March 3, 1953 R. B. JOHNSON, JR 2,629,923

METHOD OF MAKING HIGH STRENGTH ROTATING ELEMENTS

Filed Aug. 23, 1949

Fig. 1.

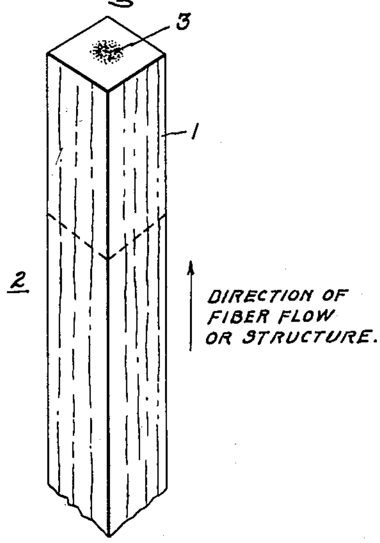


Fig. 2.

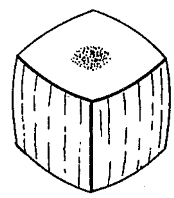


Fig. 3.

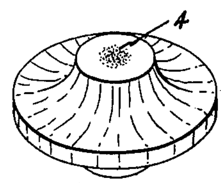


Fig. 4.

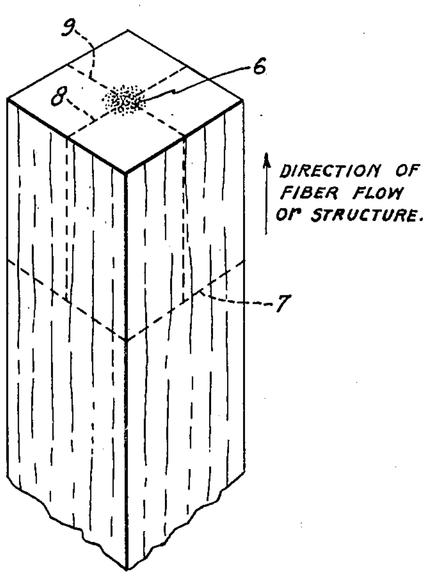


Fig. 5.

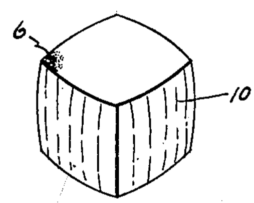
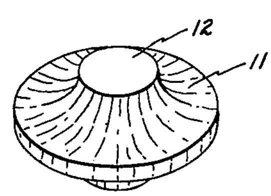


Fig. 6.



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UNITED STATES PATENT OFFICE

2,629,923

METHOD OF MAKING HIGH STRENGTH ROTATING ELEMENTS

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1 Claim. (Cl. 29—156.8)

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The present invention relates to high strength rotating elements and to the method of making the same. More particularly, my invention relates to the production of high strength, high-speed wheels, e. g., turbine wheels, such as those employed in turbosuperchargers, adapted to operate at speeds of at least 20,000 R. M. P., and in some cases as high as 60,000 R. P. M.

A primary problem connected with high-speed turbine wheels has been premature bursting at high speeds. Various alloys have been developed with the object of providing a material meeting the physical requirements for such wheels. However, up to the present time, such attempts to solve the problem have not been entirely successful.

The present invention is based on the discovery that the defect in the present forged wheels results from a low ductility of the center section thereof as compared with the remaining portions of the wheel. This difference in ductility has in turn been found to be inherent in the method now employed in making the wheels and practically independent of the alloy employed. It is, therefore, a primary object of the present invention to provide improved high strength wheels. A further object is to provide an improved method of forging high-speed wheels, particularly turbosupercharger wheels, whereby forged wheels can be obtained having greater ductility and higher strengths particularly at and adjacent to the center section of the forgings.

Further objects and features of the invention will become apparent in the following description in connection with the accompanying drawing in which Figs. 1–3, inclusive, represent the various steps presently followed in the manufacture of forged wheels and Figs. 4–6, inclusive, represent the essential steps in the practice of the present invention.

The forging method of the present invention will best be understood by first considering the prior practice in the manufacture of forged supercharger wheels. With reference to the drawing, this practice, for example, makes use of a forging slug 1 cut as indicated from a 4-inch square, hot-rolled billet 2 in which the fiber structure is longitudinal of the billet. These lugs, about 13 inches in length, are upset along their long axis, i. e., parallel to the fiber structure, using flat upset dies, to a height of about 6½ inches, as indicated in Fig. 2. In the drawing the various arrows indicate the forging direction while the grain or fiber flow lines resulting from the rolling operation are indicated on each of the figures. The upsetting operation is carried

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out at an elevated temperature of, for example, 1950° F. Thereafter, the upset slugs are forged in standard wheel dies, for example, by first hot forging the upset slug at a temperature of 1950° F. to the point where the rim of the wheel is about 1½ inches thick, solution treating the forging at 2150° F., followed by air cooling, and finally forging the wheel blank to a final 1¼ inch rim thickness at a temperature of about 1200° F. The forged wheel (Fig. 3) is then given a strain-relief anneal at 1200° F. for 8 hours and air cooled before being machined and otherwise finished.

Considering this process, it will be noted that due to the method employed in hot rolling the billets from the original ingot, there exists in the center section of the billet, regardless of its cross-sectional area, a longitudinally extending portion 3 of substantially unworked material. Not only has this center portion or so-called "dead spot" received the least amount of working during the rolling operations but, in addition, it also contains the usual segregations and inclusions normally present in the center of the ingot. Further, in following the present procedure of forging wheel blanks from slugs cut from such billets, the "dead spot" material receives the least amount of working during the forging of the slug into the form of the finished wheel. To the further detriment of the forged product, the substantially unworked center portion 3 of the billet comprises the center or axial portion 4 of the forged product where the physical properties are most critical. As an example of the results obtained by the present forging practice, test bars cut from the center section of such forgings frequently exhibit yield strengths as low as 60,000 p. s. i. and elonagtion values less than 3 per cent. The alloy employed in these wheels was a high strength alloy of about 16 per cent chromium, 25 per cent nickel, 6 per cent molybdenum, 0.7 per cent silicon, 1.35 per cent manganese, 0.1 per cent carbon, balance iron. In the overspeed testing before attaching buckets, such wheel forgings ordinarily burst at about 48,000 to 50,000 R. P. M.

The present invention provides a method whereby stronger and more ductile wheels can be obtained and by which it is assured that complete working of the "dead spot" center material of the original hot-rolled billet is attained with the resultant elimination of this "dead spot" material from the center portion of the forged product.

The hot-rolled billet from which the slugs are cut is larger than those heretofore employed and is of such a cross-sectional area that a plurality of slugs can be cut from a single billet across section. Each of the slugs so obtained will contain a portion of the substantially unworked center material of the billet along a surface portion of the forging slug, such as, for example, a longitudinal edge of the forging slug, thus permitting such portion of the substantially unworked center material to be worked upon in subsequent operations. The manner in which these slugs can be obtained will become more apparent from the consideration of Fig. 4 illustrating a hot-rolled billet substantially four times the cross-section area of the hot-rolled billet of Fig. 1 and having a substantially unworked center portion 6. Cutting along dotted line 7, there is obtained a billet section of the proper length as, for example, the same length as slug 1. This section is then quartered by two longitudinal cuts along lines 8 and 9 to obtain four forging slugs with the substantially unworked center portion of the original billet divided equally among the slugs with a portion thereof extending along only one longitudinal edge of each slug.

These slugs are then upset and die forged in accordance with the usual practice outlined hereinbefore. However, during the various steps, the "dead spot" material is forged and substantially worked, particularly during the time the upset slug 10 illustrated in Fig. 5 is converted to the forged wheel 11 of Fig. 6. This working refines and breaks up any segregation that might have occurred during the freezing of the ingot from which the hot-rolled billet was obtained. In fact, as will be evident from the consideration of the shape of the final forging of Fig. 6, the longitudinal edge portions of the forging slugs which constitute part of the material from which the rim of the wheel blank is formed are among those portions of the slug which receive the maximum working during the forging of the slug. Hence, since the "dead spot" material 6 comprises one edge of each of the slugs employed in the practice of the present invention, substantial working of this critical section of the slug is obtained. In addition, the critical center portion 12 of the forged wheel is composed of material which is free of the ingot segregations and which also received a substantial amount of working during the rolling of the billet. As a result, better physical properties can consistently be obtained in the center portion.

A further and important advantage of the present invention is the fact that the quartering operation permits the inspection of the center of the original billet for major defects which under the former practice would unknowingly be forged into the center of the wheel.

Wheel forgings prepared in accordance with the present or quartered billet practice are definitely superior to those made by the usual or conventional method as is shown by the test results set forth in the following table. The values given are average values for the same size wheel forgings which with buckets attached have an overall diameter of 9.5 inches and are designed to operate at 30,000 R. P. M. In all cases the alloy hereinbefore described was employed.

	Conventional Method	Quartered Billet Method
Yield Strength (.02% offset) ... p. s. i	70,008	73,038
Tensile Strength ... p. s. i	108,902	118,3[illegible]8
Elongation ... percent	11.65	20.35
Reduction ... do	14.50	25.17

The average values set forth in this table, based on testing of a large number of wheels prepared by both methods, clearly indicate that wheels prepared in accordance with the present invention are superior from the standpoint of all of the four physical characteristics listed in the foregoing table. In addition, overspeed or bursting speed tests on the same type and size of wheel forgings prior to bucketing have shown the present wheel forgings can be run as high as 60,000 R. P. M. without bursting, whereas wheel forgings of this type and size forged by the conventional method ordinarily burst at speed of from 48,000 to 50,000 R. P. M. As a result of the present invention, the present physical requirements of turbosupercharger wheels can readily be met and failures or rejects substantially eliminated.

While the invention has been described and illustrated with reference specifically to a turbine wheel forged from a particular alloy, it is apparent that it is applicable to the production of any rotating element, composed of any suitable alloy, where high bursting strength during operation is an important consideration. Also, it is obvious that while the method of attaining the improved high strength wheel has been illustrated by the quartering of the billet, the invention is not limited thereto since the objects sought may be attained by any subdivision of the billet whereby the "dead center" portion is presented at or adjacent to an exposed surface portion of the slug or slugs cut from the billet.

What I claim as new and desired to secure by Letters Patent of the United States is:

The method of making a high speed turbine wheel which comprises quartering a hot-rolled billet in the rolling direction to obtain a forging slug in which a longitudinal edge of the slug extending parallel to said rolling direction is composed of part of the substantially unworked center portion of the hot-rolled billet and the center of the slug is composed of material intermediate the center and surface portions of said billet, upset forging said slug in a direction parallel to the rolling direction of said billet and die forging the upset slug into the form of a wheel blank having a rim portion of a thickness less than the thickness of its hub portion by the application of forging pressure in the same direction as that applied in the upset forging of the slug whereby the material constituting the rim portion of the wheel blank and including the material forming part of the center portion of the hot-rolled billet receives substantial working during die forging step.

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