EFFECT OF TITANIUM AND VANADIUM ON THE
STRUCTURE AND PROPERTIES OF CAST HIGH-SPEED
STEEL WITH 9% W

O. Kashtanek

Cast high-speed steel, as compared with rolled steel of the same chemical composition, is more brittle, and therefore only tools of simple shape have been cast up to the present time.

Because of the high cooling rate, the structure of castings differs from the structure of a large ingot. In the structure of 9-4-2 steels (R9 type) there are two eutectics differing in shape (Fig. 1). One of them contains $\text{M}_6\text{C}$ carbides enriched in tungsten, while the other has a coarser structure, consisting mainly of vanadium carbide. It crystallizes from the solution even before the formation of austenite or solidifies at the same time and forms the eutectic.

Annealing of these steels has almost no effect on the distribution or shape of the eutectic.

Many investigators have attempted to improve the cast structure of high-speed steels by various means.

Diffusion annealing of large ingots or cast tools at temperatures around 1200°C only slightly improves the distribution of eutectic carbides. The unfavorable consequence of such annealing is strong coalescence and growth of carbides. This lowers the durability of tools, and therefore diffusion annealing has not been widely used.

Investigations have shown that high-temperature annealing has a favorable effect on the distribution of primary carbides only in small ingots and some cast tools.

The structure of cast steel can be improved more by means of the effect of additional components on solidification. Several authors have recommended that titanium be added for this purpose.

In steels with 9% W titanium prevents grain growth during solutioning, which makes it possible to use higher temperatures, leading to solution of large carbides and increasing the red hardness of the steel.

The addition of titanium resulted in a finer and more uniform structure of cast high-speed steel.

Titanium and magnesium have an effective modifying influence, but should be used in the form of a combined addition.

<table>
<thead>
<tr>
<th>TABLE 1</th>
<th>TABLE 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat No.</td>
<td>Composition, %</td>
</tr>
<tr>
<td></td>
<td>C</td>
</tr>
<tr>
<td>1</td>
<td>0.84</td>
</tr>
<tr>
<td>2</td>
<td>0.82</td>
</tr>
<tr>
<td>3</td>
<td>0.85</td>
</tr>
<tr>
<td>4</td>
<td>0.88</td>
</tr>
<tr>
<td>Note: All heats contained ≤ 0.4% Mn, ≤ 0.5% Si, and ≤9% W.</td>
<td></td>
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</tbody>
</table>

However, the addition of titanium impairs the surface quality of ingots, and an American patent has been granted for the addition of boron, niobium, and silicon with titanium.

This work concerns the possible improvement of the cast structure by the addition of strong carbide-forming elements — titanium and vanadium.

The steels (Table 1) were melted in an induction furnace and cast in a vertical centrifugal casting machine, using semichill molds (cermet), and the castings were annealed at 860°C for 20 h.

The samples were quenched from 1240°C, with cooling in a salt bath at 550°C and in air, then subjected to triple tempering.

Cutting tests were made by machining steel ChSN 12060.3 until the wear of the cutter reached 0.4 mm and the curvature of the point reached 0.8 mm. The ductility was determined on rods 6 mm in diameter by the impact torsion method.

The ductility and durability of the cutters are given in Table 2.

The carbide phase was separated electrolytically (5% HCl at +10°C, current density 0.05-0.1 A/cm²). The amount of carbide phase is given in Table 3.

Phase analysis showed that almost the same amount of carbide goes into solution in heating cast steels as in heating rolled steels.

The substitution of titanium for vanadium (heat 1) leads to refining of the structure and prevents the formation of dendrites and precipitation of primary carbides in the boundaries (Fig. 2). The ductility increases considerably as the result (Table 2). The amount of carbide in quenched and tempered steels was higher than in steel 9-4-2. Phase analysis showed that titanium does not enter into the solid solution, which contained only traces of titanium.

The cutting properties of the steel with titanium are better than those of standard steel 9-4-2. This should be regarded as characteristic of the transformations and the structure of heats 1 and 2.

The hardness of steels with titanium quenched from 1240°C (HV 950-1080) is the same as that of steel 9-4-2 after quenching from 1240°C. After triple tempering at 550°C the hardness of the steels with titanium is 8-130 HV units higher than that of steel 9-4-2 (Fig. 3).