HEAT TREATMENT USING HIGH-ENERGY SOURCES

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STRUCTURAL CHARACTERISTICS OF THE SURFACE OF COLD-ROLLING ROLLS REFITTED BY RADIATION HEAT TREATMENT

N. M. Aleksandrova, S. Yu. Makushev, and V. V. Selin

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At present, besides the conventional methods for strengthening (bulk hardening, treatment by high-frequency current) parts operating under high contact loads and elevated wear, methods of surface treatment by concentrated energy fluxes, including laser and electron-beam irradiation, are used. Treatment of the surface of parts made of tool steels by a focused beam in an optimum regime improves their hardness and wear resistance. The present work is devoted to investigating the properties of cold-rolling rolls refitted by electron beam treatment.

The methods of x-ray structural analysis and electron and optical microscopy were used to investigate the structural state of steel 90KhF-Sh in the surface layer of rolls (42, 48, and 49 mm in diameter) after service and subsequent treatment by a radiation heat treatment (RHM) method. Before service the rolls had been hardened to a hardness of 59–62 HRC_e after high-frequency current (HFC) heating.

We determined the degree of distortion of the crystal lattice of the α- and γ-phases, the content of residual austenite, and the carbon concentration in the steel.

The structure was investigated on a JEM-200CX electron microscope and a DRON-3 x-ray diffractometer in iron Kα radiation. The specimens were cut from partially worn surface layers of rolls subjected to RHT and from the middle of the rolls.

The radiation heat treatment of the rolls was conducted by a focused beam of electrons on an ELV-4 electron accelerator with an energy $E = 1.5$ MeV and a beam 1.5 mm in diameter entering the atmosphere. The investigation was carried out at the Institute of Nuclear Physics of the Siberian Branch of the Russian Academy of Sciences and the Novolipetsk Metallurgical Plant. A roll was rotated at a rate $\omega = 400$ rpm and moved translationally at a speed $v = 1$ cm/sec. The current was chosen so that the temperature of the heated region did not exceed 500°C. The rolls were treated repeatedly and after each pass they were cooled to room temperature. The radiation dose was varied from 150 to 500 Mrad. The cooling time of the treated surface was 15 msec.

After service and repeated grinding to eliminate the defects appearing on the surface, the hardened layer is worn out and its hardness decreases to 59–62 HRC_e. When the strengthened layer is worn out, the rolls are remelted although their diameter still suits the size of the rolling mill. In order to determine the possibility of restoring the hardness of the surface layer, worn-out rolls were repeatedly treated by a focused electron beam.

Depending on the regime the hardness of the rolls increases from 59 to 67 HRC_e (Table 1) and reaches the level of new rolls hardened from the HFC heating temperature. The worn-out layer is restored to a thickness of 0.80 mm.

The layer strengthened by RHT can be divided into two zones with respect to the structure formed, namely, a base zone with a thickness of 0.75 mm and a transition zone with a thickness of 0.75–0.80 mm. The structure of the base zone is lamellar pearlite. After the treatment the sides of the rolls have a hardness of 64–67 HRC_e.

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The layer strengthened by RHT can be divided into two zones with respect to the structure formed, namely, a base zone with a thickness of 0.75 mm and a transition zone with a thickness of 0.75–0.80 mm. The structure of the base zone has a pickling capacity that varies over the thickness, because of the different natures and degrees of dispersity of the steel components, namely, martensite, carbides, and residual austenite. The transition zone has a troostite structure against...
a background of fine lamellar sorbite with scattered fine carbide particles (at most 1 µm in size).

Figure 1 presents the results of an electron microscopic investigation of foils. After hardening from the HFC heating temperature the base zone exhibits round partially twinned crystals of martensite 2 - 3 µm in size (Fig. 1a).

Coarse blocks of residual austenite are seemingly squeezed between martensite plates. In some cases austenite is observed in the form of borders of cementite particles, which is associated with special features of the heating in hardening after HFC. It seems that due to the brevity of the heating action the carbides do not have enough time for complete dissolution in the austenite. Such an incompletely dissolved cementite particle 1 µm in size can be seen in Fig. 1b.

As a result of RHT martensite on the surface of the rolls becomes more disperse (Fig. 1c). The size of martensite mosaic blocks decreases to 0.1 - 0.3 µm. The observed high density of microtwins inside martensite crystals seems to be caused by high thermal stresses that appear in local heating of the surface by an electron beam. Electron micrographs show segregations of fine carbide particles 0.05 - 0.15 µm in diameter arranged over the twinning planes in the martensite (Fig. 1d). We can assume that the formation of carbides is caused by the decomposition of martensite during the irradiation.

Thus, RHT of worn-out roll surfaces makes their structure finer and causes segregation of a large number of finely dispersed carbides.

Residual austenite, like the carbide phase, is part of the structure of the hardened layer of the roll. The fraction of residual austenite before and after RHT was determined by two methods, namely, (1) by the method of homologous pairs (reflections of α- and γ-phases with close integral intensities) [1] and (2) by the ratio of the integral intensities of the reflections (110) of the α-phase (martensite) and (111) of the γ-phase (residual austenite) [2].

In order to calculate the fraction of residual austenite by the method of homologous pairs we compared x-ray patterns of specimens after different treatment regimes. On the x-ray patterns we chose pairs of reflections of the α-phase (martensite) and γ-phase (residual austenite) with the closest integral intensities. If the intensities of the lines of the homologous pair coincided, the relative content of austenite was deter-

![Fig. 1. Electron-microscopic photograph of 90KhF-Sh steel after hardening from HFC heating (a, b) and RHT (c, d): a) × 15,000; b) × 37,000; c) × 30,000; d) dark-field micrograph in the cementite reflection, × 20,000.](image-url)