RESISTANCE OF TOOL STEELS TO PLASTIC DEFORMATION

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Many tools (cold stamping dies, burnishing tools) are subject to high stresses, inducing plastic deformation, and are put out of commission due to warping. Thus, the effect of the structural components of tool steels on the resistance to plastic deformation needs to be investigated.

The resistance to plastic deformation was characterized by the elastic limit in bending, determined by loading and unloading [1]. The elastic limit was taken as the stress inducing residual deformation of 0.002% (Fig. 1).

The elastic limit is most affected by martensite, the basic component of steels with a high hardness. The effect of martensite depends on many factors. Tempering of quenching steel, inducing precipitation of carbon from martensite, raises the elastic limit (Fig. 2), lowers microstresses [2], and increases the binding force in martensite [3].

The elastic limit increases when steels are alloyed with chromium, and especially tungsten. After tempering at 300–400°C under conditions where microstresses are small the elastic limit of steel R18 with martensite containing 7% W, 5% Cr, and 1% V is 150 kg/mm² despite the elevated carbon content of martensite (0.35%), with hardness HRC 61 and ~25% retained austenite.

The elastic limit of steel Kh12M is only 130 kg/mm², the martensite containing 5% Cr and 0.3% C, with HRC 57 and ~15% retained austenite.

Fig. 1. Relationship between stress and residual deformation of steels tempered at 350°C. The quenching temperatures are given on the curves.

Fig. 2. Effect of tempering temperature on elastic limit of steels. The quenching temperatures are given on the curves.

The elastic limit was lowest (120 kg/mm²) for steel 7KhG2VM, with martensite containing only 1.3% Cr, 1.8% Mn, and 0.25% C, with hardness HRC 54.

The effect of chromium and tungsten is associated with an increase of the binding force in martensite [4, 5].

It is well known that resistance to large plastic deformation, characterized by the yield strength and hardness, hardly depends on the concentration of alloying elements in martensite, but depends mainly on the carbon concentration [5].

Thus, a combination of high resistance to large and small deformation can be obtained by quenching high-alloy steels from elevated temperatures after tempering at 350–400°C, when the martensite retains a large amount of alloying elements and there are no microstresses.

The elastic limit is almost independent of grain size (Table 1).

Raising the quenching temperature from 920 to 1000°C, inducing grain growth to grade 2, does not change the elastic limit for the tempering temperatures investigated.

The same results were obtained for carbon steels in determining the elastic limit in compression [6].

The grain size has no essential effect on the hardness or yield strength.

In the presence of retained austenite the elastic limit decreases (Table 2).

Raising the quenching temperature of steel 7KhG2VM from 860 to 950°C leads to an increase in the amount of retained austenite from 20 to 36%, while the elastic limit decreases from 43 to 30 kg/mm².

The effect of retained austenite increases after low-temperature tempering at 150°C, when some of the stresses are removed. With an increase in the amount of retained austenite from 20 to 30% the elastic limit of steel Kh12M decreases from 96 to 40 kg/mm² (Table 2).

Up to the beginning of transformation, austenite has a similar effect on high-speed steels R12 and R6M3 tempered at 300–350°C.

The resistance to large plastic deformation also decreases in the presence of retained austenite [8].

Excess carbides have no effect on the elastic limit (Table 3).

The elastic limit of steels 6KhS and 7KhG2VM with the minimal amount of excess carbides is practically the same as for steel Kh12M with a large amount of excess carbides. The hardness of these steels (HRC 54–57) and the amount of retained austenite are almost identical.