INTERNAL OXIDATION OF THE CASE ON CARBURIZED ALLOYS STEELS

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Carburizing and heat treatment of low-carbon alloy steel is used to produce a case with martensite and some amount of retained austenite, and sometimes carbides. However, nonmartensitic transformation products of austenite are sometimes found near the surface of carburized and quenched parts. This has been explained by the interaction of the steel with oxygen [1, 2], nitrogen [3], and hydrogen [4] from the carburizer.

X-ray spectral analysis was used to determine the chemical composition of thin surface layers of carburized and quenched steel 30KhGT. Carburizing was conducted at 930°C in a mixture of endothermic gas with methane (carbon potential ~ 0.87%). Contact of the samples with air was avoided in transferring the samples from the carburizing chamber of the furnace to the quenching tank (mineral oil).

Figure 1 shows the surface zone of the carburized sample. The dark particles of various sizes at a depth of as much as 20 μ contain elements with a small atomic number.

Figure 2 shows the variation of the microhardness through the depth of the case; it indicates the effect of these particles or processes associated with their formation on the transformation of supercooled austenite. Near the surface the microhardness decreases to H 100-420, which matches the microhardness of troostite.

The chemical composition of the case was investigated with the JXA-3A microanalyzer. The electron probe, focusing down to 1-2 μ, was moved from the edge of the microsection to the center. The counters recorded the intensity of Kα x-ray emissions of the chemical elements for which the spectrometer was adjusted. The concentrations of chromium, manganese, silicon, iron, and oxygen were measured. It was found that the concentrations of oxygen and silicon increase greatly in the "dark" phase (Fig. 3). At a depth of 20 μ, where particles of this phase are absent, the fluctuation of the concentration curves of oxygen and silicon ceases. The concentration of manganese and chromium (along with oxygen) increased only in particles of larger size in a surface zone 6-8 μ deep (see Fig. 1). These particles are either oxides of chromium, manganese, and silicon or complex oxides containing these elements. At a depth from 6-8 to 20 μ the phase consists only of silicon oxide. This corresponds to the lower thermodynamic potential (∆Z^2) of SiO₂ formation.

Fig. 1. Surface zone of carburized steel 30KhGT (sloping section; scale refers to normal section) (×500). The dark diagonal bands are traces of the electron probe.
Fig. 2. Microhardness in the surface zone of the case on steel 30-KhGT.

Fig. 3. Distribution of chromium, manganese, silicon, and oxygen in surface zone of carburized steel 30KhGT (curves in a and b obtained from different sections).

The data obtained indicate that oxygen from the endothermic atmosphere is adsorbed on the surface of the steel, diffuses into the steel, and oxidizes the alloying elements, the oxides of which are thermodynamically more stable than iron oxide.

The effect of internal oxidation on the kinetics of the transformation of supercooled austenite is due to the following conditions: a) the forming oxides serve as crystallization centers for the new phase and lower the stability of supercooled austenite; b) with formation of oxides the γ solid solution is impoverished due to removal of atoms of alloying elements from it. In the case investigated the effect of the second factor evidently predominates. The concentration of manganese and chromium in austenite decreases from 1.05 to 0.4% in steel 30KhGT due to the diffusion of these elements to the grain boundaries (the front of the oxidation reaction).

Nonmartensitic transformation products also occur in the structure of quenched carbonitrided steel. A surface zone a few microns thick, and sometimes a region near the grain boundaries to a depth of several hundred microns, does not undergo quenching [5].

In [6] the reduction of the stability of supercooled austenite in the thin surface zone is explained by formation of spinel containing chromium and manganese, and the deeper troostite by the formation of chromium nitrides.

Microanalyzers JKhA-3A and MAR-1 were used to determine the concentrations of alloying elements and oxygen in zones of nonmartensitic transformation products of austenite in a sample of steel 30KhGT after carbonitriding and quenching.

Carbonitriding was conducted in a mixture of endothermic gas with methane and ammonia at 850°C. The samples were transferred from the chamber to a quenching tank with oil. The distribution of carbon and nitrogen in the case is given in Table 1.

Nonmartensitic transformation products were observed after light etching of the microsection with 5% Nital. Troostite and bainite were observed in the surface layer about 10 μ thick near particles of nonmetallic phase (Fig. 4); in a lower layer 5-10 μ thick a substantial number of grains had a bainitic structure. Nonmartensitic transformation products (troostite) were also observed around nonmetallic inclusions at a depth of 0.1 mm. The overall depth of occurrence of nonmetallic particles* was 0.60 mm.

Figure 5 shows the change in the intensity of Kα emissions of chromium, manganese, oxygen, and silicon in the surface zone of the sample. The presence of synchrophased spikes to a depth of 10 μ indicates the formation of oxides of metallic elements and silicon. The overall depth at which silicon oxides occur is 20-25 μ.

It should be noted that under the layer with chromium and manganese oxides there is a layer 5-10 μ thick with a low concentration of these elements (respectively 0.5 and 0.1% as compared with 1.05% in the

*The color of the particles was grayish-pink.