TECHNOLOGY OF HEAT TREATMENT

UDC 621.785.789:620.17

EFFECT OF THERMAL-STRAIN TREATMENT OF STEEL ON ITS STRUCTURAL STATE AND LEVEL OF PROPERTIES

I. G. Uzlov,[1] V. I. Spivakov,[1] and E. A. Shpak[1]

Translated from Metallovedenie i Termicheskaya Obrabotka Metallov, No. 1, pp. 16 – 18, January, 1997.

At present the quality of steel is often improved by thermomechanical treatment (TMT). It is of interest to establish the effect of the state of austenite in strain caused by TMT on the properties of steels. This paper is devoted to the effect of various thermal-strain treatment regimes on the properties and structure of steels 25GSR and 20 with different stabilities of austenite.

The technological process of thermomechanical strengthening of rolled steel permits substantial savings in power resources because the strengthening is conducted using the rolling heating after the strain treatment of the steel is finished. TMT also makes it possible to save alloying elements because it ensures a high level of properties (both strength and toughness) of the steel. Use of rolled stock with elevated strength properties creates conditions for the production of mechanisms, machines, and metal and ferroconcrete structures with a diminished consumption of metal [1].

Another factor affecting the efficiency of such treatment of steel consists in that it can eliminate the negative effect of the processes of high-speed rolling in modern continuous mills characterized by an elevated temperature at the end of the process, which worsens the properties of the metal and especially the toughness characteristics.

In the process of hot plastic strain of steel the elements are uniformly distributed over austenite grains and the harmful impurities positioned in near-boundary zones dissolve. As a result of dynamic and static recrystallization austenite grains are fractured. The high cooling rate of the rolled stock after it leaves the mill causes formation of highly dispersed products of decomposition of austenite and diminishes the size of austenite grains [2 – 4].

The structural state that results after TMT increases the strength and fatigue resistance of the metal with a simultaneous substantial growth of the impact toughness even at negative temperatures (which is especially important). For example, low-alloy steels (09G2 – 14G2, 09G2S, and other grades) strengthened to $\sigma_r = 520$ and 600 N/mm^2 have an impact toughness $a_1 > 35$ J/cm^2 at -70°C.

[1] Institute of Ferrous Metallurgy of the National Academy of Sciences of Ukraine.

It should be noted that the parameters of the thermal-strain treatment of steel in the process of the TMT can be varied in order to form a favorable structural state and obtain a high set of properties [5 – 6].

For this purpose we studied various temperature and strain regimes for treating steels 20 and 25GSR characterized by different stabilities of austenite. The specimens were rolled in a mill at the Institute of Ferrous Metallurgy of the National Academy of Sciences of Ukraine with a 30% reduction. The furnace heating for rolling was conducted by the following regime: the specimens were heated to 1100°C, then placed in the furnace heated to various temperatures, and strained (see Table 1). The rolled specimens were cooled in water in a special device at a mean flow rate of the water equal to 45 – 50 deg/sec. The accelerated cooling was discontinued at 600 – 650°C and then the specimens were cooled in air.[2]

[2] The regime of thermal-strain treatment described by the authors is in fact strain combined with annealing, because in this case the transformation of supercooled austenite occurs at 600 – 650°C. The classical kind of TMT consists in strain with subsequent quenching in which the strained austenite undergoes a martensite transformation (Ed. note).

TABLE 1

Treatment regime	t_h, °C	t_s, °C
1	1100	1050
2	1100	900
3	1100	800

Notation: t_h is the temperature of heating before the strain, t_s is the strain temperature.
Notes. 1. The degree of strain was 30% for all the treatment regimes. 2. After the strain the preforms were cooled in water to 600 – 650°C and then in air.

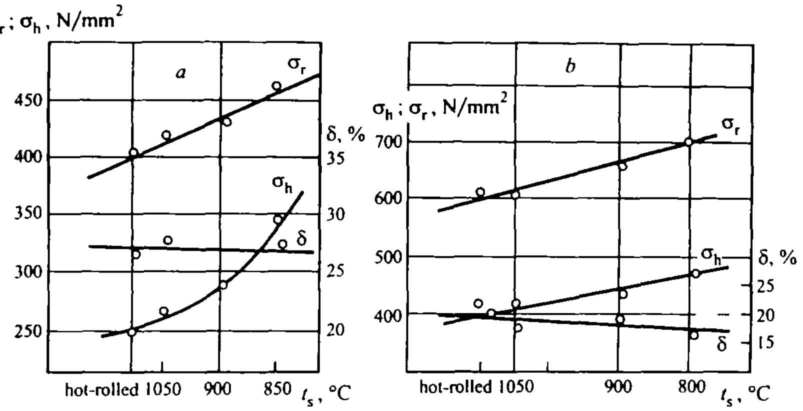

Fig. 1. Dependence of the mechanical properties of steels 20 (*a*) and 25GSR (*b*) on the strain temperature t_s.

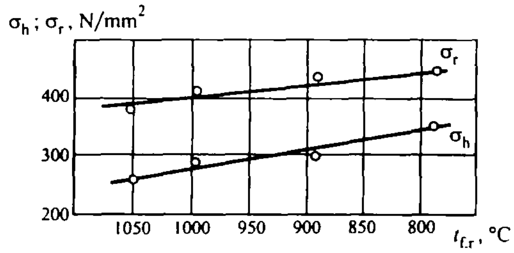

Fig. 2. Dependence of the strength properties of steel St 3 on the final-rolling temperature $t_{f.r}$.

A part of the samples was studied in the hot-rolled state: after rolling at 1100°C with 30% reduction and cooling in air.

The temperature of the critical points Ac_1 and Ac_3 was determined in advance. For steel 20 $Ac_1 = 736$°C ($Ar_1 = 630-640$°C), $Ac_3 = 868$°C ($Ar_3 = 740-750$°C); for steel 25GSR $Ac_1 = 731$°C ($Ar_1 = 620-640$°C), $Ac_3 = 836$°C ($Ar_3 = 730-740$°C).

A microstructural analysis has shown that deformation at 900 and 1050°C with subsequent accelerated cooling (regimes *1* and *2*) causes disappearance of the ferrite network over boundaries of former austenite grains in steel 25GSR. Treatment by regime *3* ($t_s = 800$°C) gives grains of various sizes, and structurally free ferrite is segregated over boundaries of former austenite grains. The structure is ferrite-pearlite.

As the rolling temperature of steel 20 is diminished from 1050 to 800°C, the sizes of the ferrite-pearlite grains decrease and begin to differ.

Plates rolled and strengthened by the regimes presented above were used to prepare specimens for tensile tests. Results of the tests are presented in Fig. 1. It can be seen that with reduction of the strain temperature the strength characteristics of steels 20 and 25GSR increase. The plasticity remains at virtually the same level. The greatest increase in the ultimate rupture strength due to the decrease in the strain temperature has been observed in low-alloy steel 25GSR (Fig. 1*b*). This can be associated with the elevated stability of its austenite. In low-carbon steel 20 the yield strength increases to a greater degree with reduction in the strain temperature (Fig. 1*a*).

We also studied the strength characteristics of shaped rolled stock (flange beams and channels) of carbon steel St 3 in a hot-rolled state after rolling in different mills. We established (Fig. 2) that preforms rolled in a continuous (high-speed) mill at a final-strain temperature of 1080°C has lower σ_r and σ_h than preforms rolled in a linear (low-speed) mill that provides a final-rolling temperature of 800°C with longer pauses between strains in the rolling strands.

The data presented show that strengthening of steel subjected to TMT occurs mostly due to grain disintegration [7] and creation of a stable dislocation structure.

REFERENCES

1. I. G. Uzlov, "Heat treatment of rolled stock: an effective way to save metal," *Metalloved. Term. Obrab. Met.*, No. 8, 18 – 21 (1985).
2. K. F. Starodubov, I. G. Uzlov, V. Ya. Savenkova, et al., *Heat Treatment of Rolled Stock* [in Russian], Metallurgiya, Moscow (1970).
3. I. G. Uzlov, V. Ya. Savenkov, and S. N. Polyakov, *Heat Treatment of Rolled Stock* [in Russian], Tekhnika, Kiev (1981).
4. A. A. Kugushin, I. G. Uzlov, V. V. Kalmykov, et al., *High-Strength Reinforcing Steel* [in Russian], Metallurgiya, Moscow (1986).
5. M. L. Bernshtein, *Structure of Strained Metals* [in Russian], Metallurgiya, Moscow (1977).
6. M. L. Bernshtein, V. A. Zaimovskii, and L. M. Kaputkina, *Thermomechanical Treatment of Steel* [in Russian], Metallurgiya, Moscow (1983).
7. A. P. Gulyaev and A. S. Shigarev, "Thermomechanical treatment of steel and its effect on the mechanical properties," *Metalloved. Term. Obrab. Met.*, No. 5, 9 – 12 (1961).