Tools are sometimes subject not only to wear and high temperatures but also corrosive media. At the present time the data are still insufficient to permit selection of tool steels combining high hardness and wear resistance with satisfactory resistance to various corrosive media, particularly in humid air (including tropical environments) and in organic and weak acids.

After heat treatment, the high-chromium stainless steels 4Kh13 and 9Kh18 with high carbon concentrations, have a hardness not over HRC 54-56 and 58-60 respectively, which is insufficient for many tools.

We investigated a group of steels with 14 and 18% Cr (the principal element increasing the resistance to corrosion). The carbon concentration was varied from 0.9 to 1.25% and the molybdenum concentration from 0 to 4%. Some of the steels were additionally alloyed with strong carbide-forming elements - vanadium, tungsten, zirconium, niobium.

Figure 1 shows the variation of the hardness with the carbon content for the quenched and tempered steels. The curves are similar to those for die steels with 12% Cr. With increasing quenching temperatures the hardness increases due to the increased carbon content of the martensite; at temperatures above 1075°C it decreases, which is due to increasing amounts of residual austenite.

To obtain a high hardness (HRC 62-63) in steels with 14-18% Cr it is necessary to increase the carbon content to 1.17-1.25%, which is higher than that in the standard steel 9Kh18 (0.9-1.0%) and in steel Э1515 (0.9-1.5%).

The same results can be obtained at a lower carbon content (0.9-1.0%) if an additional cold treatment at -70°C is used. However, this effect may be insufficient.

Increasing the carbon content (due to the increase in the amount of carbides) permits widening of the quenching temperature range ensuring high hardness (HRC 60). For steels with 0.9-1.0% C and 14% Cr this range is 10-15°C (Fig. 2), while for steels with 1.2% C and 18% Cr it reaches 75°C (from 1025 to
Fig. 2. Effect of quenching temperature on the hardness of steel with 0.9% C, 14% Cr, and 1.5% Mo. (——) quenched in oil; (---) quenched in oil + cold treatment at -70°C.

Fig. 3. Effect of chromium on the electrical resistivity of steels with 1.14% C, 0.6% Mo, and 0.5% V, quenched in oil from different temperatures.

Fig. 4. Effect of chromium and molybdenum on the corrosion resistance of steels with 0.9 and 1.2% C in a humid atmosphere. 1) 0.9% C, 14% Cr, 0.5% Mo; 2) 0.9% C, 14% Cr, 1.7% Mo; 3) 0.9% C, 14% Cr, 3.7% Mo; 4) 1.2% C, 18% Cr, 0.5% Mo.

1100°C), which makes it easier to obtain consistent results under commercial heat treatment conditions. The use of the cold treatment (-70°C) makes it possible to widen the range of quenching temperatures ensuring a high hardness from 1000 to 1125°C for steels with 18% Cr and 1050 to 1100°C for steels with 14% Cr. However, the strength and ductility of the steel subjected to cold treatment are reduced.

It is especially important that increasing the carbon content from 0.9-1.0% to 1.17-1.25% strongly inhibits the drop of the hardness during tempering due to the increasing amounts of carbides precipitated. After tempering at 150°C the hardness is HRC 57, 59, and 62 respectively for steels with 0.9, 1.05, and 1.2% C (with 18% Cr). This difference is still greater (5-7 HRC units) after tempering at 400°C - HRC 51, 56.5, and 58 respectively for the same three steels.

This effect of carbon is important for tools subjected to considerable grinding and resharpening (medical tools, wood-working tools), and particularly tools that are subject to heating during operation.

An increase of the carbon content within these limits results in a finer grain size (one or even two grades) at high quenching temperatures.

As a consequence of this, the increase of the carbon concentration hardly impairs the strength of tools with small sections (up to 25 mm).

The increase of the carbon content from 0.9 to 1.2% is accompanied by only a slight increase in the amount of retained austenite with quenching from temperatures ensuring the maximum hardness.

On quenching from the same temperatures the steels with higher carbon concentrations retain less austenite - 88% in the steel with 0.9% and 54% in the steel with 1.2% C after quenching from 1100°C.

Increasing the tempering temperature from 150-175 to 375-400°C does not lower the corrosion resistance, since the precipitation of cementite carbide occurring during heating lowers the chromium concentration of the solid solution only slightly. Tempering at 375-400°C increases the bending strength (290-340 kg/mm²) and impact toughness (3.9-4.5 kg-m/cm²) by comparison with tempering at 150°C (250-300 kg/mm² and 2.5-3.5 kg-m/cm²). In this case the hardness decreases from HRC 61-62.5 to HRC 57-59.

A reduction of the corrosion resistance is observed after tempering at 500-550°C, during which Cr₃C₆ carbides enriched in chromium are precipitated from the solid solution.

Table 1 shows the effect of carbon on the corrosion resistance in different media of steels with 18% Cr and 0.5% Mo quenched from 1075°C.

An increase of the carbon content, as the tests showed, impairs the corrosion resistance more strongly (one grade) in weak aqueous nitric acid solutions and somewhat less in weak solutions of sulfuric acid (see Table 1). The corrosion resistance is lowered mainly at carbon concentrations above 1.0-1.05%. The negative effect of carbon concentrations up to 1.25% is very slight in weaker corrosive media such as