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# LASER HEAT TREATMENT OF TOOL STEELS

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Pulsed laser hardening of tools and dies is currently in widespread use to improve their stability.

It is known that laser heat treatment is characterized by rapid heating and cooling of the zone affected by the laser [1]. The structural-phase transformations that take place in this case cannot be treated in the same manner by proceeding from data obtained under equilibrium conditions [2, 3]. The shifting of critical points [4, 5], which is accompanied by change in the quantitative relationship between the material's structural-phase components, takes place, for example, during laser heat treatment. In addition to this, the laws common to traditional bulk heat treatment are also observed; this is confirmed by the results of investigation, which are cited below.

We investigated steel R9M4K8, R6M5K5, and KhVG specimens after three forms of bulk heat treatment: annealing, quenching, and quenching with subsequent triple tempering. The specimens were exposed to laser radiation in an LTU-2M impulse-type unit. The pulse duration $\tau$ was varied from 1.2 to 6.0 msec. The radiation energy for a fixed value of $\tau$ was selected so that the temperature on the surface of the specimen in the laser-impression zone, whose dimensions did not vary, was constant and close to the material's melting point. The microhardness was measured on an PMT-3 instrument, x-ray-phase analysis was performed on an DRON-3 diffractometer in cobalt $K_\alpha$-radiation, and metallographic analysis performed using an MMR-2R microscope.

Residual austenite, whose content ($C_\gamma$) decreases with increasing duration $\tau$ of the laser pulse, is observed in the structure of the annealed steel after laser action (Fig. 1a). The $\alpha$-iron line broadens; this suggests the occurrence of hardening processes in the zone of laser influence with an increase in the microhardness of this zone. The amount of residual austenite and the broadening of the $\alpha$-phase line are similar to those observed with the conventional bulk quenching of these steels.

The laser effect on the quenched steel results in an additional broadening of the $\alpha$-phase line. The content of residual austenite is the same as that for laser treatment of the annealed steel, and decreases with increasing duration of the laser pulse (Fig. 1a). The microhardness increases negligibly. As compared with bulk heat treatment, the process of laser action on the annealed and quenched steel combines in itself the elements of quenching and subsequent tempering, which gives rise to a reduction in the amount of residual austenite and to an increase in microhardness.

It should be noted that the results of investigation of the annealed and quenched steel KhVG are qualitatively similar to those presented in Fig. 1a for steels R9M4K8 and R6M5K5.

The results of the laser's influence on steels R9M4K8 and KhVG, which were preliminarily subjected to bulk quenching with subsequent triple tempering, are presented in Fig. 1b. As would be expected from the results of investigation of repeated bulk quenching [2, 3], an increased amount of residual austenite is observed in the laser-affected zone. The increase in residual austenite with increasing duration of the laser pulse may be associated with the effect caused by a shift in the critical points [4, 5]. The shorter the pulse duration $\tau$,

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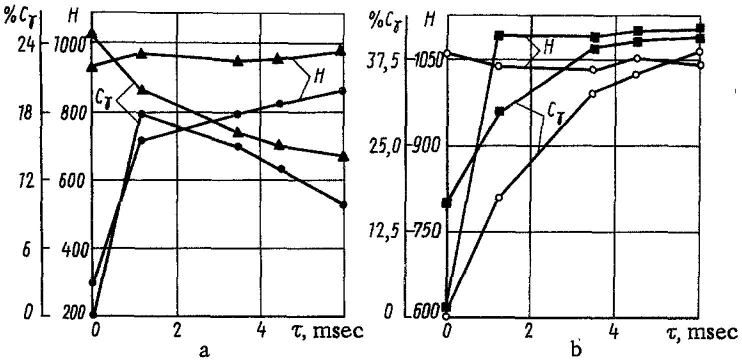

Fig. 1. Microhardness (H) and amount of residual austenite ($C_\gamma$) of steels investigated as function of duration (τ) of laser pulse: a) steel R6M5K5 (▲) preliminarily subjected to bulk quenching, and annealed steel R9M4K8 (●); b) steel R9M4K8 (○) and KhVG (■) preliminarily subjected to bulk quenching and triple tempering.

the higher the material's heating rate, even at higher temperatures, and, consequently, the $\alpha \to \gamma$-transformation will occur in a lower temperature interval. Despite the increase in the amount of residual austenite, the microhardness of the laser-affected zone remains virtually unchanged in steel R9M4K8, and increases in steel KhVG. This is governed by the fact that under rapid laser heating and subsequent rapid cooling, the austenite is saturated with alloying elements and crystal-lattice defects, as a result of which its hardness is increased, the lattice of the α-iron is distorted, and the structure becomes fine-disperse. This suggests, amoung other things, a broadening of the α-phase line by a factor of approximately two as compared with the initial line.

In addition to the features that are characteristic for laser heat treatment, it also conforms to laws common to conventional bulk heat treatment. This must be considered in solving the problem of improving the stability of cutting tools and dies, which is closely related to solution of the problem of the optimal combination of these forms of heat treatment. Use of laser hardening as a finish operation for a tool is not justified, however, after bulk heat treatment. Rehardening of the tool is inexpedient in this case. The optimal combination of bulk and laser heat treatment, however, presumes, amoung other things, basic or supplementary tempering after laser hardening. Repeated laser or induction heating to temperatures not exceeding the quenching temperature for the given material can be used, for example, as supplementary tempering of laser-hardened zones.

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