The best combination of mechanical properties and wear resistance is obtained after isothermal hardening: heating to 830-850° for 30 min, cooling and holding in a salt bath at 450-470° for 20 min (50% $NaNO_3$+ 50% KNO_3), and cooling in air.

The wear resistance is highest with a martensitic structure of the metallic base. The optimal quenching temperature is 830-850°; the temperature limits of rapid electroheating during surface hardening depend to a considerable extent on the heating rate, the original structure, and the quantity of graphite inclusions.

The study showed that with an original structure of lamellar or divorced pearlite, 100-150 graphite inclusions per mm^2, and 0.5-0.8% free carbon the graphitized steel acquires the optimal structure of fine acicular and cryptoacicular martensite after induction hardening from 930-960° with a cooling rate of 200-300 deg/h.

Under the conditions recommended for furnace or induction heating, the hardness of the steel after quenching and low-temperature tempering at 180-200° reaches HRC 59-62; the structure retains 0.3-0.6% C in the form of graphite, ensuring a low coefficient of friction ($\leq$0.35) and high wear resistance (the wear was 45-54 mg under these conditions).

Thus, the use of heat treatment makes it possible to change the mechanical properties and wear resistance of graphitized steel within wide limits, depending on the operating conditions of particular machine parts. Laboratory, bench, and field tests of machine parts such as gears, sprockets, clutches, universal joints, blades of cutting bars in farm machinery, and other parts obtained by investment casting and proper heat treatment have demonstrated their high operational reliability.

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MICROHARDNESS OF NONMETALLIC INCLUSIONS AND THE MATRIX OF LOW-CARBON STEEL

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In the production of cold-rolled plates from low-carbon steel the steel is hot rolled at 1100-900°C and cold rolled. The surface of hot-rolled and cold-rolled strips and plates often has defects, some of them (laminations, tears, ragged edges) due to nonmetallic inclusions. Thus, it is of interest to investigate the properties of inclusions and the metallic matrix, especially the microhardness at rolling temperature.

In the literature there are data concerning the microhardness of inclusions in bearing steel at room [1, 2] and high temperatures [3].

We present results on the microhardness of nonmetallic inclusions and the metallic matrix in steels 08Yu and 08 containing 0.14% Ti at temperatures of 25-1100°. The microhardness of the steels and the inclusions was measured in the high-temperature IMASh-9-66 apparatus. The tests were made with a sapphire indentor; the temperature of the testpiece and the indentor was identical. The temperature of the piece and the indentor was measured with platinum–platinum-rhodium thermocouples with an error of 0.5%. Depending on the steel and the testing temperature, the load on the indentor was varied from 1 to 20 g. The holding time of the indentor under load was 10 sec. The microhardness of the inclusions was determined from 20 measurements.

The nonmetallic inclusions were identified by metallographic and microprobe analysis with the Cameca MS-46 analyzer. We measured the microhardness of inclusions of corundum, manganese spinel, manganese

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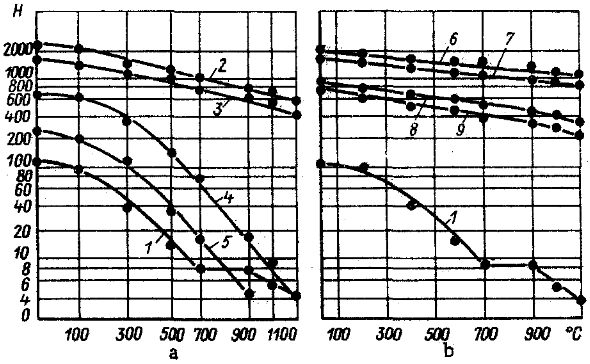

Fig. 1. Temperature dependence of the microhardness of nonmetallic inclusions and the metallic matrix of steels 08Yu (a) and 08 containing titanium (b). 1) Matrix; 2) Al_2O_3; 3) $MnO-Al_2O_3$; 4) $MnO-SiO_2$; 5) FeS−MnS; 6) TiN; 7) Ti (CN); 8) $FeO-TiO_2$; 9) TiO_2.

silicate, and iron−manganese sulfide in steel 08Yu, and titanium nitride, titanium carbonitride, titanium dioxide, and ilmenite in steel 08 containing titanium. Separate inclusions with a size of at least 15 μ were measured.

The test results are shown in Fig. 1. The microhardness of the inclusions at 25° was H 220-2050, depending on their nature, and differed greatly from the microhardness of the metallic matrix. The microhardness was lowest for sulfide inclusions and very high for corundum and titanium nitride. The microhardness of sulfides decreased sharply at elevated temperatures (Fig. 1a) and at temperatures $\geq$600° became approximately equal to the microhardness of the matrix. The inclusions of manganese silicate retain their high microhardness up to 900°; above this temperature the microhardness slightly exceeds that of the metallic matrix. The microhardness of aluminum oxide and manganese spinel in steel 08Yu was more than two orders higher than that of the matrix at all temperatures (Fig. 1a). For inclusions with titanium the microhardness substantially exceeded that of the matrix at all temperatures (Fig. 1b). The microhardness was highest for titanium nitride, which with increasing temperatures from 700 to 1100° decreases from H 1310 to H 930. The microhardness was lowest for titanium dioxide.

The results obtained on the microhardness of inclusions and the metallic matrix permit a more complete explanation of the behavior of inclusions during hot and cold deformation and their effect on the nature of surface defects in low-carbon steel. Manganese silicate and sulfide inclusions, with almost the same microhardness as the matrix at 900-1100°, are elongated during rolling. Corundum and spinels in steel 08Yu and nitrides, carbonitrides, and complex titanium oxides in steel 08 containing titanium are not deformed during hot rolling, while titanium dioxide is deformed somewhat in some cases. During cold rolling all the inclusions remain almost undeformed and often undergo brittle fracture, and the fragments of the inclusions are arranged in a line in the rolling direction; only sulfides are ductile at 250°.

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