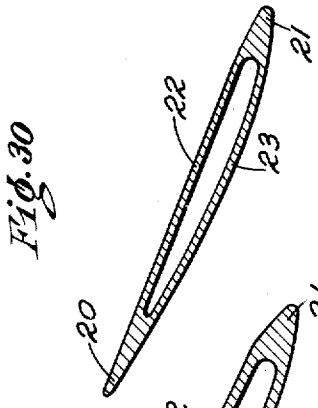


Fig. 30

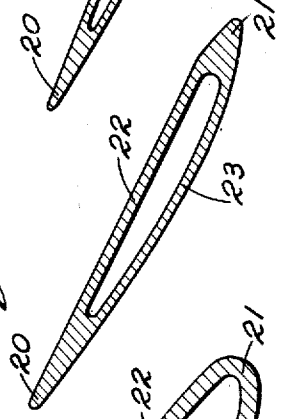


Fig. 29

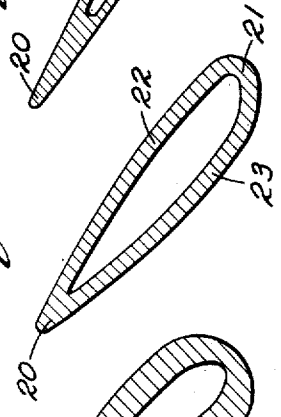


Fig. 28

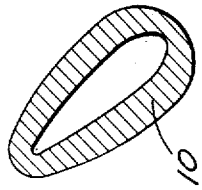


Fig. 27

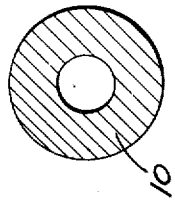


Fig. 26

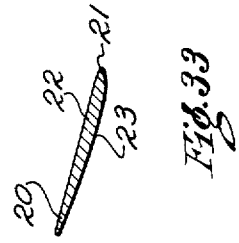


Fig. 33

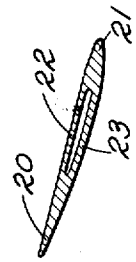


Fig. 32

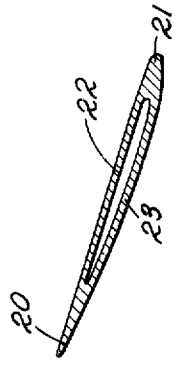


Fig. 31

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Patented Feb. 5, 1946 2,394,446

UNITED STATES PATENT OFFICE

2,394,446

PROPELLER

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

Original application July 18, 1938, Serial No. 219,711. Divided and this application October 21, 1942, Serial No. 462,811

4 Claims. (Cl. 170—159)

This invention relates to airplane propeller blades, and particularly blades made of aluminum or other light metal alloy. This application is a division of my application, Serial No. 219,711, filed July 18, 1938.

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.

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 resides in forming an integral one piece blade which is hollowed out so as to reduce the weight as much as possible, while retaining sufficient metal at every point to withstand the particular stresses imposed upon the blade at that point. Another feature is to construct the blade with substantially greater radii at the edges of the internal opening in the blade than at the corresponding parts of the exterior surface of the blade, so as to avoid sharp interior bends which might constitute stress raisers. In addition this invention includes a forged hollow blade with the flow lines of the metal conforming to the contour and with the metal worked or forged substantially the same amount throughout.

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 occurs 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.

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.

These and other features and advantages of the present invention will be more apparent from the following detailed description of a preferred embodiment of the invention.

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

Fig. 1 is a perspective view of a billet;

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

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

Figs. 4, 5, 6, and 7 are cross sections taken on the lines 4—4, 5—5, 6—6, and 7—7, respectively, of Fig. 3;

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

Figs. 9 to 16, inclusive, are cross sections taken on the lines 9—9 to 16—16, respectively, of Fig. 8;

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

Figs. 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 Fig. 17;

Fig. 23 is a plan view of the rough finished blade;

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

Fig. 25 is a diagrammatic view showing the manner of swaging the shank of the blank; and

Figs. 26 to 33, inclusive, are cross sections taken on the lines 26—26 to 33—33, inclusive, respectively of Fig. 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 Fig. 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 Fig. 1.

The major portion of the billet remote from the tong hold 2 is tapered or coned in the manner illustrated in Fig. 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 Fig. 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 Fig. 2 conform to the contour of the blank and provide the maximum strength.

The blank as illustrated in Fig. 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 Figs. 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 Fig. 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 Fig. 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 Fig. 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 Fig. 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 Fig. 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 Figs. 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 Fig. 17. This operation is preferably accomplished by swaging as illustrated diagrammatically in Fig. 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 Figs. 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 are 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 Fig. 17 is then placed in pressing or forging dies and is flattened through the blade portion substantially to the contour illustrated in Figs. 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 Figs. 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 Fig. 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 Figs. 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. I use the term "homogeneous" in the claims to describe the solid metal forming the leading and trailing edges and the tip of the blade, and to distinguish from welded or laminated metal structures produced by welding or pressing together metal parts which were originally made separate. All stress raisers, cleavage planes, and other weaknesses of heterogeneous structures made by pressing or welding together separate metal parts are eliminated by the present invention.

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 parts may be resorted to without departing from the scope of the invention. Accordingly I do not wish to be limited except by the following claims.

I claim:

1. A hollow propeller blade composed of a single piece of metal having side faces and curved leading and trailing edges diverging from the hub end to an intermediate point and then converging to the tip end of the blade, said blade having a similarly shaped opening formed therein which

diverges from the hub end to said intermediate point and then converges toward the tip end of the blade and the walls of said blade outwardly from the opening throughout the length of the trailing edge and around and through the tip portion being solid and homogeneous metal of substantially greater thickness than at the sides of the blade, said blade having a forged metallic structure throughout.

2. A propeller blade composed of a single piece of metal having a leading edge, a relatively sharp trailing edge and side faces terminating in a tip, said leading and trailing edges diverging from the hub end to an intermediate point and converging to the tip, said blade having an opening formed therein through the greater part of its length having a cross-sectional contour corresponding generally to the external contour of the blade, the edges of said opening diverging from the hub end to an intermediate point and then converging toward the tip of the blade, the tip of said blade beyond the end of said opening being solid and homogeneous, the wall of said blade being substantially thicker at said trailing edge than the walls constituting said side faces, said opening having a substantial radius of curvature adjacent said trailing edge and said tip and said blade having a forged metallic structure throughout.

3. A propeller blade composed of a single piece of light metal alloy having a leading edge, a relatively sharp trailing edge and side faces terminating in a tip, said leading and trailing edges diverging from the hub end to an intermediate point and converging to the tip, said blade having an opening formed therein through the greater part of its length having a cross-sectional contour corresponding generally to the external contour of the blade, the edges of said opening diverging from the hub end to an intermediate point and then converging toward the tip of the blade, the tip of said blade beyond the end of the opening being solid and homogeneous throughout, the wall of said blade being substantially thicker at said trailing edge than the walls constituting said side faces, said opening having a substantial radius of curvature adjacent said trailing edge and said tip and said blade having a forged metallic structure throughout.

4. A hollow propeller blade composed of a single piece of metal having a substantially cylindrical shank portion merging into a flattened blade portion, said blade portion having side faces and leading and trailing edges diverging from the shank to an intermediate point and converging to the tip end of the blade, said shank portion having a hole substantially circular in cross section extending into the same from the hub end and merging into a fluid hole in the blade portion having an oval cross section, the edges of said opening diverging from the shank portion to an intermediate point and then converging toward the tip of the blade, the perimeter of the hole in the shank portion being substantially less than the perimeter of the hole in the blade portion at the largest point, the walls of said shank portion, blade portion and tip end having a homogeneous forged metallic structure throughout and the walls of said blade portion being of substantially greater thickness at one of the edges than at the side faces.

ALFRED A. HANDLER.

CERTIFICATE OF CORRECTION.

Patent No. 2,394,446. February 5, 1946.

ALFRED A. HANDLER.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 4, second column, line 22, claim 4, for the word "fluid" read --blind--; and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 16th day of April, A. D. 1946.

Leslie Frazer

(Seal) First Assistant Commissioner of Patents.

diverges from the hub end to said intermediate point and then converges toward the tip end of the blade and the walls of said blade outwardly from the opening throughout the length of the trailing edge and around and through the tip portion being solid and homogeneous metal of substantially greater thickness than at the sides of the blade, said blade having a forged metallic structure throughout.

2. A propeller blade composed of a single piece of metal having a leading edge, a relatively sharp trailing edge and side faces terminating in a tip, said leading and trailing edges diverging from the hub end to an intermediate point and converging to the tip, said blade having an opening formed therein through the greater part of its length having a cross-sectional contour corresponding generally to the external contour of the blade, the edges of said opening diverging from the hub end to an intermediate point and then converging toward the tip of the blade, the tip of said blade beyond the end of said opening being solid and homogeneous, the wall of said blade being substantially thicker at said trailing edge than the walls constituting said side faces, said opening having a substantial radius of curvature adjacent said trailing edge and said tip and said blade having a forged metallic structure throughout.

3. A propeller blade composed of a single piece of light metal alloy having a leading edge, a relatively sharp trailing edge and side faces terminating in a tip, said leading and trailing edges diverging from the hub end to an intermediate point and converging to the tip, said blade having an opening formed therein through the greater part of its length having a cross-sectional contour corresponding generally to the external contour of the blade, the edges of said opening diverging from the hub end to an intermediate point and then converging toward the tip of the blade, the tip of said blade beyond the end of the opening being solid and homogeneous throughout, the wall of said blade being substantially thicker at said trailing edge than the walls constituting said side faces, said opening having a substantial radius of curvature adjacent said trailing edge and said tip and said blade having a forged metallic structure throughout.

4. A hollow propeller blade composed of a single piece of metal having a substantially cylindrical shank portion merging into a flattened blade portion, said blade portion having side faces and leading and trailing edges diverging from the shank to an intermediate point and converging to the tip end of the blade, said shank portion having a hole substantially circular in cross section extending into the same from the hub end and merging into a fluid hole in the blade portion having an oval cross section, the edges of said opening diverging from the shank portion to an intermediate point and then converging toward the tip of the blade, the perimeter of the hole in the shank portion being substantially less than the perimeter of the hole in the blade portion at the largest point, the walls of said shank portion, blade portion and tip end having a homogeneous forged metallic structure throughout and the walls of said blade portion being of substantially greater thickness at one of the edges than at the side faces.

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