

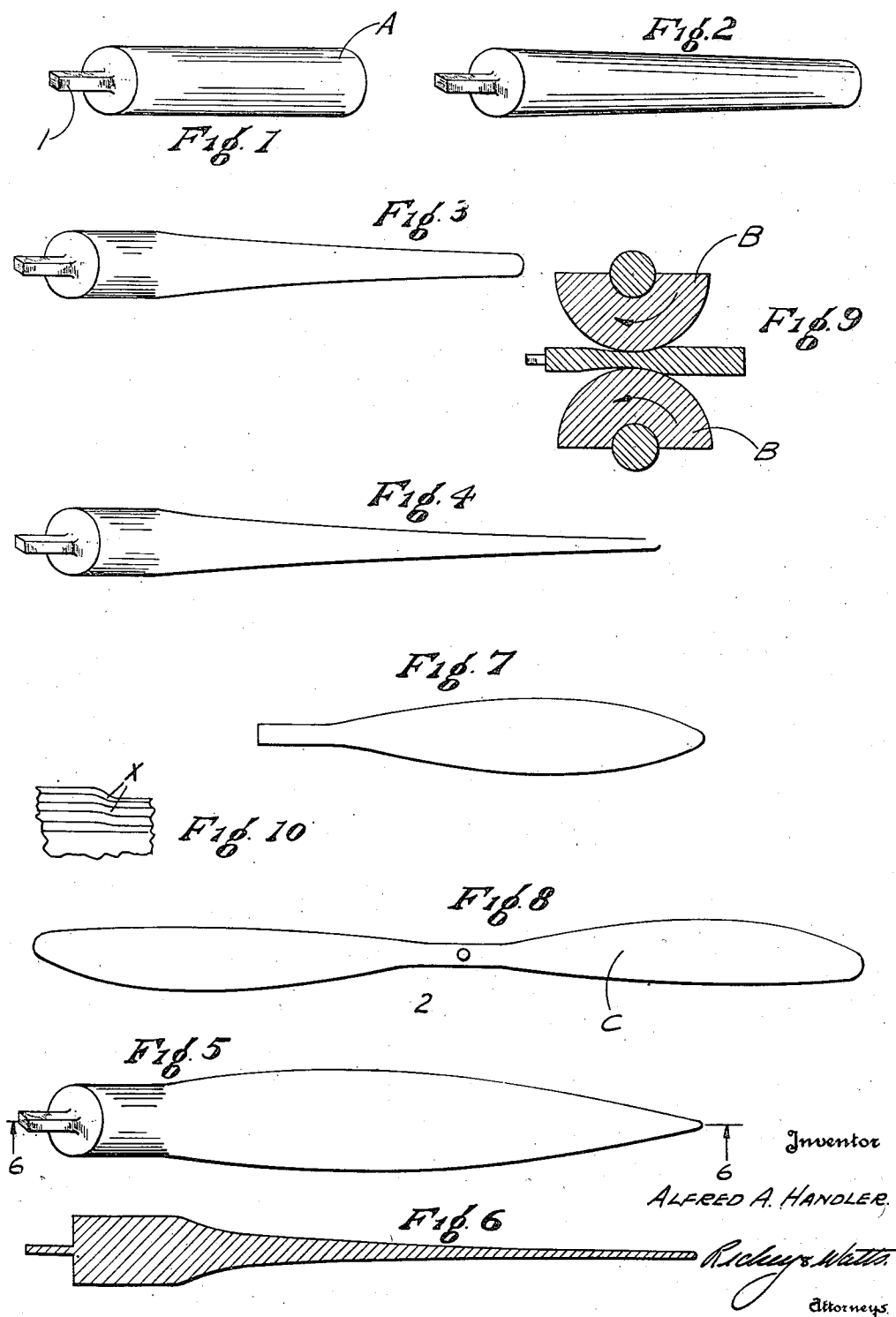
June 16, 1936.

A. A. HANDLER

2,044,293

METHOD OF MANUFACTURING PROPELLERS

Filed Aug. 19, 1929



UNITED STATES PATENT OFFICE

2,044,293

METHOD OF MANUFACTURING
PROPELLERSAlfred A. Handler, Cleveland, Ohio, assignor to
Aluminum Company of America, a corporation
of Pennsylvania

Application August 19, 1929, Serial No. 387,017

15 Claims. (Cl. 29—156.8)

This invention relates to a method of making aeronautical propeller blades and more particularly to a method of working the metal of a solid billet so as to obtain in the finished blade the maximum strength and fatigue resistance of the metal under the stresses to which it is subjected in service.

The method consists generally of longitudinally rolling a billet of rolled stock into the rough shape of a propeller blade by a series of one-way rolling passes toward the portion which becomes the tip in the finished blade, each pass being complete by continuing to the tip of the blade, and the series of passes serving to convert the billet or blank into a rough blade and thereby creating longitudinally extending flow lines converging at the tip and generally conforming to the contour of the finished blade. The effect of said rolling passes progressively and gradually refines the grain structure whereby the grain size contrast is maintained at a minimum from the hub to the tip of the blade.

The method described and claimed herein constitutes an improvement over the prior commercial methods of making propeller blades in which a billet of metal was hammer forged to rough blade shape and finished by die forging and the like. The hammer forging produces wavy irregular flow lines in the metal which are not removed in the final finishing operations so that the finished blade contains irregularities in the flow lines, each of the irregularities constituting a point at which the vibration stresses in use are concentrated, tending to start a fatigue failure in the metal. The hammer forging also produces a sharp contrast in the sizes of the grains along the cross sectional plane between the areas hammered to different amounts. In the subsequent heat treatment or in natural aging the areas of sharp grain size contrast constitute areas of excessive grain growth.

It will be understood that the sizes of the grains in the metal are reduced substantially in proportion to the amount of working and the strength and other physical properties of the metal are increased by the refinement of the grain structure. During grain growth the larger grains tend to assimilate smaller adjacent grains and thereby grow and increase in size at the expense of the smaller grains. The tendency to grain growth increases with an increase in the initial contrast between the sizes of adjacent grains. The more uniform the variation in grain size, the smaller is the tendency to grain growth. Where the grains grow the physical

properties produce by the working of the metal are lessened in proportion to the amount of grain growth.

As a consequence in the blades hammer forged to rough blade shape and subsequently finished by die forging or the like a series of cross sectional areas of excessive grain size contrast exist along the length of the blade and at these areas the grains, when grain growth occurs, increase in size out of proportion to the other grains in the blade. These points of excessive grain growth constitute cross sectional areas of weakness in the completed blade at which failure may occur either through tensile stress or as a result of fatigue. The blade in service is subjected to centrifugal stresses, bending stresses from the reaction of the air, and vibratory stresses from the repeated explosions or application of power in the engine driving the blade which also cause pulsations in the first mentioned stresses.

A further defect associated with the prior art hammering method of making a propeller grows out of the laminations therein caused by the presence of voids, dross, impurities, or undissolved constituents of the alloy. In hammering out a longitudinal billet, there is less resistance to flow of the metal under the force of the hammer in a transverse direction, the area on each side of the hammer in a longitudinal direction serving to restrict the axial flow and the unsupported sides of the billet permitting free lateral flow. When a volume of metal containing one of the above mentioned defects productive of a lamination is struck by a hammer the defect present will follow the flow of metal and thus extend transversely of the billet being worked. Regardless of the shape ultimately given the mass of the billet by hammering the lamination caused by a void or like defect frequently extends transversely of the length of the blade and thus constitutes a zone of weakness when bending stress is put upon the blade.

To overcome the defects growing out of the hammer forging method of making a propeller and to produce propellers uniformly reliable and less subject to fatigue failure phenomena it is among the objects of my invention to provide a method of making a propeller wherein the flow lines will extend generally longitudinally of the blade, will converge at the tip of the blade and will conform intermediate the ends of the blade to the contour of the propeller in its finished form. It is a further object of my invention to provide a method of making a propeller which

will minimize the effect of voids, dross or impurities in the billet and which will minimize the grain size contrast, and which will effect a progressive or gradual variation in grain size from the hub to the tip portion of the blade. Further objects and advantages will appear from the following description and the appended drawing wherein:

Figure 1 is a perspective view of a billet before it is subjected to the methods hereof.

Figure 2 is a view similar to Figure 1 and develops the billet after it has been put through the first rolling pass.

Figures 3 and 4 are perspectives similar to Figure 2 bringing out the shape of the billet subsequent to further passes through the forging rolls.

Figure 5 is a plan view of a propeller after it has been roughly shaped by the forging rolls.

Figure 6 is a section taken about on the line 6—6 of Figure 5.

Figure 7 is a plan view of a finished single bladed propeller.

Figure 8 is a plan view of a finished double bladed propeller and,

Figure 9 is a showing, somewhat diagrammatically, of the forging rolls and the action of the latter on the billet, and

Figure 10 is an enlarged fragmentary view in elevation of a piece of metal which has been hammered out in accordance with the known methods above discussed.

By way of illustrating and describing a preferred specific embodiment of the invention the method of making an aeronautical propeller from an aluminum base alloy containing approximately ninety-four percent aluminum, four and five-tenths percent copper, seventy-five hundredths percent manganese, and seventy-five hundredths percent silicon, is herein set forth. It is to be clearly understood that propellers designed for purposes other than aeronautical, and from metals and alloys other than that noted may be manufactured in accordance with the precepts of this invention without departing from the scope thereof. Not only may other aluminum base alloys be availed of as the material from which the propellers are made but magnesium base alloys may also be employed. Such alloys have many of the properties and qualities of the aluminum alloys which render them particularly adaptable for the making of aircraft propellers. Propellers of the type noted may also be made from iron and steel, copper and its alloys, such as brass and bronze, and nickel in combined form, such as Monel metal. In fact, any metal which can be made into propellers by forging and rolling is susceptible to working by the methods of this development.

The article initially worked upon according to the method such as is proposed hereby is shown in Figure 1 in the form of a billet or casting A. The billet A may take the form of an ingot as originally cast or a billet that has been rolled from an ingot. In the present instance the method is described, for exemplary purposes, as beginning with the billet A, but it is obvious that the original step of a method involving rolling requires a casting operation. A preferred method of working an ingot into the billet form as depicted by the billet A is by rolling, but other operations for working the ingot into the billet may be substituted for rolling.

The billet A is formed with a handle portion or tong hold 1 in any suitable manner and this portion is gripped by tongs or like tools to manipu-

late the billet during the forming operations. After the propeller has been shaped this handle portion 1 is removed, as by cutting off.

The billet A is first heated to a condition wherein it is readily workable, say for instance, eight hundred twenty degrees F. It is then subjected to the action of the forging rolls indicated diagrammatically in Figure 9 and referred to as B. As the manufacturing processes are herein described as beginning with a billet of the shape shown in Figure 1, it would not be desirable to attempt to reduce such a shaped billet to propeller shape by one rolling operation or pass through the forging rolls. A preferred rolling method comprises several of these passes which gradually work the billet, by successive deformings, into the shape shown in Figures 5 and 6. It is noted that rolling out operations illustrated by the change in billet form as shown in Figures 1, 2, 3, and 4 have maintained the round shape of the 20 billet and merely drawn it out into a conical formation. The final pass through the forging rolls, however, serves to flatten out the conical or tapered portion into something resembling blade shape. The conical shape of the billet after the 25 preliminary rolling operations and the blade shape after the subsequent rolling operations are preferably obtained by suitable profiles formed on the faces of the rolls.

The action of shaping by rolling is characterized 30 by the application of a metal deforming force which increases progressively in intensity during a rolling pass and which also progressively advances the point of application of the force along the article being rolled in the direction of the 35 rolling. This action works the metal and therefore refines the grain structure and by reason of the uniform gradual gradient of the working force or strain, the fineness of the grains produced varies progressively without material grain size 40 contrast.

I also use the term "coning" to describe generally the operations which draw the billet out into a conical formation as illustrated in Figures 1 to 4 inclusive and as described above. It will be understood that the invention is not limited to the 45 formation of a mathematical cone or to the maintaining of a precisely circular cross section and accordingly I use the terms "coning" and "conical shape" to include all equivalent shapes and operations in which the flow lines are gathered or 50 bunched substantially concentric about the longitudinal axis of the billet. It will be observed that the coning of the end of the billet A remote from the handle maintains the blank symmetrical 55 throughout its length and the elongation accompanying the coning operation positions that metal receiving the maximum amount of work toward the tip of the blade. In other words, by reference to Figure 4, the metal which is least worked 60 merges into the unworked tong handle end of the billet and thus retains the relatively coarse grain structure of the billet whereas the other end of the cone is formed of metal worked to a greater degree and therefore has a finer grain structure. 65 The change in grain size is gradual in response to the uniform decrease in diameter throughout the tapered portion of the blank. It will also be observed that any laminations which might result from voids or impurities in the blank will extend 70 longitudinally of the coned blank rather than transversely and thus the effect of the laminations will be minimized and that the flow lines present in the blank of Figure 4 will converge at the small end of the blank.

Subsequent to the coning of the billet as shown in Figure 4 the blank is flattened as indicated in Figures 5 and 6. This flattening pass is ineffective to disturb the longitudinal and converging arrangement of the flow lines and the elongation attending the flattening pass is ineffective to disrupt the convergence of the flow lines at the tip of the blade. As illustrated in Figure 5 the flattening is substantially equal on each side of the longitudinal axis of the coned blank. This arrangement or amount of flattening with respect to the axis of the coned blank may be varied depending upon the shape or design desired in the finished article. The blank of Figure 5 may be identified as a rough blade shape and subsequent to acquiring this shape it is transferred to forging or pressing dies and further flattened and shaped. As in the case of the rolling the blank may be heated prior to the pressing or forging operations in order to render it more readily workable.

For the purposes of this specification the various shaping operations which may be performed on the propeller after rolling are classified generally as forging. This term is intended to include any of the forming methods carried out after rough shaping in which the metal is worked by a force applied under pressure, such as forging by dies and pressing.

After the propeller has been shaped by the forging or pressing dies, it is finished by the conventional finishing processes, including cleaning, trimming and sizing. It is then heat treated by first being subjected to a temperature of about nine hundred sixty degrees F. (960° F.) for about twelve to sixteen hours, if the propeller be of the composition previously mentioned. The time is dependent on the size of the article and the amount of working the metal thereof has received, as well as the composition of the alloy. The propeller is then quenched and aged at a temperature of approximately three hundred ten degrees F. (310° F.) for about eighteen (18) hours.

During this heat treatment any large grains of the metallic structure tend to assimilate and grow at the expense of any adjacent relatively small grains, since the thermal stability of the aggregate would be increased by an increase in grain size. By reason of the progressive variation in grain size produced by the uniform and gradual strain gradient in working, all of the grains possess substantially equal powers of orientation, and grain growth is, therefore, reduced to a minimum.

Substantially the same methods as above outlined are availed of in the manufacture of a double bladed propeller. As in the case of the single bladed article the billet is rolled from the hub or root portion, towards the ends or tips. In addition the hub portion is formed with an opening to provide for a hub mounting. This operation is preferably effected after the propeller has otherwise assumed its final form. A double bladed product is shown in Figure 8 and designated C. The latter is provided with an opening 2 as above noted.

The rolling out operations provide a product having a metallic structure that is relatively free from coarse grains, and a grain structure that is characterized by flow lines and laminations conforming in direction to the contour of the propellers, and in which the size of the grains varies in a uniformly progressive manner throughout the propeller. Moreover, the metal is substan-

tially free from localized voids at the surface or extending across the blade.

To illustrate the adverse effect with respect to flow line structure of the old hammer forging action on a billet I have shown diagrammatically in Figure 10 how the hammer, since it extends but a small portion of the length of the billet, produces an undesirable irregularity in the flow lines. For instance at the edge of the hammer as indicated at X there is a sharp step or juncture in the direction of the metallic fibers. In the event that another hammer blow is struck above the juncture at X and overlapping both sides of the juncture another pair of irregular lines such as X will appear at each side as determined by the edges of the hammer. This action continues throughout the hammering of the blank and although the blank may appear to be uniform as the work progresses, it is obvious that the entire blank will present a large number of transverse bends or steps such as X. A hammered blank having flow line characteristics such as indicated at X is to be distinguished from one having smooth continuous flow lines such as produced by the novel rolling method herein described.

Although I have described one embodiment of my invention in considerable detail it will be appreciated by those skilled in the art that numerous variations may be made therein without departing from the scope of my invention. For instance, the billet A may be cast or worked in any suitable way, although the preferred embodiment describes it as being rolled and it will also be understood that the method may be carried out upon a double ended billet wherein the tong or handle portion 1 is omitted and the hub portions merge into each other. Other colorable variations may be made such as employing magnesium or other alloys in casting the billet and therefore I do not wish to be limited other than by the appended claims.

What I claim is:

1. The method of making a propeller blade comprising gradually deforming a billet of metal into the shape of a tapering blade by applying a deforming force to the metal, progressively advancing the point of application of force from the root portion to the tip portion of the blade, progressively increasing the force from the root portion to the tip portion of the blade to gradually refine the grain structure throughout the length of the blade with a minimum of grain size contrast and to form flow lines conforming to the contour of the blade, and completing the shaping of the blade by forging operations without increasing the grain size contrast or destroying the flow lines.

2. The method of forging propeller blades which includes heating a bar blank, elongating and coning one end portion of the bar blank by successive passes between roll dies, further elongating and tapering the elongated portion of the bar blank between roll dies, the elongated portion being worked to a predetermined size and shape during each successive pass, and then forging the partly completed product to a finished forging.

3. The method of forging propeller blades which includes heating a bar blank, elongating and coning one end portion of the bar blank by successive passes between roll dies, further elongating and flattening the elongated portion of the bar blank between roll dies, the elongated portion being worked to a predetermined size and shape during each successive pass, and then

forging the partly completed product to a finished forging.

4. The method of forging propeller blades which includes heating a bar blank of magnesium, elongating and coning one end portion of the bar blank by successive passes between roll dies, further working the elongated portion of the bar blank by successive passes between roll dies to a rough blade shape, the elongated portion being worked to a predetermined size and shape during each successive pass, and then forging the partly completed product to a completed forging.

5. The method of forging propeller blades which includes heating a bar blank of magnesium, elongating and coning one end portion of the bar blank by successive passes between roll dies, further elongating and flattening the elongated portion of the bar blank between roll dies, the elongated portion being worked to a predetermined size and shape during each successive pass, and then forging the partly completed product to a finished forging.

6. The method of forging propeller blades which includes heating a bar blank, elongating and coning one end portion of the bar blank by successive passes between roll dies, further elongating and tapering the elongated portion of the bar blank between roll dies thereby producing a partly finished product of slightly less width and greater thickness than desired in the finished blade, the elongated portion being worked to a predetermined size and shape during each successive pass, and then forging the partly completed product to a completed forging.

7. The method of forging propeller blades which consists in heating a bar blank of light metal alloy, roll forging the bar blank by a series of successive one-way rolling passes to elongate and cone one end portion of the bar blank, further roll forging the end portion to further elongate and flatten said end portion, and then forging the partly completed product to a finished forging.

8. The method of forging propeller blades which consists in heating a bar blank of light metal alloy, roll forging the bar blank by a series of one-way rolling passes to cone and elongate one end portion of the bar blank, further roll forging said one end portion passes to further elongate and taper the same outwardly producing a product of slightly less width and greater thickness than desired in the finished blade, and then forging the partly completed product to a finished forging.

9. The method of roll forging a propeller blade from a billet of light metal comprising subjecting the billet to a series of rolling passes to elongate and taper one end of the billet into a substantially conical form, further rolling the billet to further elongate and flatten the same into a rough blade shape and completing the shaping of the blade by operations maintaining the fiber and flow line structure created by said rolling.

10. The method of roll forging a propeller blade from a billet of light metal comprising sub-

jecting the billet to a series of one-way rolling passes to elongate and taper one end of the billet into a substantially conical form, further rolling the billet to further elongate and flatten the same into substantially the shape of the finished blade, and completing the shaping of and finishing the blade.

11. That method of making a propeller which comprises rolling a cone at one end of a cylindrical blank to elongate same and establish longitudinally extending flow lines converging at the coned end thereof, exerting pressure on the coned blank to flatten the same to form a blade with the longitudinally extending flow lines conforming to the contour of the blade and the converging lines terminating at the tip of the blade.

12. That method of making a propeller blade which comprises rolling a cylindrical blank, rolling a cone with its apex disposed at that end of the blank which forms the tip of the blade in the finished article to effect a progressive decrease in grain size from the hub to the tip of the blade, exerting pressure on the coned blank to flatten the same without disturbing the resultant grain size arrangement or the flow lines extending longitudinally of the blank.

13. That method of making a propeller blade which comprises rolling a cylindrical rolled stock billet to form a blank having a gradually decreasing diameter and a substantially round cross section and an axial extent exceeding the length of the original cylindrical billet whereby the grain structure is characterized by gradually decreasing grain size from one end of the blank to the other, thereafter exerting pressure on the said blank to flatten the same to a blade shape without disturbing said grain size arrangement.

14. That method of forming a propeller blade which comprises rolling a cylindrical blank to effect a progressive diameter reduction toward one end and simultaneously elongate the blank by progressively increasing the deforming force near said end, said rolling action maintained on all sides of the blank to result in an elongated conical blank with the distribution of the mass of the metal corresponding to the mass required throughout the axial extent of the finished propeller, said rolling action also effective to establish longitudinally extending flow lines converging in that area which becomes the blade tip in the finished article, exerting pressure on the conical blank to shape the same into rough blade shape in a manner to maintain said flow line arrangement.

15. The method of making a metal propeller which includes rolling a blank of metal longitudinally to effect a tapered cone at one end by a series of one-way rolling passes, thereafter flattening the coned blank into a blade of rough propeller form by subjecting it to further rolling passes extending in direction from the hub to the tip, and thereafter further shaping the rough propeller form by die forging or pressing operations.

ALFRED A. HANDLER.

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CERTIFICATE OF CORRECTION.

Patent No. 2,044,293.

June 16, 1936.

ALFRED A. HANDLER.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 1, second column, line 1, for the word "produce" read produced; page 4, first column, line 49, claim 8, strike out the word "passes"; and that the said Letters Patent should be read with these corrections therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 15th day of September, A. D. 1936.

Henry Van Arsdale

(Seal).

Acting Commissioner of Patents.