HEAT TREATMENT TECHNOLOGY

EFFECT OF PRELIMINARY QUenchING ON SPHEROIDIZATION OF CARBIDES

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Spheroidizing of steel to obtain a structure of granular pearlite is a long technological operation. Granular carbides are obtained more rapidly by preliminary quenching of the steel, i.e., rapid cooling after rolling. The favorable effect of preliminary quenching on acceleration of the process to obtain granular pearlite has been known for a long time, although, for many reasons, no commercial use has been made of it. The principal reason is the traditional separation of the two processes—rolling and spheroidizing—in which parts are usually cooled in air after rolling and then subjected to spheroidizing. Rolled sections of high-carbon steels (bars, wire, pipe, strips) are usually not quenched from the rolling heat due to the possibility of cracking, the complicated technology, and lack of the necessary equipment for this operation.

The problems involved in heat treatment and thermomechanical treatment of various rolled sections immediately after rolling have now been solved [1]. Research has been conducted on rapid cooling of many rolled sections, with the prerequisites for the development of the theory and technology of rapid spheroidizing of rolled and forged products. Data have been published concerning the use of preliminary quenching to accelerate spheroidizing. At the Zlatoust Metallurgical Plant spheroidizing is accelerated by use of interrupted quenching of steels U7 and U8 in water from the rolling heat [2]. At State Bearing Factory No. 6 (6GPZ) roller bearings are sorbitized with a water spray after forging and flaring, which shortens the subsequent spheroidizing time, improves the structure, and increases the productivity of the furnaces [3].

We investigated* spheroidizing of quenched steels U8 and ShKh15 from commercial heats with a structure of thin lamellar pearlite after rolling. Samples of steels U8 and ShKh15 10 mm high and 15 and 30 mm in diameter were quenched from 800 (U8) and 840°C (ShKh15). After quenching in oil, steel U8 had a troostomartensitic structure, and after quenching in water a martensitic structure. After quenching in oil, steel ShKh15 had a martensitic structure with excess carbides. The quenched samples were spheroidized with recrystallization (heating above Ac1) and without recrystallization (heating somewhat below Ac1). For spheroidizing with recrystallization the quenched samples were heated to 740, 760, and 780°C with holding for 5-30 min. The samples were then transferred to another furnace heated to 650, 670, and 690°C (i.e., below Ac1) and held for 10, 30, and 60 min after reaching the given temperature (1 min per mm of section was allowed to reach this temperature). The structures resulting from austenitizing were examined after quenching. To determine the effect of the cooling rate after austenitizing on the structure, one sample was cooled in air after each treatment. For spheroidizing without recrystallization the samples were heated to 680 (U8) and 710°C (ShKh15), with holding for 1-6 h.

Examination of the microstructure showed that steel U8 tempered for 2 h and even for 1 h and then quenched to martensite has a structure of granular pearlite with evenly distributed cementite globules (Fig. 1a). With quenching of steel U8 to troostomartensite a satisfactory structure of granular pearlite was obtained only after tempering for 4 h, although the size of the cementite globules was smaller than after tempering of steel U8 quenched to martensite for 2 h (Fig. 1b). Tempering for 1 h of steel ShKh15 quenched to martensite also results in a granular structure, although the decomposition products of martensite retain their acicular orientation (Fig. 1c). With tempering for 5 h a satisfactory finely dispersed ferrite-carbide mixture is obtained (Fig. 1d). Thus, spheroidizing without recrystallization

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Fig. 1. Microstructure of steel U8 (a, b) and steel ShKh15 (c, d) after tempering for 2 (a), 4 (b), 1 (c), and 5 h (d); a, b) ×700; c, d) ×1000.

(high-temperature tempering) of quenched carbon steel U8 and chromium-bearing steel ShKh15 makes it possible to obtain a satisfactory structure of granular pearlite several times faster than annealing of the hot-rolled steel (not quenched).

Spheroidizing with recrystallization of quenched steels U8 and ShKh15 showed that heating to Ac₁ of steel quenched to martensite leads to decomposition of martensite and retained austenite, the steel consisting of a finely-dispersed ferrite-cementite mixture up to recrystallization. With heating to Ac₁ of steel U8 quenched to troostomartensite the martensite decomposes to a ferrite-cementite mixture but the shape of the troostite precipitations remains unchanged and only partial transformation of lamellar to globular precipitates occurs; the steel consists of a fine granular and thin lamellar ferrite-cementite mixture up to recrystallization.

At higher temperatures, the α → γ transformation occurs as the temperature passes through Ac₁. Subsequent holding at 740-780°C induces solution of cementite particles in austenite, with preferential solution of platelets and fine globules of cementite. Spheroidizing and coalescence of carbide particles occur simultaneously, the structure consisting of a mixture of austenite and fine granular carbides.

The quantity of carbide depends on the austenitizing temperature and the holding time – the higher the temperature and the longer the time the fewer the carbides remaining undissolved. With the same austenitizing temperatures and times, the quantity of carbides and the size are larger in steel ShKh15 than in U8. In the quenched steel the carbides formed in the process of heating to Ac₁ dissolve in austenite less completely and at a slower rate than the carbide in the annealed steel, and therefore undissolved carbides are retained for some time even when quenched steel U8 is heated above Ac₁ (740-780°C). Only after holding steel U8 for ~30 and 20 min at 760 and 780°C, respectively, are the cementite particles completely dissolved, which agrees with the data in [4].

Austenitizing at 740-780°C for 5-30 min and cooling in air of steel U8 previously quenched to martensite leads to formation of a mixture of granular and lamellar pearlite. The quenched steel austenitized at 690-650°C and cooled in air has a good granular structure (Fig. 2a). Spheroidizing, consisting of quenching and subsequent spheroidizing with recrystallization, will hereafter be called dispersion spheroidizing.

The experiments showed that dispersion spheroidizing of steel U8 (austenitizing at 740°C for 5-20 min, holding at 690-670°C for 30 min, and cooling in air, or austenitizing at 760-780°C for 5 min, holding at 690-650°C for 30 min, and cooling in air) produces a good structure of granular pearlite with evenly distributed globules of cementite of the same size in a ferrite matrix. The hardness is HB 179 (d_indent = 4.5 mm).