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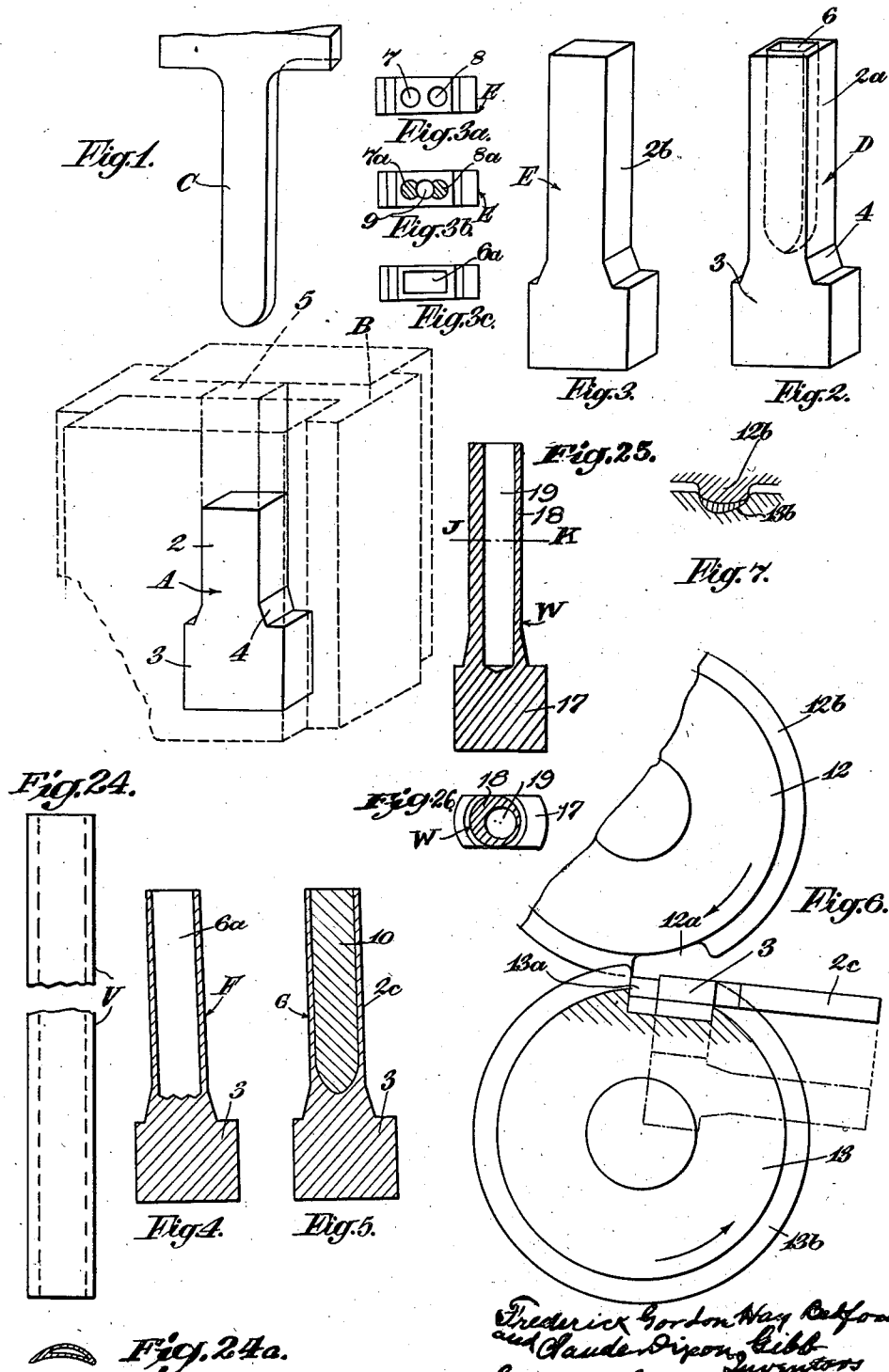
F. G. H. BEDFORD ET AL

2,013,622

METHOD OF MAKING TURBINE BLADES

Filed Oct. 27, 1932

2 Sheets-Sheet 1



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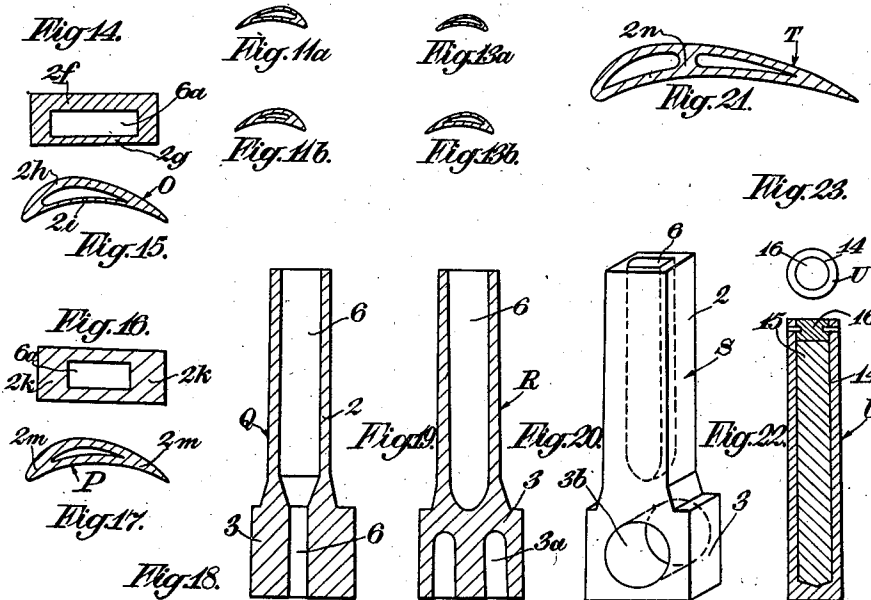
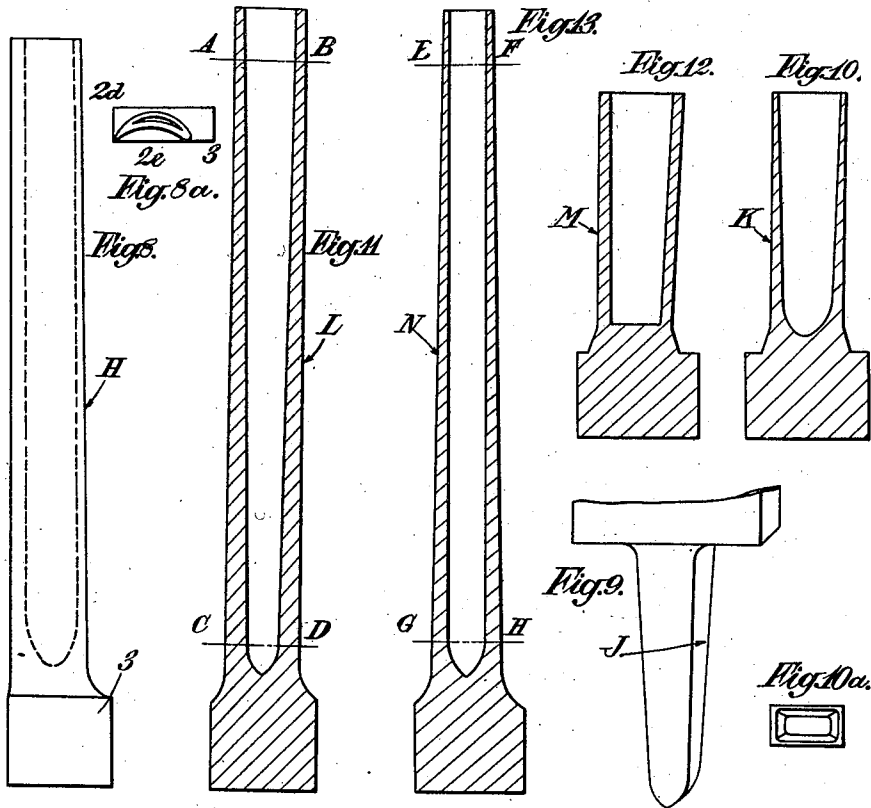
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METHOD OF MAKING TURBINE BLADES

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UNITED STATES PATENT OFFICE

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METHOD OF MAKING TURBINE BLADES

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The invention relates to the manufacture of blades suitable for steam turbines, compressors and the like, hereinafter referred to generically as "turbine blades" or "turbine blading".

5 In such applications, the rotor blades in some cases are subjected to very heavy centrifugal forces and proposals have been made to lessen the resulting stresses on blades and rotors by the provision of hollow blades.

10 With the same object of reducing weight, solid blades have sometimes been tapered for the whole or a part of their length in the direction from root to tip, such tapered blades being commonly used only at the low-pressure end of the turbine

15 where the peripheral speeds attain a maximum. At the low-pressure end, however, it is not a practicable mechanical operation to machine a hollow of the difficult cross-section required out of a solid blade of the very considerable length

20 now often used.

To overcome these difficulties, the hollow is made of a convenient shape in a blade blank of only a short length, an operation involving no special mechanical difficulties, and the hollow 25 blade is then elongated by some suitable process such as rolling between profiled rollers, thereby not only increasing the length of the blank to the extent required but simultaneously defining both the external and internal cross-sectional con- 30 tours of the finished blade.

The invention consists in the processes of manufacturing hollow seamless turbine blades as hereinafter described and particularly pointed out in the claims.

35 Referring to the accompanying drawings which form part of the specification and are of a diagrammatic nature:—

Figure 1 shows in perspective one form of apparatus for producing a hollow blade by punch 40 and die,

Figure 2 showing a similar perspective view of the resulting hollow blank,

Figure 3 shows a perspective view of a form of solid blade blank prior to its being given a hol- 45 low formation,

Figure 3a showing an end view of the blank with two holes drilled endwise in the blade-forming part thereof,

Figure 3b is a like view showing the addition 50 of a third hole and

Figure 3c a like view showing the final form of the hole in the blade-forming part of the blank, while

55 Figure 4 shows a corresponding longitudinal section of the blank produced;

Figure 5 shows a longitudinal section through a tubular blank filled with resistant material;

Figure 6 shows in outside elevation a filled tubular blade blank about to be passed between 5 gapped rolls,

Figure 7 being a cross section through the profiled rims of the rolls;

Figure 8 shows in elevation a hollow tubular blade integral with its root,

Figure 8a being a corresponding end view; 10

Figure 9 shows a form of tapered punch;

Figure 10 shows a longitudinal sectional elevation of a form of blank with tapered walls,

Figure 10a being a corresponding end view of the blade-forming part of the blank; 15

Figure 11 shows a longitudinal sectional elevation of a hollow blade integral with its root, the blade proper being parallel externally with walls decreasing in thickness from root to tip,

Figures 11a and 11b being corresponding sections respectively on the lines A—B and C—D of 20 Figure 11;

Figure 12 shows a flared hollow blank with walls of uniform thickness;

Figure 13 shows a longitudinal sectional elevation of a hollow blade integral with its root, the blade proper being parallel internally with walls decreasing in thickness from root to tip, 25

Figures 13a and 13b being corresponding sections respectively on the lines E—F, and G—H 30 of Figure 13;

Figure 14 shows an end view of the blade-forming part of a blank in which the hollow is displaced to one side,

Figure 15 showing a cross-section of the resulting blade; 35

Figure 16 shows an end view of the blade-forming part of a billet in which the length of the hollow rectangle as seen in cross-section is relatively reduced,

Figure 17 showing a cross-section of the resulting blade with extra metal at the edges; 40

Figure 18 shows a longitudinal section of a hollow blank in which the hollow passes through both the blade-forming and root-forming parts 45 of the blank;

Figure 19 shows a similar view of a blade blank in which the root-forming part is lightened by an axial hole and

Figure 20 is a perspective view in which the 50 lightening hole runs transversely;

Figure 21 shows a cross-sectional plan of a hollow blade provided with a transverse bridge of metal serving as a stiffener;

Figure 22 shows in sectional elevation a cir- 55

cular rootless blank of tubular form, filled and plugged,

Figure 23 being a corresponding end view;

Figure 24 shows in longitudinal elevation a view of a length of hollow strip blading without root,

Figure 24a being a corresponding cross-sectional view; while

Figure 25 shows in longitudinal elevation a view of a blade blank having an integral root, in which the hollow blade-forming part is circular, and

Figure 26 a corresponding cross-section on the line J—K of Figure 25.

Where desirable, the same reference symbols are used in the different figures to denote corresponding parts.

In carrying the invention into effect according to one form, applicable to the blades of a steam reaction turbine, a blank, A, is formed (see Figure 1) having a blade-forming part, 2, of uniform rectangular cross-section and a laterally-extending root-forming part, 3, integral therewith, such blade-forming and root-forming parts being connected by a fillet, 4, of the kind described in U. S. patent specification No. 1,772,876.

According to one method of procedure, the blank, A, so formed and at a proper temperature is suitably held in a built-up die, B, the blade-forming part, 2, being enclosed in an elongated recess, 5, in the die or mould of like cross-section, and a former punch, C, likewise of rectangular cross-section, it may be with the corners rounded, is forced longitudinally into the blade-forming part, 2, of the blank, A, from one end, with the sides of the two rectangles approximately parallel; the metal of the billet is thus caused by an extrusion action to flow into the annular space between the punch, C, and mould, B, thereby elongating the blade-forming part, 2, of the blank, A, to the length, 2a, (see Figure 2) and giving it a hollow, 6, so that the blade-forming part, 2a, has a preliminary tubular form for a desired length.

The hollow blank assumes the form, D, shown in Figure 2.

According to another method of procedure, a solid blank, E, is prepared having the form shown in Figure 3, with a blade-forming part, 2b, of the required length; a hole, 6a (see Figure 3c) of the required shape is then formed longitudinally in the blade-forming part, 2b, of the blank, E, by drilling two holes, 7 and 8, (see Figure 3a), providing these holes with plugs, 7a and 8a, and drilling an intermediate hole, 9, (see Figure 3b); a hole of irregular shape is thus produced which may be given its final shape, 6a, (see Figure 3c) by milling, broaching, drifting, punching or other machine or hand operation.

The hollow blank then assumes the form, F, shown in Figure 4.

Or again, the three holes, 7, 8 and 9 may be pin drilled, smaller pilot holes being first drilled at the appropriate centres.

In order to give the desired cross-section to the blade-forming part of the hollow blank produced by any of the above methods, (or by any other suitable method), the hollow, 6 or 6a, is filled with a suitable resistant material, 10, a longitudinal section through the filled blank, G, being shown in Figure 5, and the filled blade-forming part, 2c, of the blank is then elongated to a straight blade of uniform cross-section by passing it between suitable dies or rolls, 12, 13, preferably of the same diameter (see Figure 6) having peripheral gaps, 12a, 13a, for the reception of the root, 3, of a blade, the remainder of the periphery,

12b, 13b, being profiled, (see Figure 7) to impart the desired cross-section to the blade.

The filling material, 10, is then removed to give as a final result of the process (apart from any finishing processes such as grinding, buffing or the like, or machining as hereinafter indicated) a blade and root, H, (see Figure 8) the hollow blade proper, being of the correct reaction cross-section, with walls, 2d, 2e, of substantially uniform thickness, and integral with its root, 3.

If the blade is of stainless steel, which is rolled at a temperature of about 950° C. and melts at approximately 1500° C. copper may very suitably be used as the filling material, this metal having a melting point of about 1085° C. so that it can very readily be melted out by raising the temperature of the filled blade to, say 1100° C.

By tapering the former punch of Figure 1, in both directions, if necessary, as shown at J, (Figure 9), it will be seen that the thickness of the walls of the resulting blank, K, (Figure 10), and finished blade, L, (Figure 11), gradually decreases from the root towards the tip, the external form of the blade being maintained parallel.

Or alternately, a blank, F, with parallel hole, 6a, may be formed as described with reference to Figure 4, and a tapered mandril forced into the hole so as to flare out the blade-forming part of the blank and give it the shape, M, shown in Figure 12; the flared blank, M, is then forged or machined on the outside, to restore the external parallel form and leave a tapered hole internally as shown at K, (Figure 10).

While the weight of the blade is thus decreased with a corresponding reduction in root and rotor stresses, the parallel external form of the blade gives a steam passage between the blades that is much superior to that obtained with externally-tapered solid blades so that the blading efficiency is improved.

With higher blade-tip speeds, however, it may in some cases be necessary to taper the blades externally, this result being secured according to one form by preparing a hollow blade such as F, (Figure 4), but with relatively thick walls of parallel (or tapered) cross-section in the manner above described, and subsequently machining the outside of the blade on the concave and/or convex face or faces to give externally-tapered form desired, (see blade N, Figure 13).

A non-uniform disposition of the metal in the walls of the finished hollow blade can be obtained by locating the hollow asymmetrically in the blank in any desired manner.

For example, by arranging the hollow, 6a, in the blade-forming part of the blank (see Figure 14) nearer to one side of the rectangle so as to provide a thick wall, 2f, and a thin wall, 2g, the corresponding wall 2h, 2i, of the resulting blade, O, may be given different thicknesses as shown (see Figure 15).

Or again, in order to strengthen the thin outlet edge of the blade and/or in order to provide a solid attachment for erosion-resisting shields, if fitted on the leading edges, it may be desirable to reduce the length of the rectangular hole, as seen in cross-section, (see Figure 16) in relation to that of the blank so as to provide extra metal, 2k, for the formation of the solid leading and outlet edges, 2m, of the resulting blade, P.

In any of the processes described, the axial hole, 6, in the blank may in some cases pass not only through the blade-forming part, 2, but also through the root-forming part, 3, of the blank, Q, (see Figure 18) or alternatively or in addition, the

latter may be lightened by the removal of metal by any suitable method such as drilling holes either axially or transversely, grooving, hollow milling and so forth. Thus in Figure 19, a blank, R, is shown in which two axial lightening holes, 3a, are shown in the root while in Figure 20, the root, 3, of the blank, S, is lightened by a transverse hole, 3b.

The lightening of the root may be carried out either before or after the extension of the blade-forming part of the blank.

Again, in any of the forms of the invention described, instead of forming a single rectangular, circular or other longitudinal hole in the blank, two or more parallel (or tapered) holes, such as 7 and 8, (Figure 3a), may be formed to a desired depth, or alternatively, two or more such holes at the base may merge into a single hole at the tip end.

According to this plan, one or more bridges of metal, 2n, which may be made to decrease in thickness from root to tip, will extend transversely from the convex to the concave wall of the resulting blading, T, (see Figure 21) and serve as efficient stiffeners.

With such processes, it will be seen that the thickness of each wall of the resulting hollow blade may be made substantially uniform, though the thickness of the concave side and of the convex side may differ. Similarly the thickness may vary over any desired length of the blade by decreasing in the direction from root to tip, any of these forms being readily obtained either by forming the blank with a tapered hole or by external machining of the surface of the blade, or by a combination of these methods.

Parallel blades with walls of uniform thickness may also be finished by external machining.

Hollow turbine blades manufactured as above described have all the characteristics desirable in the rotor blade of a steam turbine running at high peripheral speeds, since the blade proper is integral with its root, the latter, which is the most highly stressed part, being solid, while by virtue of the hollow formation of the blade, its weight is much reduced in comparison with a solid blade of the same external contour, and consequently the stresses on the root and on the turbine rotor are also reduced to a corresponding degree.

According to another part of the invention, hollow blading is manufactured in long strips of uniform section, e. g., reaction section, and cut up into appropriate lengths to form the blades themselves.

Such strip blading according to one form is produced from a circular billet, U, (Figures 22, 23) through which an axial hole, 14, has been drilled, concentrically or eccentrically. The hole, 14, is then filled with copper or other material, 15, which may be retained in place by a plug, 16, the compound billet being broken down to a rectangular shape by rolling or pressing the billet in directions alternately at right angles.

The rectangular billet so formed with the similar more or less rectangular centre suitably filled is then passed through profiled rolls to give it the required section and the filling material removed, to give a length of hollow blading, V, as shown in Figures 24 and 24a.

Alternatively, a length of blading may be rolled direct from the billet of circular cross-section without prior reduction to rectangular form.

Strip blading so produced may have walls of substantially uniform thickness with plenty of metal available to form the inlet and outlet edges,

or the thickness of the two walls may differ as explained above.

Such strip blading may also be formed with transverse stiffening means as above described.

A similar method of procedure may be applied to the case of a blank having a hollow blade-forming part and an integral root. Thus the blank, W, (see Figures 25 and 26) comprises a root, 17, and a circular tubular blade-forming part having walls, 18, and a hollow, 19, eccentrically disposed. As described above, the blade-forming part of such a blank may be broken down to a substantially rectangular cross-section and subsequently elongated to give the desired cross-section by any suitable means, or the blade may be elongated direct from the blank of circular cross-section.

The filling material used may be a metal with a melting point lower than that of the material of which the blade is formed, so that when the rolling is completed, the core may be melted out. Copper has been found suitable and convenient in conjunction with the usual blading materials, e. g., stainless steel, because its melting point is above the rolling temperature, but below the melting temperature of the blade material.

Other metals or alloys may, however, be used in the same way.

Alternatively, the filling material may be a non-metallic substance of a granular nature, such as sand or sand mixed with a suitable oil, which can be broken up for removal from the rolled blade. With this type of filling the ends of the hollow blank must be plugged with copper or other suitable material to retain the filling during the rolling process described above.

It will be understood that the illustrative methods of manufacturing hollow blading above described are not confined to blades of the reaction type, but are equally applicable to blades of the impulse or other type or to vanes used in impulse-turbine diaphragm nozzles.

We claim:

1. A process of manufacturing hollow seamless turbine blades which consists in providing a seamless blade blank having at least one longitudinal hollow, filling said blank with resistant material, elongating said filled blank and simultaneously imparting a blade-shaped configuration to the external and internal cross-sections of the blade and removing said resistant material.

2. A process of manufacturing hollow seamless turbine blades, which consists in providing a seamless blade blank having at least one longitudinal hollow asymmetrically disposed in said blank, filling said blank with resistant material, elongating said filled blank and simultaneously imparting a blade-shaped configuration to the external and internal cross-sections of the blade and removing said resistant material.

3. A process of manufacturing hollow seamless turbine blades which consists in providing a blank of circular cross-section, with at least one circular longitudinal hollow in said blank offset in said circular cross-section, filling said blank with resistant material, reducing said circular section to a rectangular cross-section, elongating said filled and reduced blank and simultaneously imparting a blade-shaped configuration to the external and internal cross-sections of the blade and removing said resistant material.

4. A process of manufacturing hollow seamless turbine blades as claimed in claim 1, in which said blank is provided with a parallel longitudinal hollow which is subsequently flared out and the

outer surface of the walls of said hollow remade to parallel longitudinal form before said hollow is filled with resistant material.

5 A process of manufacturing hollow seamless turbine blades which consists in providing a seamless blade blank having at least one longitudinal hollow, elongating said blank and simultaneously imparting a blade-shaped configuration to the external and internal cross-sections of the blade.

10 6. A process of manufacturing hollow seamless turbine blades, which consists in providing a seamless blade blank having at least one longitudinal hollow asymmetrically disposed in said blank, elongating said blank and simultaneously imparting a blade-shaped configuration to the external and internal cross-sections of the blade.

15 7. A process of manufacturing hollow seamless turbine blades which consists in providing a blank of circular cross-section, with at least one circular longitudinal hollow in said blank offset in said circular cross-section, reducing said circular to a rectangular cross-section, elongating said reduced blank and simultaneously imparting a blade-shaped configuration to the external and internal cross-sections of the blade.

20 8. In the process of producing a hollow turbine blade having an integral root portion, the steps which comprise forming a blank consisting of a root-blank portion at least as large as the root portion of the finished blade, and a blade-blank portion whose length is less than that of the finished blade portion, forming a hollow extending longitudinally in the blade-blank portion, and thereafter displacing the metal of the blade-portion only, in the direction of its length until said blade-portion is elongated to at least the length of the finished blade-portion, and simultaneously during said displacement of the metal imparting a blade-shaped configuration both externally and internally to the cross-section of said blade-portion.

25 9. In the process of producing a hollow turbine blade having an integral root portion, the steps which comprise forming a blank consisting of a root-blank portion at least as large as the root portion of the finished blade, and a blade-blank portion whose length is less than that of the finished blade portion, forming an asymmetrical hollow extending longitudinally in the blade-blank portion, and subsequently displacing the metal of the blade-portion only, in the direction of its length until said blade-portion is elongated to at least the length of the finished blade-portion, and simultaneously during said displacement of the metal imparting a blade-shaped configuration both externally and internally to the cross-section of said blade-portion.

30 10. In the process of producing a hollow turbine blade having an integral root portion, the steps which comprise forming a blank consisting of a root-blank portion at least as large as the root portion of the finished blade, and a blade-

blank portion whose length is less than that of the finished blade portion, forming a hollow extending longitudinally in the blade-blank portion, filling said hollow with resistant material, displacing the metal of the blade-portion only, in the direction of its length until it is elongated to at least the length of the finished blade-portion, and thereafter removing the resistant material.

10 11. In the process of producing a hollow turbine blade having an integral root portion, the steps which comprise forming a blank consisting of a root-blank portion at least as large as the root portion of the finished blade, and a blade-blank portion whose length is less than that of the finished blade portion, forming a hollow extending longitudinally in the blade-blank portion, filling said hollow with resistant material, displacing the metal of the blade-portion only, in the direction of its length until it is elongated to at least the length of the finished blade-portion, simultaneously imparting a blade-shaped configuration to the external and internal cross-sections of the blade, and thereafter removing the resistant material.

15 12. In the process of producing a hollow turbine blade having an integral root portion, the steps which comprise forming a blank consisting of a root-blank portion at least as large as the root portion of the finished blade, and a blade-blank portion whose length is less than that of the finished blade portion, forming a hollow extending longitudinally in the blade-blank portion, thereafter heating the blank, and while it is hot displacing the metal of the blade-portion only, in the direction of its length until said blade-portion is elongated to at least the length of the finished blade-portion, and simultaneously during said displacement of the metal imparting a blade-shaped configuration both externally and internally to the cross-section of said blade-portion.

20 13. In the process of producing a hollow turbine blade having an integral root portion, the steps which comprise forming a blank consisting of a root-blank portion at least as large as the root portion of the finished blade, and a blade-blank portion whose length is less than that of the finished blade portion, forming a hollow extending longitudinally in the blade-blank portion, filling said hollow with resistant material, heating the blank and while it is hot displacing the metal of the blade-portion only, in the direction of its length until it is elongated to at least the length of the finished blade-portion, simultaneously imparting a blade-shaped configuration to the external and internal cross-sections of said blade portion, and thereafter removing the resistant material.

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