

[54] **PROCESS OF MANUFACTURING FORGED OR ROLLED ROD STEEL FROM LEDEBURITIC TOOL STEEL**

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[58] Field of Search..... 29/527.5, 527.7, 29/DIG. 18, DIG. 32, DIG. 5; 164/76

[56] **References Cited**

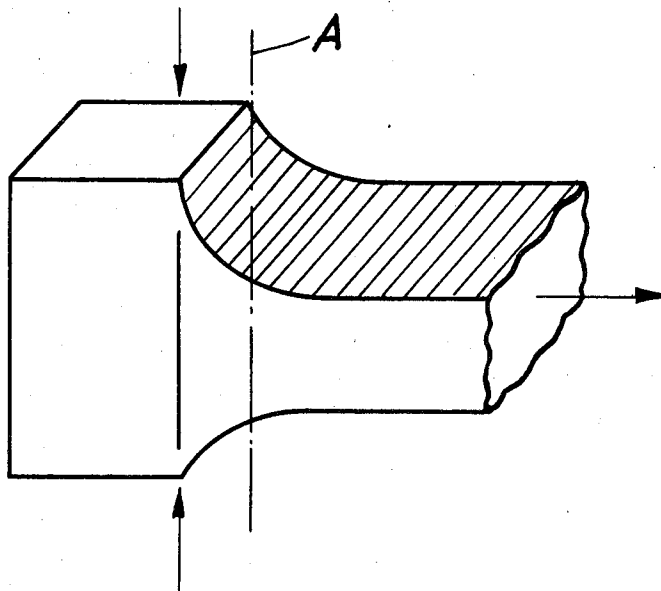
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[57] **ABSTRACT**

A fusible electrode is provided, which consists of ledeburitic tool steel and is suitable for use in a remelting process. Said electrode is melted. A slab ingot is built up by solidifying the resulting melt in a water-cooled slab ingot mold. Said slab ingot is upset by a succession of forging steps in the direction of the longitudinal axis of said slab ingot to provide a semifinished product. Said semifinished product is subjected to a stretching deformation to an extent of at least two times, based on the cross-section of said semi-finished product, to form a stretched product having the cross-section desired for said rod. From said stretched product, a rod is obtained which has a fairly homogeneous carbide distribution throughout its cross-section and length.

5 Claims, 6 Drawing Figures



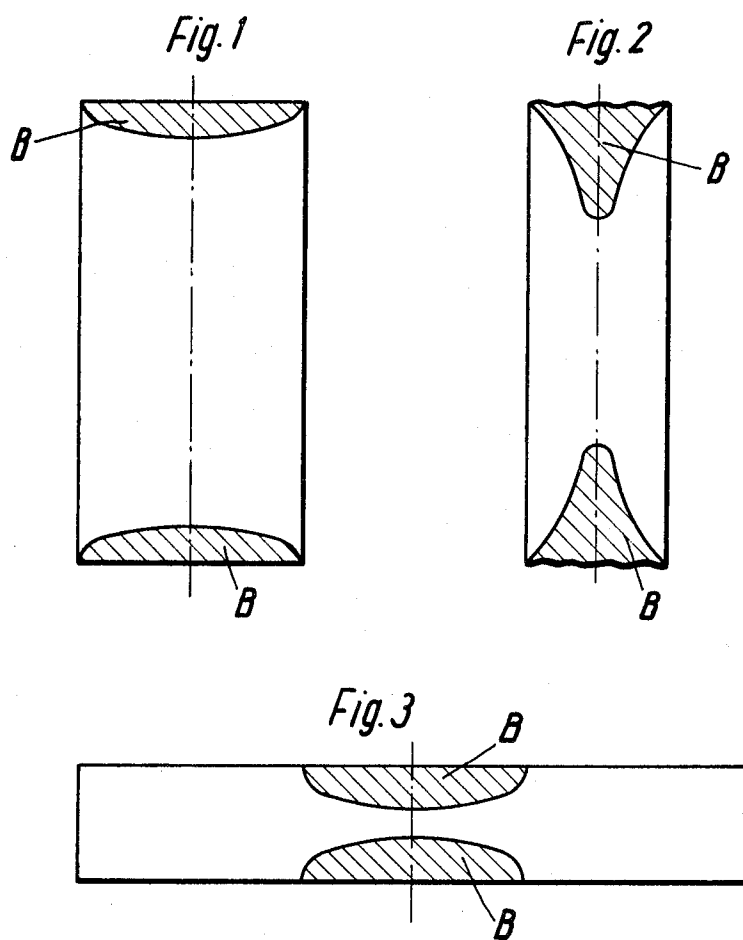


Fig. 4

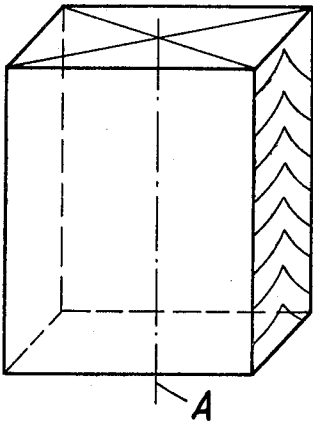


Fig. 5

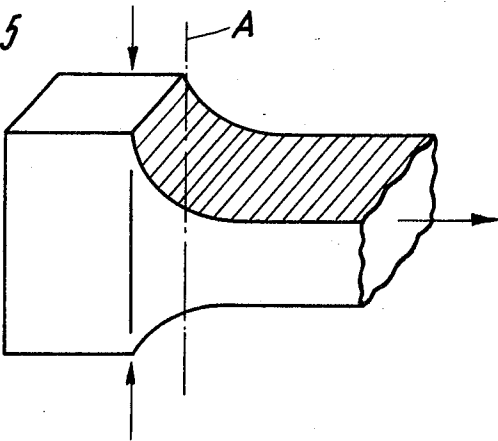
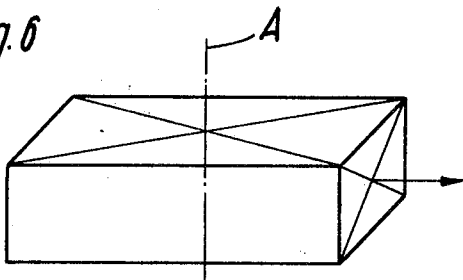


Fig. 6



PROCESS OF MANUFACTURING FORGED OR ROLLED ROD STEEL FROM LEDEBURITIC TOOL STEEL

This invention relates to the manufacture of semi-finished or finished products of ledeburitic tool steels.

In the making of steel, the structure of the ingot can be improved by remelting processes compared to the known ingot-casting processes. Remelting processes result in a higher yield in the steelmaking plant and in an improved crystallization throughout the ingot. But even the improved structure which can be obtained by a remelting process is not satisfactory for ledeburitic steels, particularly high-speed steels, because these steels must meet in operation much higher quality requirements. For instance, the users impose certain specifications as regards the distribution and the grain size of carbides. In most cases, the steel is evaluated as to these requirements with reference to the Stahl-Eisen-Richtreihen. Where very high requirements are to be met by these steels in operation, the carbide and austenite grain size should be minimized and the carbides should be uniformly distributed. These requirements cannot be met only if the steels can be subjected to a deformation above a certain minimum. Depending on the thickness and the desired dimension, the deformation must be carried out to such an extent that the primary ledeburite network of the cast ingot or of the remelted ingot is destroyed as completely as possible. A deformation of at least 16 times is required for certain, very high requirements. For this reason, these steels can be supplied only with relatively small dimensions. A deformation which is smaller than 8 times is not sufficient in most cases to destroy the primary structure of the steel to such an extent that the distribution of carbides is tolerable and the carbide grains are sufficiently small. In processes such as the electric slag refining process, a process involving the use of a self-consuming electrode in a vacuum arc furnace, a melting in the electron beam furnace or plasma furnace, the controlled solidification results in a relatively uniform distribution of carbides but the carbides still form such coarse grains that a deformation of at least 8 times is required. Where large final dimensions are required, even a deformation of at least 8 times cannot result in a sufficiently fine division of the carbides because the raw ingot having the cross-section required for this purpose has a relatively coarse primary structure due to the slow solidification of such large ingots.

When it is attempted to provide for relatively large final dimensions with a deformation of at least 8 times in that smaller raw ingots are first upset and then subjected to a stretching deformation, this process involves the disadvantage that the upsetting of the ingot in the direction of its axis A leaves virtually undeformed zones B at the top and bottom ends of the ingot. This undeformed zones result from the fact that the top and bottom ends of the ingot directly engage the forging saddles and for this reason cannot be subjected to such flowing deformation as the remaining parts of the ingot. When such upset raw ingot is subsequently subjected to a stretching deformation in the direction of the ingot axis, inadequately deformed zones of the ingot may become disposed in the axis A of the ingot and may then result in impermissible inhomogeneities as regards carbide grain size and carbide distribution in the finished rod.

When the upset ingot is subjected to further deformation by transverse forging, the above phenomenon has also undesired results because a zone B which is insufficiently deformed at its surface is formed in the middle of the resulting rod over about one-third of the total length and said zone may extend as far as into the core zone and from a metallurgical aspect has still a virtually as-cast structure. For this reason, this portion of the steel must either be rated down to a lower quality or may even have to be scrapped if the structure is very poor. To remove this undeformed or only slightly deformed zone, the rod must be severed, so that the length of the rod which can be made is limited. In the final product, this limitation undesirably results in underlength rods or in remainders leading to considerable losses of material.

It has been found that the requirement for a deformation of at least 8 times is particularly undesirable if large final dimensions, such as a diameter of 250 millimeters, are required. In this case, the starting ingot must be so large in cross-section that even the use of remelting processes does not result in a satisfactory primary structure. With such cross-sections, the use of the conventional processes does not enable the meeting of quality requirements as regards carbide grain size and carbide distribution.

It is an object of the process according to the invention to avoid the disadvantages which have been described hereinbefore, such as an irregular distribution of structure over the length and cross-section of the rod, unsatisfactory carbide grain size and carbide distribution in certain zones of the rod, poor yield and increased danger of rejects.

In the manufacture of tool steels having square, circular, flat or profiled cross-sections and consisting, if desired, of forgings, the starting steel is usually in the form of a circular, square or polygonal ingot. The starting product used to make such steel with small dimensions, such as sheet or strip, consists of a slab.

After extensive experiments and forging tests, it has surprisingly been possible to overcome the above-mentioned difficulties in the manufacture of rod steel from ledeburitic tool steels, even of rod steel having large final dimensions, if the rod steel was made from a starting product in the form of a remelted slab.

The invention will now be explained more fully with reference to the accompanying drawings, in which

FIG. 1 illustrates an ingot obtained as an intermediate product in a known process by upsetting a relatively small ingot.

FIG. 2 shows an ingot made in said known process by subjecting the upset ingot of FIG. 1 to a stretching deformation in the direction of its axis.

FIG. 3 shows an ingot made in said known process by transversely forging the ingot of FIG. 1.

FIG. 4 illustrates the making of a slab by remelting in the process according to the invention.

FIG. 5 illustrates the upsetting of the slab of FIG. 4 and

FIG. 6 illustrates the transverse forging of the product of the step shown in FIG. 5.

By means of an electric slag refining process, a slab which was close-grained and free of shrinkage cavities and ingotism and had dimensions of 450 × 150 × 375 millimeters was made from a high-speed steel composed of 1.25 percent carbon, 4.3 percent chromium, 5.2 percent molybdenum, 9.5 percent tungsten, 3.5

percent vanadium, 10.5 percent cobalt, balance iron and inevitable impurities (FIG. 4). On a press for exerting an applied pressure of 1,200 metric tons, that slab was upset in a series of steps in the direction of the axis A of the slab to a square cross-section having a side length of about 190 millimeters (FIG. 5). The upset blank was then forged transversely to its axis A (FIG. 6) to a final cross-section 100 millimeters in diameter and to a length of 1,950 millimeters. The metallographic investigation of disc-like test specimens cut from said forged rod revealed a most uniform and fine distribution of carbides from the skin to the core and throughout the longitudinal axis of the product rod. Using the standards of Stahl-Eisen-Richtreihen, the carbide distribution at a distance of 15 millimeters from the edge of the disc was rated 1-1.5 l. The most inferior zones of the rod had no rating poorer than 2 l. For comparison, rods having comparable dimensions and made by conventional processes quite often had a rating up to 4 d in the core zone.

Another experiment was made with a remelted slab having dimensions of 1,100 × 250 × 750 millimeters and composed of 0.85 percent carbon, 4.3 percent chromium, 5 percent molybdenum, 6.5 percent tungsten, 2 percent vanadium, balance iron and inevitable impurities. That starting slab was subjected to preliminary deformation by a plurality of upsetting steps in the direction of the axis A of the slab to a square cross-section having a side length of 350 millimeters and was subsequently stretch-forged transversely to the axis A of the initial slab to a final diameter of 230 millimeters. When the end portions of the forged billet had been cut off, a satisfactory material remained in a total length of 4,500 millimeters, corresponding to a yield of 92 percent. Even with this relatively large final dimension, a highly uniform distribution of carbides was obtained throughout the length and cross-section of the rod. According to the Stahl-Eisen Testing Standard, the carbide distribution was rated 1.5 l near the skin, 2 l to 3 l in the core zone, and 2 d in individual outliers.

Hence, the invention provides a process of making forged or rolled steel rod from ledeburitic tool steels, which steel rod has a highly homogeneous carbide distribution throughout the cross-section and length of the steel, and the process is characterized in that a fusible electrode suitable for a remelting process is made first from such tool steels and is remelted, the resulting melt is caused to solidify in a water-cooled slab ingot mold to form a building-up slab ingot, the resulting slab ingot is upset by a succession of forging steps in the direction

of the axis A of the slab ingot to form a semi-finished product, which is approximately square or circular in cross-section, and said semi-finished product is subjected to a stretching deformation by forging or rolling transversely to the axis A of the original slab to the desired final cross-section, which stretching deformation has an extent of at least 2 times, based on the cross-section of said semi-finished product.

Within the scope of this process, the structure of the slab may be improved by a mechanical vibration of the ingot mold and/or the ingot during the remelting operation. The structure of the ingot may also be improved by a magnetic agitation of the melt during its solidification. Further improvements are possible by metallurgical measures comprising an inoculation of the molten steel during the remelting operation.

What is claimed is:

1. A process of making steel rod from ledeburitic tool steel, which comprises

providing a fusible electrode, which consists of ledeburitic tool steel and is suitable for use in a remelting process,

melting said electrode,

building-up a slab ingot by solidifying the resulting melt in a water-cooled slab ingot mold,

upsetting said slab ingot by a succession of forging steps in the direction of the longitudinal axis A of said slab ingot to provide a semi-finished product,

subjecting said semi-finished product to a stretching deformation to an extent of at least two times, based on the cross-section of said semi-finished product, to form a stretched product having the cross-section desired for said rod, and

obtaining from said stretched product a rod having a fairly homogeneous carbide distribution throughout its cross-section and length.

2. A process as set forth in claim 1, in which said slab ingot is upset to form a semi-finished product which is substantially circular in cross-section.

3. A process as set forth in claim 1, in which said slab ingot is upset to form a semi-finished product which is substantially square in cross-section.

4. A process as set forth in claim 1, in which said semi-finished product is subjected to said stretching deformation by rolling.

5. A process as set forth in claim 1, in which said semi-finished product is subjected to said stretching deformation by forging.

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