TECHNOLOGICAL AND CUTTING PROPERTIES OF HIGH-VANADIUM HIGH-SPEED STEELS

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We investigated the technological and cutting properties of high-vanadium steels [1] (Table 1).

The steels were melted in an electric arc furnace and cast in ingots weighing 45 kg. The ingots were forged to bars 20 mm in diameter. The initial forging temperature was 1150°C and the final forging temperature 900°C.

Eutectic vanadium high-speed steels have a fan-shaped structure in the cast condition. This type of eutectic is more easily broken up in forging than the skeleton type, characteristic of tungsten steels, and therefore the distribution of carbides is more favorable in vanadium steels. The carbide heterogeneity is approximately the same (grade 1 on the standard scale), which is 1–2 grades smaller than in steel R18 rolled to the same section.

The steels were annealed by the standard treatment. The hardness was HB 229–255; the steel with 5% Co had the hardness of HB 255.

Steel R5F8 retains a grain size of grade 10 when heated to 1280°C. When 2.5% W is replaced with molybdenum this temperature decreases to 1260°C, and with 4% Mo it is 1220°C.

Chromium also lowers the temperature at which a grain size of grade 10 is retained.

With an increase from 4% to 6% in steel with 2.5% W and 3.0% Mo this temperature decreases to 1220–1230°C.

The resistance of retained austenite in tempering of steels with a high vanadium content depends on the molybdenum content. For steels with 4% Mo (type R2M4F8) the grain size of grade 10 is obtained after quenching from 1220°C.

An increase of the chromium content from 4% to 6% increases the amount of retained austenite after quenching from optimal temperature (1220–1230°C) and increases the resistance to tempering. Steels of the R2M3F8 type (5.8% Cr) retain 5–6% austenite after triple tempering at 560–570°C.

Steel R2M3F8 with 5.6% Cr does not retain austenite after triple tempering.

The change in the hardness of quenched steels with 8% V obeys the general rule for all high-speed steels. The highest secondary hardness of HRC 66–67 is reached after triple tempering at 560–570°C. Steel R2M3F8 with 5% Cr has a hardness of HRC 68 after triple tempering at 540–550°C (quenched to a grain size of grade 10).

The heat resistance of steel with 8% V is high – for steel R2M3F8 the hardness of HRC 58.5–59 is retained up to 630–635°C, which is 15–20°C higher than for steel R18.

The red hardness at 500°C is also higher for high-vanadium steels than for steel R18 – it amounts to HRC 54, 57, and 58 respectively for steels R18, R2M3F8, and R2M3F8K5.

### Table 1

<table>
<thead>
<tr>
<th>Steel</th>
<th>Composition, %</th>
<th>C</th>
<th>W</th>
<th>Mo</th>
<th>Cr</th>
<th>V</th>
<th>Co</th>
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<td></td>
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<td></td>
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<td></td>
<td>2.082</td>
<td>2.6</td>
<td>3.0</td>
<td>5.6</td>
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</table>

The strength of high-vanadium steels, as for all high-speed steels, decreases with increasing quenching temperatures from 290-300 kg/mm² when quenched to a grain size of grade 11 to 260-240 kg/mm² with quenching to a grain size of grade 10 (steels R2M3F8 and R2M4F8K5), the toughness changing in a similar way.

High-vanadium steels are not susceptible to decarburizing. With heating in an unreduced bath at 1220°C for 10 min the depth of decarburizing is 0.03 mm on steel R2M3F8. This is due to the high sensitivity of these steels to oxidation at high temperatures.

It should be noted that high-vanadium steels are not susceptible to intercrystalline fracture or impairment of the properties after repeated quenching without intermediate annealing.

The presence of a large amount of hard vanadium carbide should substantially increase the wear resistance. The wear resistance was determined by accelerated tests with use of radioactive isotopes. The wear criterion was taken as the specific weight of wear ΔP, mg, from the tool steel per unit weight of material removed in the process of machining.

The cutting tool was a hobbing cutter of the composite type with an inserted blade with a modulus of 2.5 mm manufactured from the various steels (see Table 1). The hardness of the blades was HRC 65-66; the hardness of the machined material (steel 18KhGT) was HB 170-187. The tests were made on the model 5D32 gear-milling machine from the Komsomolets Factory. The gear was cut with a single-blade cutter, with cooling by means of spindle oil. Identical machining conditions were provided by cutting the same blank with blades of different steels.

The radioactivity of shavings was measured with the B2 radiometer by means of the VS-4 counter tube. The dose rate of the irradiated blades was determined in the Cactus microroentgenometer with use of an ionization chamber.

The results show the specific weight of wear vs cutting rate and specific weight of wear vs feed rate. Each experiment was repeated six times.

The relationship between the wear and cutting rate was determined at a feed rate of 0.25 mm/rev at speeds of 21-81 m/min (Table 2) and at a cutting speed of 40 m/min with feeds of 0.16-0.75 mm/rev (Table 3); the depth of the cut was the same – 5.6 mm.

The tests showed that the wear of R2M3F8 cutters heat treated to grain sizes of grade 11 and grade 10 was the same, and therefore it is expedient to quench cutters to a grain size of grade 11 in order to improve the mechanical properties of the steel. The cutting properties are retained in this case.

The wear resistance of high-vanadium steels exceeds that of steel R18; this is particularly evident at cutting rates over 60 rev/min.

With an increase of the feed from 0.16 to 0.75 mm/rev at a cutting speed of 40 m/min the wear rate increases by a factor of 3. The wear resistance of high-vanadium steels is two to three times higher than that of steel R18 at feeds of 0.25-0.75 mm/rev (Table 3).