RAILROAD RAILS MADE OF BAINITIC STEEL

Results are presented from a study of the mechanical characteristics and microstructure of rails made at the Novokuznetsk Metallurgical Combine from steel alloyed with manganese, silicon, chromium, molybdenum, and vanadium. It was established that obtaining high strength and hardiness in the steel by increasing its contents of carbon and alloying elements has an adverse effect on the service properties of rails made of steels with a bainitic structure. Normalizing is the most effective means of increasing strength and improving microstructure. The required level of mechanical characteristics can be obtained by tempering the steel at 350–370°C. The adverse effect of cold straightening – which is manifest in a reduction in the rails’s impact toughness – can be offset by subjecting the steel to preliminary tempering or normalizing and tempering. Rather than further increasing the strength of rail steel to improve its overall quality, this objective is better served by making sure that the steel is cleanly made, that the rails have little or no curvature, and that the residual stresses in the steel are favorably distributed.

A new trend has recently developed in rail production – the manufacture of high-strength rails based on steel with a bainitic structure. It is known that such a structure can be obtained either by heat treatment or by complex alloying of the steel. The Novokuznetsk Metallurgical Combine has developed and studied a steel of this type, which is being made in electric-arc furnaces (Table 1).

Earlier laboratory studies established that the mechanical characteristics of bainitic steels are improved after normalization and tempering. In light of this, experimental R65 rails made at the combine were subjected to normalization from 870°C and tempering at 350–460°C.

Specimens for tests in tension and impact bending were prepared from the heat-treated rails to study the mechanical characteristics. The tensile tests were performed on two cylindrical specimens with a diameter $d = 6$ mm and a gage length $l = 30$ mm. Two impact specimens ($10 \times 10 \times 55$ mm, with a notch having $R = 1$ mm and a depth of 2 mm) were tested in impact bending at +20°C and –60°C. Hardness was measured on the tread surface and over the cross section of the rail. The metal of the specimens was subjected to metallographic study on a Neophot-21 microscope.

The mechanical tests (Table 2) showed that the rails made of steel from trial heats É1 and É2 were strengthened by cooling them in air from the rolling heat. Higher levels of strength ($\sigma_u = 1420–1490$ N/mm$^2$, $\sigma_y = 1130–1170$ N/mm$^2$) and hardness (HB 415–429) were obtained on the rails made of steel É1, which has higher contents of carbon, manganese, silicon, and chromium than steel É2. An attempt to increase the hardness of the rail by increasing the carbon content of the steel and subjecting it to complex alloying produced negative results: hardness on the flange of the rail reached very high values (HB 495–514). Another adverse effect of the chemical composition of steel É1 was manifest in the very low ductility properties ($\psi = 10–13\%$, $\delta = 4–5\%$) for the head of the rail.
The rails of steel É2 had the optimum combination of mechanical characteristics, which were comparable to those of quenched-and-tempered rails of medium-carbon steel. A decrease in the steel’s contents of carbon and the main alloying elements led to some reductions in strength ($\sigma_u = 1270–1290$ N/mm$^2$, $\sigma_y = 880–890$ N/mm$^2$) and hardness (HB 363–375) and an improvement in the ductility properties ($\psi = 25–33\%$, $\delta = 15–17\%$).

The metallographic study showed that the difference in the mechanical characteristics of the experimental rails made of steels É1 and É2 was due to the character of their microstructure. The steel with the ultimate strength of 1420–1490 N/mm$^2$...