Oct. 5, 1948. G. W. HARDY 2,450,660

METHOD OF FORMING PROPELLER HUBS

Filed Nov. 15, 1945 2 Sheets-Sheet 1

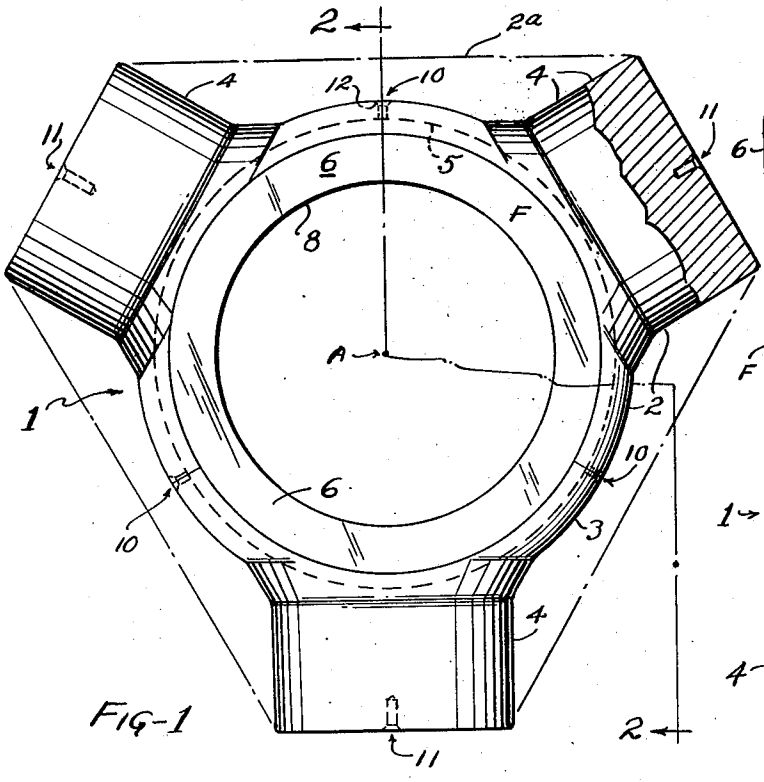


FIG-1

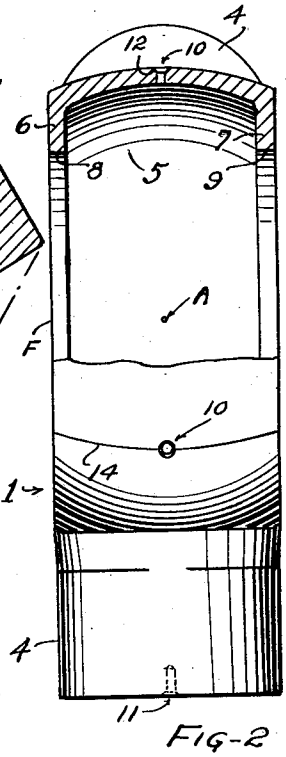


FIG-2

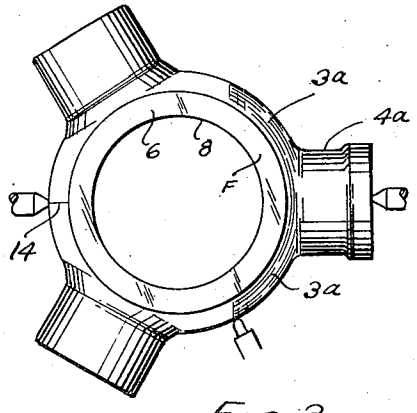


FIG-3

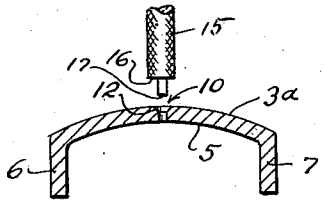


FIG-4

INVENTOR
GORDON W. HARDY
BY George M. Soule
ATTORNEY

Oct. 5, 1948. G. W. HARDY 2,450,660

METHOD OF FORMING PROPELLER HUBS

Filed Nov. 15, 1945 2 Sheets-Sheet 2

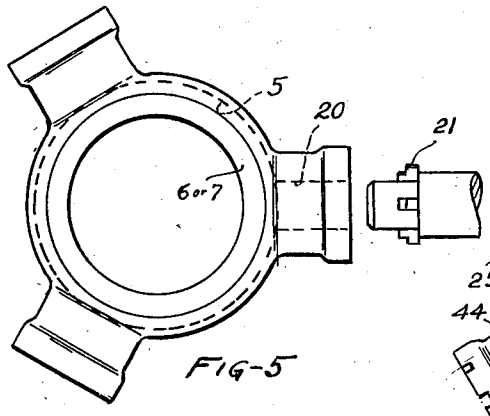


FIG-5

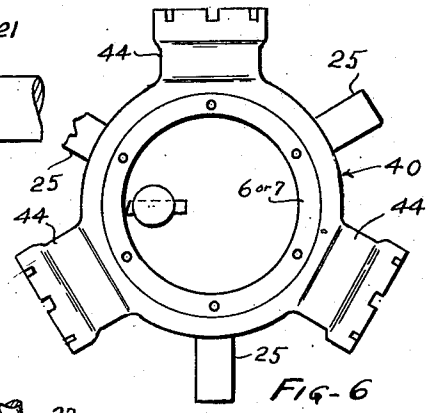


FIG-6

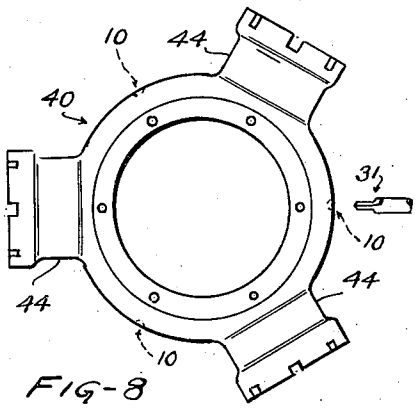


FIG-8

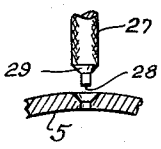


FIG-7

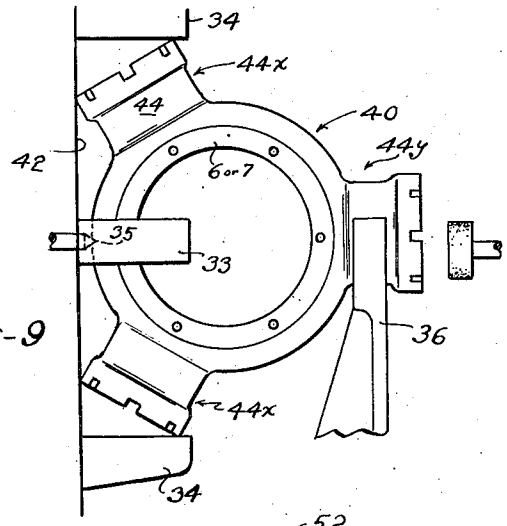


FIG-9

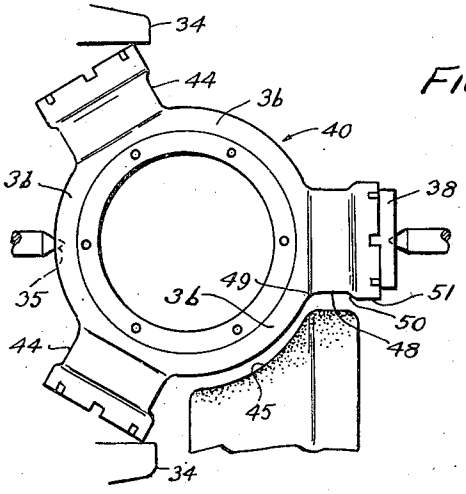


FIG-10

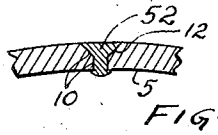


FIG-11

INVENTOR
GORDON W. HARDY
BY George M. Soule
ATTORNEY

Patented Oct. 5, 1948

2,450,660

UNITED STATES PATENT OFFICE

2,450,660

METHOD OF FORMING PROPELLER HUBS

Gordon W. Hardy, Euclid, Ohio, assignor to The Marquette Metal Products Company, Cleveland, Ohio, a corporation of Ohio

Application November 15, 1945, Serial No. 628,771

6 Claims. (Cl. 29—156.8)

1

This invention relates to a method of making hubs for aircraft propellers, and more especially to making such hubs large enough to contain blade pitch controlling and equalizing mechanism for changing pitch during flight. The above indicates the general object.

A further object is to provide a method of forming a propeller hub arranged to support three blades and in such manner that the external exposed surfaces are smooth, gradually merging into each other to minimize noise and drag and without requiring timetaking hand finishing operations such as heretofore considered unavoidably necessary in propellers of that type or class.

Another object is to provide a simple and efficient method of making a hub comprising a central portion in the form of a spherical zone and equidistantly spaced radiating arms in a plane cutting an axial or absolute center of said zone.

Other objects will become apparent from the description below of the method as applied to one exemplary form of propeller hub (three blades with controllable pitch).

In the drawings, Fig. 1 is a plan or end view of a hub blank in the form of a rough forging after two series of operations have been performed on it, namely, central boring and radial center socket forming; Fig. 2 is a side elevation or edge view of the forging in the same condition (partly in radial plane section as indicated on Fig. 1); Fig. 3 is an end view corresponding to Fig. 1, showing further progress of the work of forming a propeller hub from the forging; Fig. 4 is a detail sectional view illustrating one type of gage used to test wall thickness after rough formation of spherical inner and outer surfaces of the hub; Fig. 5 is an end view of the semi-finished hub following the operation depicted by Fig. 3 and as mounted for drilling and counterboring blade receiving arm portions of the hub; Fig. 6 is a view of the still partially finished hub as mounted for recutting (turning and facing) central hub flange surfaces after hardening; Fig. 7 is a side view of another form of gage and, in section, a centering-socketed portion of the hub to which the gage is applied; Fig. 8 is a view similar to Fig. 6 showing the nearly finished hub as mounted for cutting or truing certain centering sockets to precision form as reference and center positioning surfaces; Fig. 9 is a view of the hub as mounted for internal grinding of the blade supporting arms or barrels of the hub; Fig. 10 is a similar view showing the manner of externally grinding and/or polishing the principal external spherical

2

central body and cylindrical barrel surfaces of the hub; and Fig. 11 is a detail sectional view showing one manner of plugging the centering socket openings in the hub wall prior to installing the hub in a propeller assembly.

The term spherical as used herein means having characteristics of a sphere or part of a sphere.

Referring to the drawings Figs. 1 and 2, the blank 1 there shown (partly worked upon) will be described, by way of example, as a steel forging in the form of a flat block, the edges of which define roughly, as indicated in broken lines 2a, an irregular hexagon with alternately equal sides but preferably the blank is forged more nearly to the shape of the finished hub as illustrated in full lines at 2. The forging may have a generally triangular or spherically rounded central portion 3 and radial arms 4 spaced 120° apart about the center of the forging. The forging, in any event, has arm portions corresponding in position to the arms 4 somewhat longer or further radially extended than the blade supporting arms or barrels of the finished hub (see 44, Fig. 10) and the central portion of the block is of a thickness which is somewhat greater than the axial length of the hub to be formed. The forging is preferably electric-furnace-produced unkilled steel on the general order of 3140 Nichrome steel as identified, for example, in an American Steel & Wire Company bulletin published January 1935, as "Official S. A. E. Standard Steel Specifications." Any other steel which may be heat treated and surface hardened to something less than 50 Rockwell without appreciable distortion in fairly large hollow pieces with relatively thin walls may be used.

The blank or forging 1 is first centrally bored as by supporting the blank between self centering chuck jaws (e. g. three interconnected jaws) of a machine tool on the order of a lathe or boring mill. The jaws of the chuck may be forced against the outer ends of the arms or against symmetrically disposed surfaces between the arms. In any operations in accordance herewith requiring such mounting in a chuck, the work piece is usually forced against the main chuck face to bring the arms into a common plane perpendicular to the chuck axis before the jaws are set. The boring to form the central generally spherical cavity indicated at 5 and defined in part by inturned circular flanges 6 and 7 may be done on a Hall planetary machine. The flanges 6 and 7 would, in that event, be at least partially turned on the same machine. One main central outside face of the forging as at F, Fig. 3, is finished in

the same machine on and around one flange 6 or 7 substantially to finished position for reference purposes. The spherical cut at 5 is a final cut and is made substantially smooth, being generated as a true sphere about the point A, Figs. 1 and 2, as the center and located with reference to the first faced surface F mentioned. One important boring operation partly illustrated by Figs. 1 and 2 is to finish form the inner peripheral surfaces 8 and 9 of the flanges 6 and 7 which, in cooperation with the end face F, become reference surfaces upon which subsequent operations are based.

The forging is now placed on a dividing head (not shown) as of a milling machine, using the surfaces F, 8, and 9 to locate the piece and with a travelling drilling fixture, with the drill chuck axis midway of the top and bottom of the forging, in position for drilling parallel to the planes of the flanges 6 and 7. The centering drill or drills on such drilling fixture forms or form three coacting pairs of centering sockets in the forging, the elements of which pairs lie on coplanar axes converging at the center A and spaced exactly 120° apart. The three centering sockets 10 are through holes intersecting the inner spherically bored surface 5. Those holes are precision counterbored as at 12, Fig. 1, to uniform depths successively about the forging while mounted on the dividing head and turned thereon to three of the socket forming positions. When forming the conical surfaces defining the counterbores 12, the active movement of the drilling fixture at each operation is limited by a suitable single stop so that the conical shoulders on the circles defining the inner ends of the counterbores 12 (see Fig. 4) are exactly the same distance from the axis of the hub. The depths of the centering counterboring at 11 are similarly controlled and limited. The axes of all the centering sockets are located in a common plane and, in the exemplary construction illustrated, are substantially exactly halfway between the inner faces of the two inturned flanges 6 and 7, which is also the position of the center A of the spherical boring 5. The position along the axis of the central bore or cavity for the centering drilling may readily be determined by using said face F as a reference plane. Scribe marks such as shown at 14 in Fig. 2 are now made on the blank parallel to the axis of the centerboring 5 and intersecting the axis of each centering socket 10 to define the limits of subsequent external spherical turning operations as will be described below.

For turning the external spherical surfaces (one at 3*a*, Fig. 3) and the blade supporting barrel-forming arms at 4*a*, the blank is mounted in a lathe and located successively by the diametrally disposed pairs of centering sockets 10 and 11. One third parts only of the spherical surface portions 3*a* are rough and finish turned for each mounting of the blank in the lathe. The arms 4 may each be fully turned externally nearly to desired final shape (somewhat oversize). The spherical rough and finish surface turning is terminated at the scribe marks 14.

As each two adjacent sphere surface portions 3*a* of the blank are finished turned to the associated scribe marks 14, the thickness of the walls of the hub adjacent the centering sockets 10 may be checked with a flush pin gauge of the character shown at 15 in Fig. 4. The flat shoulder 16 of the flush pin gauge rests on the spherically turned surface and when the inner end 17 of the plug of the gauge is found, as by finger test, to be flush with the inner spherically bored surface 5, the spherical turning passes inspection. The spherical form to which the central portion of the hub is turned is left oversize sufficiently to provide for removal of a small amount of stock later by grinding and to compensate for expected slight change in shape during heat treatment.

The hub blank, Fig. 5, is now mounted on a dividing head as in the case of forming the centering sockets 10 and 11 (e. g. on the same mandrel as previously used or a similar one), and the three blade mounting barrel-forming arms 4 are rough drilled as at 20 along the axes of the centering sockets 11. The drillings 20 intersect the spherically bored central hub cavity surface 5. Then suitable enlargements of the cavities and seats (not shown) for blade mounting bearing assemblies etc. are formed by counterborings of suitable type depending upon the nature of the blade mounting desired. 21 shows a typical rough boring tool. Threads may be formed in the barrels to receive blade locking nuts as well known in the art after drilling and boring of the arms 4 and while the piece is mounted as just described.

The nearly finished hub 40, when completed by successive operations on a divided head as described in connection with Fig. 5 and with all necessary bolt, dowel, etc. holes (not shown) completely formed, is then heat treated to harden all external surfaces to such extent that they will adequately resist accidental disfiguration in use and, in respect to the internal surfaces of the barrels, to such extent that any of those surfaces can be made to serve directly as bearing races (without requiring bearings race sleeves). Hardening to between 42 and 47 Rockwell is adequate and does not prevent formation of further cutting (truing) operations as by turning with carb-alloy tool points. Hardening of steel of the class earlier referred to herein increases the tensile strength as much as 8%, which insures that the spherical walls of hub will not change in shape under test and severe loading stress, and that the blade mounting barrels will not become elongated or otherwise distorted by the enormous forces imposed upon them in supporting propeller blades during high speed rotation in flight. Movement of the metal during hardening is usually insignificant.

The hardened, practically finished hub 40 is now mounted as in a three jaw chuck as indicated at 25, Fig. 6, and the inner peripheral surfaces of the flanges 6 and 7 and the front and rear surfaces thereof are finish bored and faced by use of appropriately shaped cutting tools. The outer face of the flange (6 or 7) which is to serve as the rear flange in the propeller is finished first in order that it can later be used as a reference surface in forming the forward face of the forward flange on which a blade pitch adjusting servo motor block (not shown) may be carried.

To mount the hub on the chuck in forming both flanges 6 and 7, the hub may be placed with the three jaws 25 lightly engaging the spherical part of the hub between the barrels 44 or the ends of the barrels; a presser plate (not shown) is disposed across the hub flange nearest the tail stock, and the tail stock is forced against the plate to press the flange nearest the head stock firmly against the chuck plate or head to dispose the axes of the barrels 44 in a common plane of rotation on the chuck. The chuck jaws are then tightened against the hub. Then the boring and facing operations are performed on the hub by appropriate tools.

The hub (Fig. 8) is now placed on a dividing head supported centrally as when first forming

the center sockets, and the counterbores 12 of the sockets 10 between the barrels 44 are precision cut to final form. This removes any misplacement of the centering sockets which may have occurred during hardening. 31 in Fig. 8 represents a suitable tool with carballoy cutting teeth or points such as may be used to final finish the counterbore surfaces 12 of the centering sockets 10. Incidentally, the through drilling of the sockets 10 into the inner cavity surface 5 may be done by the carballoy tool while reforming the sockets, since the through holes of the sockets have not had to serve any essential purpose thus far. A flush pin gauge of the type shown by Fig. 7 at 27 having precision related feeler plug and conical socket engaging surfaces 28 and 29 respectively is now used to check the trued center sockets 10 with reference to the inside spherical boring surface 5. The plug of the flush pin gauge passed into the through openings of the sockets 10 are felt by a finger to be flush with the cavity surface 5 to make the tests. Since the centering socket counterbores as trued by the tool 31 are identical distances from the center of the hub and the wall thickness as measured by each flush pin gauging operation is the same at each centering socket, the central portion of the hub is necessarily balanced for rotation and the inside and outside spherical surfaces are known to be concentric. The hub is now ready to receive final finish grinding internally of the barrels 44.

The centering socket truing operations (counterbores 12) provide precision reference surfaces by which positioning shoulders for the blade mounts (bearing, sleeves, etc.) may be finish ground or otherwise precision finished, so that blades of equal weights at corresponding radially spaced points and pressed against the shoulders will be certain to balance about the center of rotation of the hub.

Referring to Fig. 9, the hub 40 is placed in a four jaw chuck 42, such as of a lathe head stock with two of the jaws 33 (one shown) gripping the forward and rearward main central faces of the hub at the flanges 6 and 7, and the other two jaws 34 gripping the outer ends of the barrels 44 in positions 44*x*. The arm or barrel at position 44*y* is thus presented centrally of the chuck axis where it may be centered by the head stock center point 35, left Fig. 9, engaging a centering socket 10 in cooperation with a V-shaped work rest 36 fixed on the machine tool bed and having any suitable friction reducing means for contact with the associated barrel at 44*y* (rollers or soft metal strips not shown). The inner peripheral surfaces of the barrels 44 are now finish ground sucessively, one barrel at each mounting of the hub in the chuck, by a suitable self contained grinder unit (not shown) slidably mounted on the machine tool bed for movement parallel to and/or laterally of the chuck axis as well understood in the machine tool art.

Referring to Fig. 10, the hub is now mounted in a four jaw chuck or the same chuck as described in relation to Fig. 9 with the head stock center point 35 engaging one of the sockets 10 (at the trued counterbore surface 12) and the tail stock center point engaging a centering socket in a turned mandrel or dummy plug 38 nicely fitting the inner finished surface of the barrel 44 which is aligned with such socket 10. So mounted successively in three positions, all external, spherical and cylindrical surfaces are final finish ground accurately to size and all exterior surface distortions due to heat treatment are removed.

In Fig. 10, 45 illustrates a portion of a profile grinding wheel set up for traversing movement only at right angles to the lathe axis so that the one third part 3*b* of the spherical surface, the cylindrical external barrel surface 48, and both radius surfaces 49 and 50 are finish ground, in one or more operations per mounting depending upon the particular wheel profile or profiles used, as the hub is turned slowly by the lathe. Preferably surfaces 3*b*, 48, 49 and 50 are all done with one grinding wheel to save time. Due to the fact that the counterbores of the centering sockets 10 have all been determined to be identically positioned with reference to the hub center, each spherical profile grinding operation, if carried out to the same point with reference to respective blade barrel axes on each above described mounting of the hub, there can be no possibility of error in forming the defining spherical surfaces of the central part of the hub, assuming of course that the wheel used has proper profile as can easily be provided; that the wheel is not moved axially between successive operations, and that the previous operations performed on the hub have left sufficient metal for removal by final grinding.

The final finish grinding operations on the barrel flanges or thickened portions 51 of the hub are preferably affected by a separate grinding wheel (not shown) either before or after profile grinding as above described, but while the hub is mounted as in Fig. 10. Absolutely no hand finishing operation is necessary on any part of the exterior hub surface.

The finished hub shown by Fig. 10 is ready for use in a propeller such as shown by any of my prior applications, Serial No. 476,398 filed February 19, 1943; Serial No. 498,492 filed August 13, 1943, issued as Patent No. 2,433,990, January 6, 1948; or Serial No. 528,412 filed March 28, 1944. The particular design shown (except for details purposely omitted from the illustrations submitted herewith) is for the controllable pitch propeller substantially as shown in the last above mentioned application. As there shown, one inturned flange (6 or 7 hereof when provided with suitable bolt or stud receiving holes) supports a hub carrier which fits the engine crank shaft and the other has a hydraulic servo motor unit and spinner secured thereto. The servo motor, through appropriate blade pitch changing and equalizing gearing located in the central space of the hub defined by the surface 5 and the flanges, adjusts the blades which are swivelled in the barrels corresponding to those at 44 hereof.

Before installing the hub in the propeller assembly, all the centering sockets 10 are plugged as illustrated by Fig. 11. The plugs, as shown, are in the form of rivets 52 having heads filling the countersunk portions 12 of the sockets and shanks filling the through holes which intersect the inner surface 5. The shanks are riveted over at 51 on the inside of the hub.

While the spherical portion of the hub as shown, neglecting the barrel forming arms, is a bisymmetrical or central spherical zone, it may be any other spherical zone or a sphere with one segment only removed. In that case, the closed region of the sphere would constitute the spinner of the propeller assembly and the flat end only would have a mounting flange.

I claim:

1. In a method of forming a propeller hub having three equidistantly spaced radiating arms adapted to support blades, the procedure com-

prising boring a circular cavity centrally through a metal blank having three equally spaced radial arms so that the arm portions of the blank radiate from the center of the cavity, supporting the blank at peripheral portions of the cavity for rotation on a fixed axis about the cavity center and, while so supported, forming centering sockets axially of each of the arms of the blank and additional centering sockets in intermediate portions of the blank angularly equidistant from the arm socket axes, and then using said sockets in pairs aligned diametrally of the cavity to locate the blank successively into three positions and, while so located in said positions, cutting the arm portions of the blank into generally cylindrical form and the arm-connecting portion of the blank into generally spherical form.

2. In a method of forming a propeller hub for a three-bladed propeller, the procedure comprising starting with a blank having a central body portion and three coplanar arms radiating therefrom 120° apart, boring the central body portion in a manner to form a circular cavity open at least at one side of the blank and whose axis extends at right angles to the common plane of the arms, mounting the blank for rotation using peripheral portions of the blank adjacent the cavity for engagement with an indexable support and, while so mounted, forming centering sockets 120° apart about the cavity center in the outer ends of the arms and an additional set of centering sockets 120° apart, 60° from the axes of the first mentioned sockets and in the wall of the body portion defined in part by the cavity, rotarily mounting the blank by using diametrally opposed pairs of sockets, one from each set, to locate the blank and, while so mounted and turned, cutting the arms into generally cylindrical form and portions of the central body portion into generally spherical form wherever contiguous to the generally cylindrical surfaces.

3. In forming a three-bladed propeller hub from a metal blank having a central portion and radiating arms 120° apart, the method comprising gripping the blank and boring a circular cavity through the central portion transverse to the plane of the arms, using a marginal portion of the cavity for centering contact with an indexable support for rotation of the blank into positions enabling formation of coacting pairs of centering sockets in the blank axially of the arms, one at each arm end and the others axially opposite the arms and between adjacent arms, then supporting the blank successively for rotation about the axes of the arms on said centering sockets whereby to turn the arms into generally cylindrical form and the central portion of the blank into generally spherical form contiguous to said cylindrical surfaces, then, while using said marginal portion of the central circular cavity for engagement with an indexable rotary support, axially boring the arms from their outer ends to form blade supporting sockets, heat treating the hub thus nearly completely formed to harden the surface portions, mounting the hub for rotation in the plane of the arms about the cavity center and truing peripheral and end face portions of the hub adjacent the central hub cavity to final form, then mounting the blank with the trued peripheral surface engaging an indexable support and refacing the centering sockets which lie between the arms to identical distances from the hub center, mounting the hub by gripping the same at four points successively to finish the inner surfaces of the blade supporting sockets identically in reference to the refaced centering sockets, and finally rotarily mounting the hub using the finished blade supporting sockets successively in cooperation with the respectively opposite refaced centering sockets to finish or polish the exterior spherical surface portions of the hub and adjacent external cylindrical portions of the arms.

4. In forming a three-bladed propeller hub from a metal blank having a central portion and radiating arms 120° apart, the method comprising gripping the blank and boring a circular cavity through the central portion transverse to the plane of the arms, using marginal portions of the cavity for centering contact with an indexable support for rotation of the blank into positions enabling formation of coacting pairs of centering sockets in the blank axially of the arms, one at each arm end and the others axially opposite the arms and between adjacent arms, then supporting the blank successively for rotation about the axes of the arms on said centering sockets whereby to turn the arms into generally cylindrical form and the central portion of the blank into generally spherical form contiguous to said cylindrical surfaces, then, while using said marginal portions of the central circular cavity for engagement with a rotary support, axially boring the arms from their outer ends to form blade supporting sockets, heat treating the hub thus nearly completely formed to harden the surface portions, mounting the hub for rotation in the plane of the arms about the cavity center and cutting inner peripheral portions of the hub adjacent the central hub cavity to final form, then mounting the blank with said inner peripheral surface engaging an indexable support and re-forming the centering sockets which lie between the arms to identical distances from the hub center, flush pin gaging the reformed surfaces of the centering sockets with reference to the central cavity inner wall, mounting the hub successively for rotation on axes of the arms and re-formed sockets to finish the inner surfaces of the blade supporting sockets identically in reference to the re-formed centering sockets, and finally rotarily mounting the hub using the finished blade supporting sockets successively in cooperation with the respectively opposite re-formed centering sockets to finish the exterior cylindrical and spherical surface portions of the hub.

5. In forming a three-bladed propeller hub from a flat three-armed blank, the method comprising gripping the blank as in a conventional chuck and turning a circular spherical cavity through the center portion of the blank, using inner limiting circular surfaces adjacent the cavity for centering contact with an indexable support for rotation of the blank and then forming coacting pairs of centering sockets in the blank axially of the arms of the blank so that one element of each pair of sockets lies between adjacent arms and the other element is on one of the arms, then supporting the blank successively for rotation about the axes of the arms on said centering sockets whereby to turn the arms into generally cylindrical form and the entire central portion of the blank into generally spherical form contiguous to said cylindrical surfaces, then, using the inner limiting circular surfaces adjacent the cavity for rotary support positioning of the blank and axially boring the arms from their outer ends to form blade supporting sockets, heat treating the hub thus formed to harden

the surface portions, mounting the hub for rotation in the plane of the arms about the cavity center and refacing peripheral portions of the first formed circular limiting surfaces, then mounting the blank with the refaced surfaces engaging an indexable support and truing the centering sockets which lie between said arms to exact identical distances from the hub center, mounting the hub for rotation about the axes of the arms successively to finish the inner surfaces of the blade supporting sockets identically in reference to the trued centering sockets, and finally rotarily mounting the hub using the finished blade supporting sockets successively in cooperation with respectively opposite trued centering sockets to finish grind the exterior circular, cylindrical and spherical surface portions of the hub.

6. In a method of forming a propeller hub adapted to support three blades, the procedure comprises starting with a generally flat forged steel blank with three equally spaced arm portions and a connecting central body portion, boring a generally spherical cavity in the central portion and centrally of the blank so that the spherical limits of the cavity terminate between the side walls of the blank, and additionally through-boring and turning the blank around the spherical cavity and on each side of the blank to form inturned concentric flanges for mounting the finished hub, mounting the blank on a rotary support, centeringly engaging the inner limits of the flanges and, while so mounted, forming six equally angularly spaced centering sockets all of which are coaxial with the arm portions and which are diametrally aligned in pairs across the center point of the spherical cavity, three of the centering sockets entering the cavity at spherical surface portions thereof, mounting the blank successively in three positions for rotation about coacting pairs of centering sockets and, in each position, turning one of the arm portions of the blank generally cylindrically and an adjacent one third portion of the connecting portion spherically, axially boring the arms at their outer ends to receive the blades, heat treating the hub thus formed to harden it, reforming and flush-pin-gaging the centering sockets which intercept the outer spherical surface with reference to the spherical surface of the cavity, and finally surface finishing the spherical and cylindrical external surfaces while using the centering sockets and the blade receiving bores of the arms for rotarily supporting the hub.

GORDON W. HARDY.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
420,338	Everson	Jan. 28, 1890
1,616,150	Teller	May 2, 1923
1,915,657	Findlater	June 27, 1933
2,285,772	Groene	June 9, 1942
2,344,242	Flygare	Mar. 14, 1944
2,369,828	Humphreys	Feb. 20, 1945