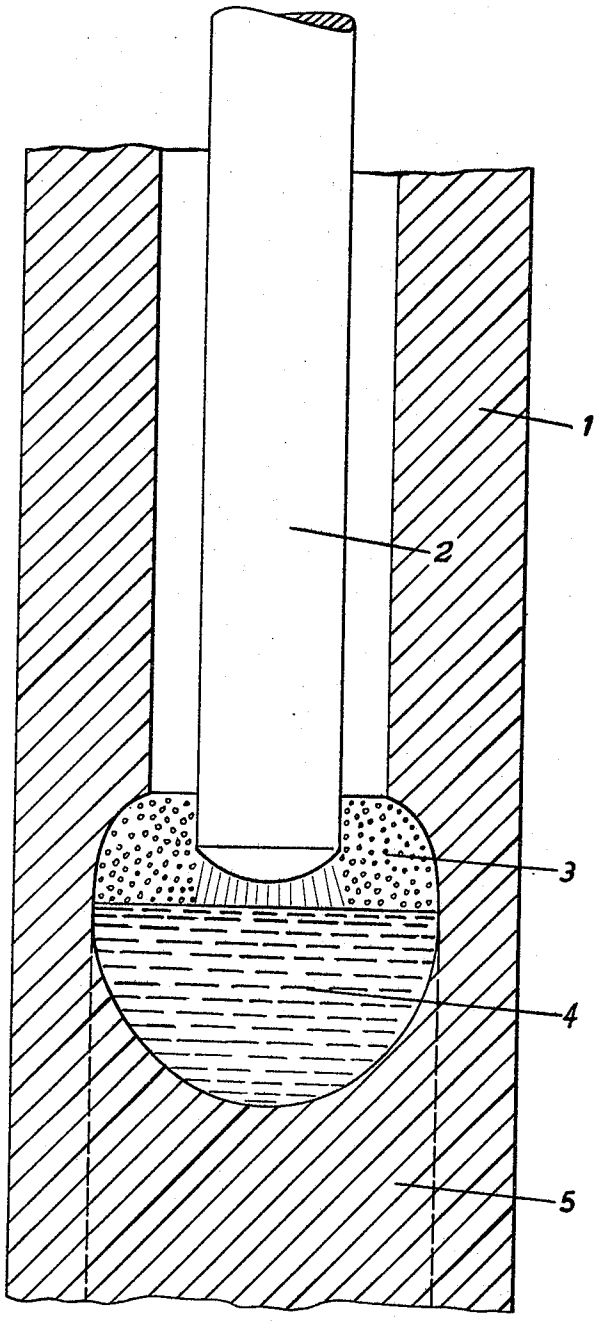
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PROCESS OF PRODUCING LEDEBURITIC TOOL STEEL

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PROCESS OF PRODUCING LEDEBURITIC TOOL STEEL

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ABSTRACT OF THE DISCLOSURE

This invention provides an improved process of producing ledeburitic tool steel by providing a tube of ledeburitic tool steel containing carbides only in fine-grained form and filling the hollow interior of said tube with a similar ledeburitic tool steel by zone refining under such conditions that the resulting core is fusion-bonded to the tube. The resulting tube and core may then be processed to form tools. The invention comprises also various methods of producing the tube and various zone refining processes for producing the core within said tube.

In ledeburitic tool steels, particularly high-speed steels, coarse dendrites are formed during the making of the steel at a certain distance from the surface of the ingot. These dendrites are surrounded by a carbide network. The formation of this dendritic zone is believed to be due to the fact that in a certain depth of the ingot the heat loss which is due to the conduction of heat is offset by the heat of crystallization so that the solidification takes place almost at a constant temperature.

This structure and particularly the coarse carbide network can adversely affect the quality of ledeburitic tool steels and particularly of high-speed steels.

The previous attempts to control the problem of the uniform globular solidification in ingots of large cross-section so as to obtain a fine distribution of the carbides have resulted in improvements but the degree of improvement decreases with the cross-section of the ingot.

A certain improvement has been obtained by the zone refining method, which is used, e.g., in the electric slag refining process. In this process, an electrode consisting of the desired tool steel or high-speed steel is remelted in a layer of liquid slag. The molten metal from the electrode trickles in droplets through the slag into a water-cooled mold, where the ingot is progressively built up. Other processes in which zone refining can be practiced are electric arc remelting processes carried out in a vacuum or in a shielding gas and electron beam remelting processes.

Compared to the usual casting of ingots, zone refining results in different crystallization conditions so that there is no formation of a fine-grained skin nor of a coarse-grained core or intermediate zone. Ingots made in such a remelting process have an approximately uniform structure and medium grain sizes at the center and at the surface.

On the other hand, a fine-grained skin would certainly be desirable in many tool steels.

The present invention is based on the idea to combine the advantages of the usual ingot casting process with those of the zone refining process and to avoid the disadvantages of both kinds of processes.

To carry this idea into effect, it is suggested to provide a tube made from the desired steel and to fill the hollow interior of said tube by zone refining with a material which has the same temperature expansion and phase transformation characteristics as the material of the tube.

The molten metal may consist of the same alloy as the tube or, e.g., in the making of composite tools, of a different alloy. A material which has the same temperature expansion and phase transformation characteristics as the tube material will be referred to hereinafter as an "akin material".

Hence, the invention provides a process of producing a ledeburitic tool steel having carbides only in fine-grained form, particularly a high-speed steel, which steel is suitable for the manufacture of tools, and the invention resides in that the hollow interior of a tube of the desired steel is filled by zone refining with an akin material.

The tube may be cast, for instance. In this case the casting must be cooled so rapidly that a fine-globular solidification results. The melting rate of the electrode material must be selected so that a perfect fusion bond to the tube results, on the one hand, and that sufficient tube material is not affected in its crystal structure by this fusion bonding. To this end, it has been found satisfactory to spray cooling water from nozzles onto the outside surface of that tube portion which is below the level of molten metal in the tube. Without such cooling, the buckling strength of the tube may not be satisfactory. The tube may be preheated before molten metal is poured into the tube.

Instead of a cast tube, a tube consisting of a previously worked material may be employed. This will be desirable if a specific distribution and size of carbides is desired in the skin of the material to be made according to the invention.

The tube may also be obtained by forming a bore in a casting. This will be desirable where castings having a fine-grained skin are available.

The accompanying drawings shows diagrammatically the principle of the present process.

The drawing shows a tube **1**, an electrode **2** of akin material, molten slag **3**, a pool **4** of molten metal and solidified metal **5**.

The material according to the invention may be used in the manufacture of tools without working. In this case the material must be process-annealed before it is machined. Alternatively, the material may be hot-worked, e.g., by rolling or forging, and be used in a deformed state and after the required process-annealing may be used as a starting material in the manufacture of tools.

The present invention eliminates a difficulty which previously prevented a manufacture of high-grade tools, particularly of large-size tools, from ledeburitic steels, which can be metallurgically controlled only with difficulty.

The understanding of the invention will be facilitated by the following examples:

EXAMPLE 1

A high-speed steel consisting of 0.70% carbon, 4% chromium, 1% vanadium, 18% tungsten, balance iron and inevitable impurities, was cast to form a tube having a wall thickness of 35 mm. and an outside diameter of 180 mm. According to the invention, this tube was filled with molten high-speed steel having the same composition in an electric slag zone refining process. The solidified product was homogeneous and contained carbides only in fine-grained form and was suitable as a starting material in the manufacture of ledeburitic tool steels.

EXAMPLE 2

A tube consisting of a high-speed steel containing 0.80% carbon, 4% chromium, 2% vanadium, 6% tungsten, 5% molybdenum, balance iron and inevitable impurities had in an as-cast condition an outside diameter

of 250 mm. and a wall thickness of 42 mm. and was forged to a diameter of 200 mm. and a wall thickness of 37 mm. The hollow interior of the tube was filled with the same material in an electric arc zone remelting process carried out in a vacuum.

EXAMPLE 3

A cylindrical ingot consisting of 1.10% carbon, 3.75% chromium, 1.15% vanadium, 1.50% tungsten, 9.50% molybdenum, 8% cobalt, balance iron and inevitable impurities, and having a diameter of 430 mm. was bored to form a tube having a wall thickness of 50 mm. The hollow interior of the tube was filled with the same material in an electric arc zone remelting process under argon as a shielding gas.

What is claimed is:

1. A process of producing a material which consists of ledeburitic tool steel and contains carbides only in a fine-grained form, said process comprising providing a tube consisting of ledeburitic tool steel which contains carbides only in fine-grained form, and producing in situ in said tube a core of ledeburitic tool steel having the same thermal expansion and phase transformation characteristics as said ledeburitic tool steel of said tube by a zone-refining process, said core being simultaneously fusion-bonded to said tube.

2. A process as set forth in claim **1**, which comprises casting said tube.

3. A process as set forth in claim **1**, which comprises providing a starting material for making said tube and working said starting material to form said tube.

4. A process as set forth in claim **1**, which comprises providing a casting consisting of ledeburitic tool steel containing carbides only in fine-grained form, and forming a bore in said casting to provide said tube.

5. A process as set forth in claim **1**, in which said ledeburitic tool steel is a high-speed steel.

6. A process as set forth in claim **1**, which comprises hot-forming said tube and core, process-annealing said hot-formed tube and core, and making tools from said process-annealed tube and core.

7. A process as set forth in claim **6**, in which said hot forming is effected by hot rolling.

8. A process as set forth in claim **6**, in which said hot forming is effected by hot forging.

9. A process as set forth in claim **8**, in which the outside surface of said tube is maintained in a solid state during said zone refining.

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