

July 17, 1951

W. N. MARTIN ET AL

2,560,973

METHOD OF FORMING TURBINE ROTORS

Filed Dec. 3, 1945

4 Sheets-Sheet 1

*Fig. 1.*

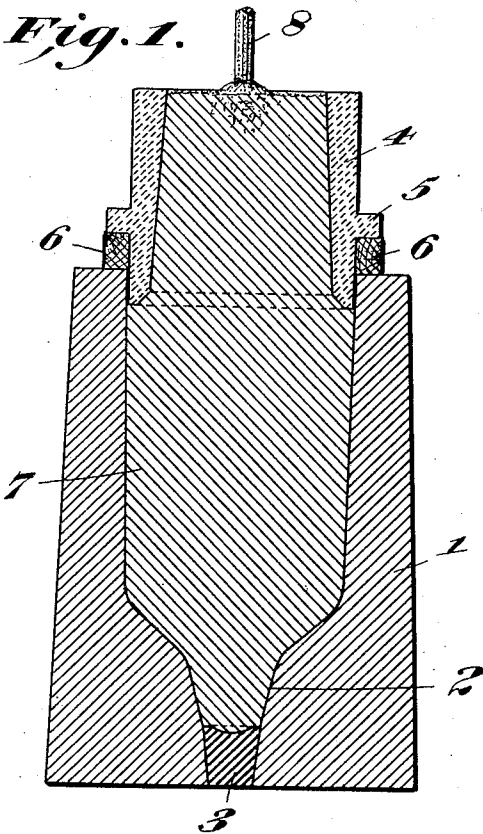


*Fig. 2.*

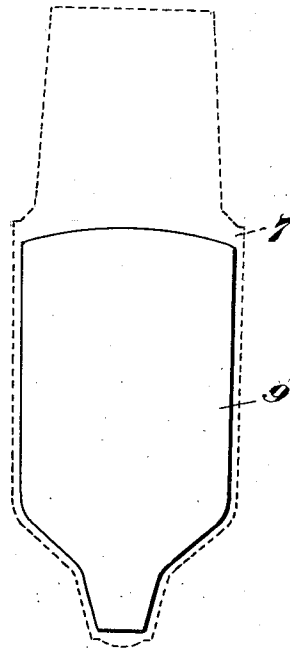


*Fig. 3.*

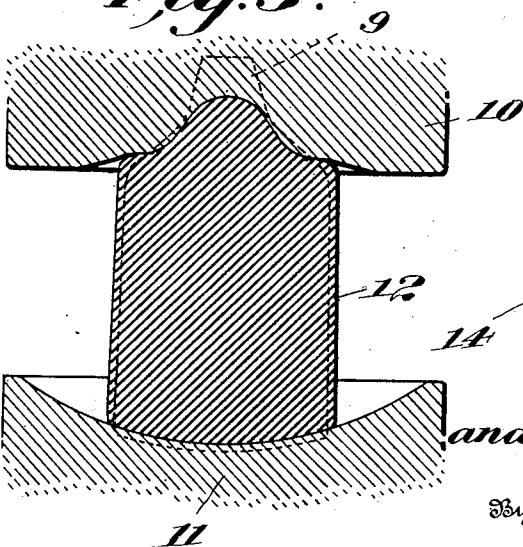
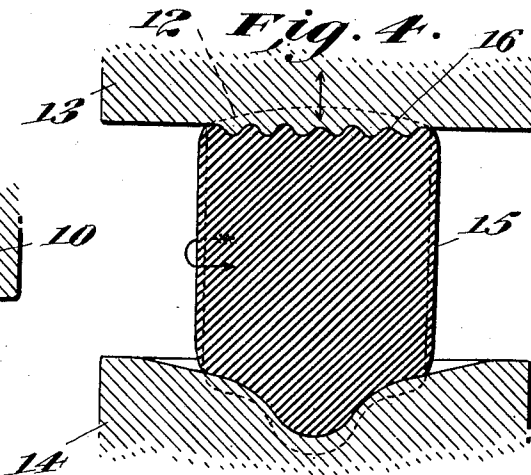


*Fig. 4.*



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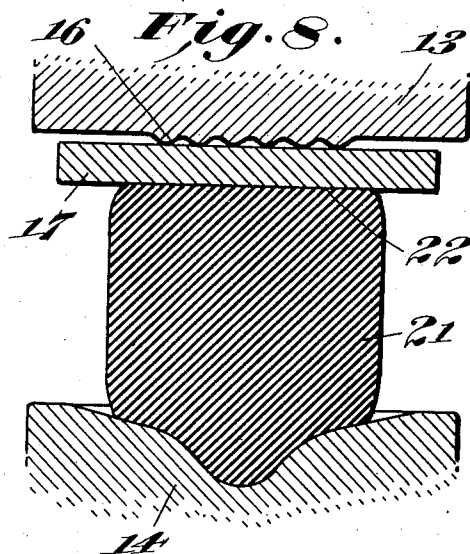
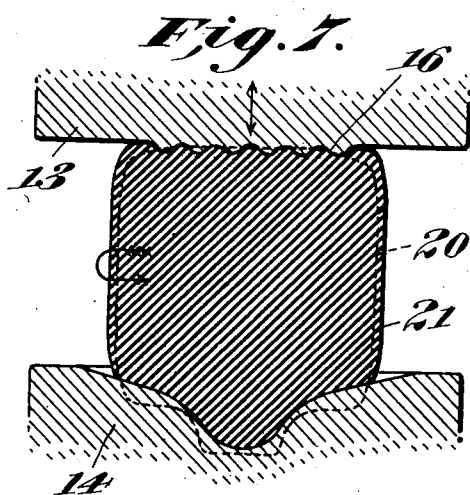
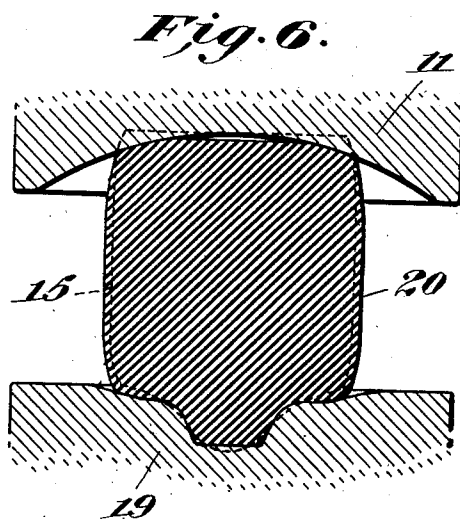
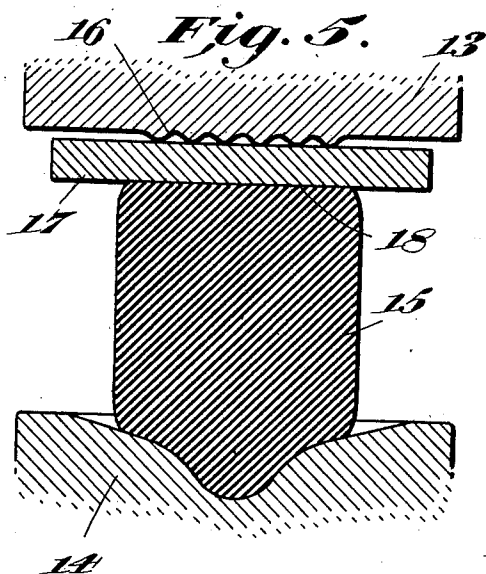
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*Fig. 9.*

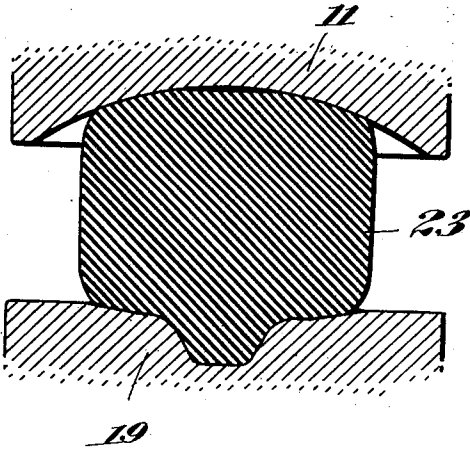


*Fig. 10.*

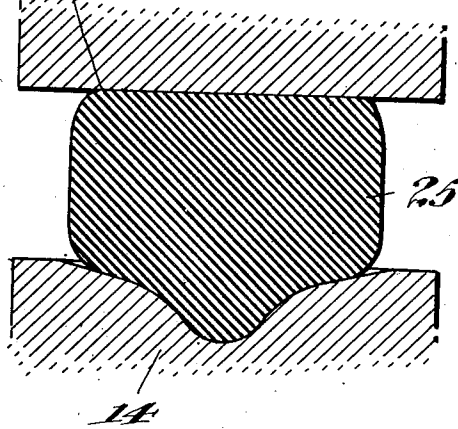


*Fig. 11.*

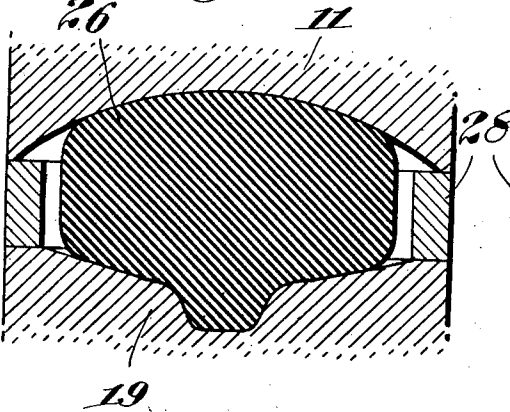
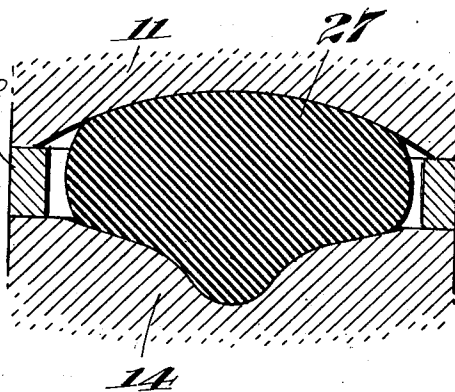


*Fig. 12.*



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*Fig. 13.*

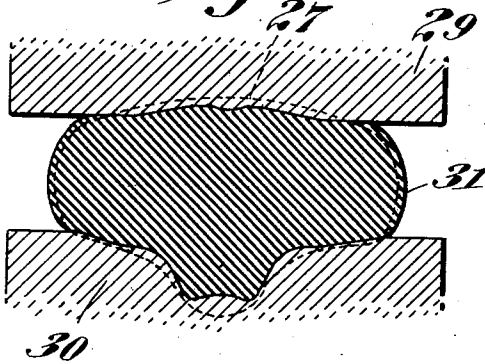


*Fig. 14.*

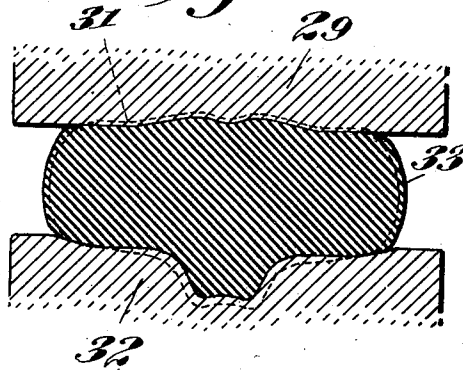


*Fig. 15.*

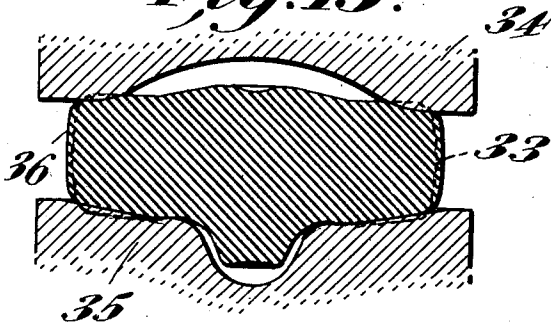


*Fig. 17.*

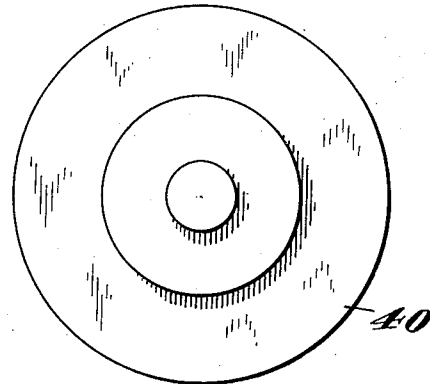


*Fig. 16.*

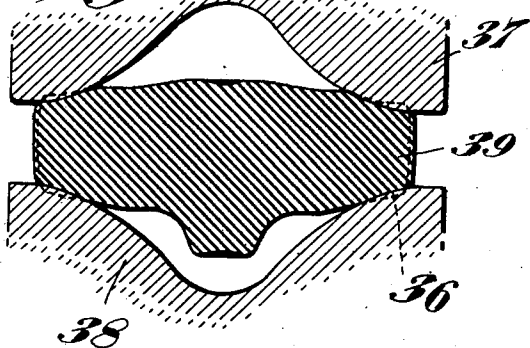
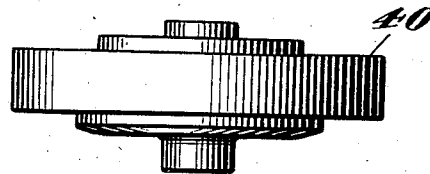


*Fig. 18.*



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## UNITED STATES PATENT OFFICE

2,560,973

## METHOD OF FORMING TURBINE ROTORS

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5 Claims. (Cl. 148—12)

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This invention relates to the method and apparatus for manufacturing turbine rotors for gas turbines, and more especially to the manufacture of rotors for gas turbines for use in a jet propulsion aircraft or the like in which the gases of combustion are led directly into the turbine motor. The turbine rotor drives the compressor which is necessary to furnish heat for combustion. Then the exhaust gas from the turbine, from which only a small part of the available energy has been extracted is discharged through a tail cone to produce the jet effect which propels the plane.

The gases of combustion discharged into the turbine heat the rotors to a substantially red heat, and it is therefore necessary to obtain high efficiencies to form the rotors of a high alloyed steel to resist oxidation and to withstand the heat to which it is exposed and to carefully forge and treat the rotors to give maximum strength and the highest possible factor of safety.

In carrying the present invention into effect, an ingot containing, for example approximately 16% chromium, 25% nickel, 6% molybdenum and 1.5% manganese, .6% silicon and 51% of iron is first cast in a mold having a hot top of refractory material forming a sinkhead for maintaining the molten metal which is poured therein fluid at or near the top portion of the ingot for a longer time than that in those portions of the mold which are adjacent to, or subjected to the cooling effect of the metal lower part of the mold. By means of this construction and arrangement the pipes and segregated metalloids due to shrinkage in cooling will be localized within the top portion of the ingot, leaving the body of the said ingot substantially solid and of good quality and to further maintain the top portion of the ingot fluid for a longer period, additional heat is supplied by an electrode which is provided adjacent to the top surface of the ingot for that purpose.

After the ingot has been stripped from the mold and cooled, the part which was cast in the sinkhead is cut off and the main portion of the ingot machined to form a blank which is then heated to 1950° F. maximum, and subjected to a plurality of hot forging operations between dies in a press to form a blank and between each forging operation the blank is reheated to 1950° F. After the last hot forging operation the blank is heated to 2200° F. and held at that temperature for two and one half hours and then quenched in water. As this type of alloy is not properly hardened by quenching it has to be

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hardened by means of a relatively cold forging operation which consists in taking the blank formed by hot forging and heating it to 1200° F. maximum and then subjecting it to a plurality of forging operations between dies in a press and between each forging operation the blank is reheated to 1200° F. It is necessary in the cold forging operation to forge the blank first in the central portion, then at intermediate points and finally adjacent to the peripheral edge at the sides of the blank otherwise the blank will crack or become fractured. After the cold forging operation the blank is again heated to 1200° F. and held at that temperature for ten hours for stress relief and then air cooled. The blank is then machined after which the peripheral edge of the rotor is provided with a series of buckets or vanes.

One of the objects of the invention pertains to the method and apparatus for forming a rotor of alloyed steel which consists in taking a cast billet and then subjecting it to a plurality of hot forging operations between dies in a press to compress the same longitudinally and expand it laterally to form a blank and then subjecting the blank to a plurality of relatively cold forging operations to harden the blank.

Another object of the invention relates to the method and apparatus for forming a rotor of alloyed steel adapted to resist oxidation and to withstand heat which consists in taking a cast billet and then subjecting it to a plurality of hot forging operations between dies in a press to compress the same longitudinally and expand it laterally to form a blank free from pipes or segregations, then hardening the blank by subjecting it to a plurality of relatively cold forging operations first at the central portion of the blank, then at intermediate points, and finally at the sides adjacent to the peripheral edge of the blank.

A further object of the invention relates to the method and apparatus for forming a rotor of alloyed steel adapted to resist oxidation and withstand heat, which consists in taking a cast billet which has been machined and then subjecting it to a plurality of hot forging operations at 1950° F. to form a blank. Then heating the blank to 2200° F. and hold at that temperature for two and one half hours and then quenching in water, then hardening the blank by a relatively cold forging operation which consists in heating the blank to 1200° F. and then subjecting the blank at this temperature to a plurality of relatively cold forging operations, first at the central portion of the blank, then at intermediate portions and finally to the sides of the blank adjacent to

its peripheral edge, and after the cold forging operation again heating the blank to 1200° F. and holding it at that temperature for ten hours for stress relief and then cooling the blank in air.

Other objects of the invention will appear hereinafter.

Having thus given a general description of the objects of the invention we will now in order to make the same more clear refer to the accompanying four sheets of drawings forming a part of this specification in which like characters of reference indicate like parts.

Figures 3 to 12, inclusive, illustrate the dies and shape of the billets in the steps for the hot forging operation.

Figure 1 is a vertical section of an ingot mold provided with a hot top of refractory material and illustrating the manner of casting the ingot therein.

Figure 2 is a side elevation of the machined billet formed from the cast ingot which is shown in dotted lines.

Figure 3 is a sectional view showing the reciprocating forging dies after the first forging operation with the billet shown in Fig. 2 turned over and indicated in dotted lines.

Figure 4 is a sectional view of the dies and billet after the second forging operation. In this figure the billet has been turned over in relation to the position shown in Fig. 3, and the lower face of the top die is corrugated.

Figure 5 is a sectional view of the third forging operation in which the same dies are used and a flat plate is inserted between the corrugated top die and the top of the billet to flatten the corrugations formed therein.

Figure 6 is a sectional view of the dies and billet after the fourth forging operation.

Figures 7 and 8 show the fifth and sixth forging operations in which the same dies are used as in Figures 4 and 5.

Figure 9 is a sectional view of the dies and billet at the end of the seventh forging operation.

Figure 10 is a sectional view of the dies and billet after the eighth step in the forging operation in which the lower face of the top die is formed flat.

Figure 11 is a sectional view of the dies and billet at the end of the ninth forging operation, and Figure 12 shows a sectional view of the final step in the hot forging operation thereby forming a blank for the relatively cold forging operation.

Figures 13 to 16, inclusive, show sectional views of the dies and blanks for the successive steps in the relatively cold forging operations.

Figure 17 is a plan view of the rotor after the blank formed by the relatively cold forging operation has been machined, and Figure 18 is a side elevation of the rotor shown in Figure 17.

Referring now to the various characters of reference in the drawings and first to Figs. 1 to 12, inclusive, the numeral 1 indicates a metal mold having the lower portion of its mold cavity tapered inwardly as at 2 and provided with a bottom plug 3. The metal mold is provided with a refractory hot top 4 having a flange 5 for engaging supporting blocks 6 mounted on top of the metal mold 1. The refractory hot top forms a sinkhead for maintaining the molten metal which is poured therein fluid at the top portion of the ingot a longer time than that in the lower portion of the mold subjected to the cooling effect of the metal lower part of the mold, and to further maintain the top portion of the ingot 1 fluid for a

longer period an electrode 8 is provided adjacent to the top surface of the ingot.

After the ingot has been cast and stripped from the mold and cooled the part which was cast in the sinkhead which might have defects therein is discarded and the main portion of the ingot machined to form a billet 9 of the shape indicated in Figure 2. The billet 9 is then heated to 1950° F. The heated billet is then turned over from the position shown in Figure 2 and placed in a forging press between dies 10 and 11 in the position indicated in dotted lines in Figure 3 and given the first forging operation thereby shaping the billet 12. The billet 12 is then heated to 1950° F. and turned over from the position shown in Figure 3 and placed in a forging press between dies 13 and 14 in the position indicated in dotted lines in Figure 4 and then given a second forging operation to form the billet 15. In this second forging operation the upper die 13 is adapted to reciprocate intermittently and its lower forging surface is corrugated as at 16, while the lower forging die 14 is adapted to revolve intermittently approximately 30° in succession and then stop to allow the top corrugated die to engage the top of the billet 15 thereby kneading, compressing and condensing the metal. The upper die 13 for illustration is vertically movable and may be relatively fixed against rotative movement; the billet operated upon being rotated by the lower die 14 to change the relation of the successive operations of the upper die 13 upon the billet, but the upper die may be rotated with respect to the lower die or the billet may be revolved with both dies stationary if desired.

In Figure 5, the same dies 13 and 14 are used as in Figure 4 but a flat plate 17 is inserted between the corrugated lower face 16 of the top die 13 and the top surface of the billet 15 to flatten the top surface of the same as shown at 18. The billet 15 is again heated to 1950° F. and inserted between dies 11 and 19 and the billet forged into the shape indicated at 20 in Figure 6.

It will be noted that in the several figures some of the dies have the same shape and where this occurs the same reference numerals will apply thereto and it will be further understood that before each of the hot forging operations the billet is heated to 1950° F. The dies used in Figures 7 and 8 are the same as those used in Figures 4 and 5 and the billet is treated in the same manner with the top die 13 reciprocating and the bottom intermittently rotating 30° in succession. In Figure 7 the billet 21 is shown with its top corrugated and in Figure 8 the top of the billet is flattened as at 22. The billet is then inserted between dies 11 and 19 and a billet 23 formed in the shape shown in Figure 9 with an arc shaped top surface, then transferred to dies 14 and 24, the latter having a flat lower forging surface adapted to flatten the arc shaped top surface of the billet and form it in the shape shown at 25 in Figure 10. Billet 25 is then forged between dies 11 and 19 to produce a billet 26 shown in Figure 11 and finally forged between dies 11 and 14 to produce a blank 27 for the relatively cold forging operation as indicated in Figure 12. In Figures 11 and 12, gage blocks 28 are used between the dies to limit the movement of the dies to prevent over forging.

These steps complete the hot forging operation in which the billet is gradually compressed and expanded laterally.

The blank 27 is then heated to 2200° F. and

held at that temperature for two and one half hours and then given a water quench.

Referring now to Figures 13 to 16, inclusive, which shows the relatively cold forging operation for hardening the blank as this kind of an alloy cannot be hardened properly for the purpose intended by quenching and has to be forged from the central portion of the blank outwardly to prevent cracking or fracturing the blank.

The blank 27 is first heated to 1200° F. and inserted between the top and bottom dies 29 and 30 respectively in a press to forge the central portion of the blank 27 into the form shown at 31 in Figure 13. The blank 31 is again heated to 1200° F. and inserted between the same top die 29 and a bottom die 32 which further forges the central and intermediate portions of the blank as indicated at 32 in Figure 14. The blank 32 is reheated to 1200° F. and inserted between dies 34 and 35 and forged on the side faces of the blank adjacent to the peripheral edges to produce a blank as shown at 36 in Figure 15. The blank is again heated to 1200° F. and inserted between dies 37 and 38 and the extreme peripheral edge of both top and bottom faces of the blank is forged to produce the blank 39 as shown in Figure 16. This completes the relatively cold forging operation for hardening in which the blank is further reduced in thickness and expanded laterally. The blank 39 is then heated to 1200° F. and held at that temperature for ten hours for stress relief and finally air cooled. The blank 39 is then machined to form a rotor 40 or turbine wheel as indicated in Figures 17 and 18.

Although we have shown and described our invention in considerable detail, we do not wish to be limited to the exact and specific details shown and described, but may use such substitutions, modifications or equivalents thereof as are embraced within the scope of our invention or as pointed out in the claims.

Having thus described our invention, what we claim as new and desire to secure by Letters Patent is:

1. The method of forming a turbine rotor of high alloy steel, containing 16% chromium, 25% nickel, and 6% molybdenum, which consists in hot forging a billet successively at a temperature of 1950° F. in a plurality of sets of dies to form a blank, heating the blank to 2200° F. and holding it at that temperature for two and one half hours, quenching the blank and then reheating the blank to 1200° F. and hardening the blank by subjecting it at that temperature successively in a plurality of sets of dies to a relatively cold forging operation.

2. The method of forming a turbine rotor of high alloy steel, containing 16% chromium, 25% nickel, and 6% molybdenum, which consists in taking a billet and performing successive hot forging operations on the billet after successive heats at approximately 1950° F. to form a blank, heating the blank to 2200° F. and holding it at that temperature for two and one half hours, and then quenching the blank, reheating the blank to 1200° F. and performing successive steps of relatively cold forging operations on the blank from the center of the blank to its peripheral edge to harden the blank, heating the blank again to 1200° F. and holding it at that temperature for ten hours, and then air cooling the blank.

3. The method of forming a turbine rotor of high alloy steel to resist oxidation and withstand heat, and containing 16% chromium, 25% nickel and 6% molybdenum, which consists in taking a billet and performing successive hot forging operations on the billet at a temperature of 1950° F. to form a blank, heating the blank to 2200° F. and holding it at that temperature for two and one half hours, quenching the blank, and then hardening the blank by subjecting it at a temperature of 1200° F. in successive steps to relatively cold forging operations from the center of the blank to its peripheral edge.

4. The method of forming a turbine rotor of an alloy of the class described resistant to corrosion and oxidation at high temperatures, which consists in hot forging a billet in successive operations at a temperature of 1950° F. between dies engaging the ends of the billet to gradually compress the billet and expand it laterally to form a blank, heating the blank to 2200° F. and holding it at that temperature for two and one half hours, quenching the blank, reheating the blank to 1200° F. and hardening the blank by subjecting the faces of the blank to a plurality of relatively cold forging operations at that temperature between dies in steps in succession from the center of the blank to the peripheral edge, holding the blank at a temperature of 1200° F. for ten hours for stress relief, and then cooling the blank in air.

5. The method of forming a turbine rotor of an alloy of the class described resistant to corrosion and oxidation at high temperatures, which consists in hot forging a billet in successive operations at a temperature of 1950° F. between dies engaging the ends of the billet to gradually compress the billet and expand it laterally to form a blank, corrugating one end of the billet intermittently at 30° intervals thereby forming successive impressions in the billet, flattening the corrugations after each of the series of the corrugating operations, heating the billet to 2200° F. and holding it at that temperature for two and one half hours, quenching the blank, reheating the blank to 1200° F. and hardening the blank by subjecting the faces of the blank at that temperature to a plurality of cold forging operations between dies in steps in succession from the center of the blank to the peripheral edge, holding the blank at a temperature of 1200° F. for ten hours for stress relief, and then cooling the blank.

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