The method of deformation-free hardening developed is most effective under conditions of single-piece and small lot production in the machine building and tool industry.

STRENGTHENING OF 10G2S1 STEEL IN RELATION TO THE TEMPERATURE OF CYCLIC BENDING DEFORMATION

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The mechanical properties of steels in relation to deformation temperature have been widely investigated after rolling and drawing [1-3]. There is little information on the influence of cyclic bending deformation and it basically relates to cold [4] or hot deformation [5, 6]. In addition, existing data was obtained on various steels, which does not make it possible to evaluate the effectiveness of strengthening in a broad temperature range and to select the optimum deformation temperatures.

The purpose of this work was an investigation of the influence of cyclic bending deformation temperature on the mechanical properties of 10G2S1 steel and determination of the most effective deformation temperature ranges.

For the investigation 8 × 60 × 300 mm pieces of normalized 10G2S1 steel were used. These were deformed by pure bending using a symmetric cycle with a constant degree of single deformation ($\varepsilon_0 = 2\%$) at temperatures from normal to 950°C. Tensile (type 2, All-Union State Standard (GOST) 1497-73) and impact bend (type 2, GOST 9454-78) specimens were cut from the pieces. The structure of the steel was investigated on a Neophot-2 optical microscope and the quantitative evaluation of structural constituents was made by the point method of A. A. Glagolev.

The change in mechanical properties of the previously normalized 10G2S1 steel after cyclic bending deformation in the 20-950°C temperature range is shown in Fig. 1. It was established that deformation is accompanied by strengthening of the steel, and with an increase in temperature the degree of strengthening changes unsteadily. With an increase in deformation temperature to 300°C the tensile σ_t and yield σ_y strengths increase by 120 and 240 N/mm^2, respectively, with a reduction in the elongation by 9% and in the impact strength at −70°C by 55 J/cm^2 in comparison with these properties of 10G2S1 steel in the undeformed condition. With a further increase in temperature the degree of strengthening drops.

The minimum degree of strengthening of the steel is reached at 710°C. In this case the increase in σ_t and σ_y is 20 and 35 N/mm^2, respectively, with a decrease in elongation of 1.5% and in impact strength at −70°C of 10 J/cm^2. Deformation in the intercritical temperature range causes an increase in the degree of strengthening, and the maximum strength of 10G2S1 steel is reached as the result of deformation at 810°C. It is characteristic that strengthening is accompanied by maintenance of the original values of elongation and impact strength. With a further increase in deformation temperature the degree of strengthening drops, reaching a minimum value at 880°C. The combination of mechanical properties of the steel after deformation at 710 and 880°C is practically the same. With an increase in deformation temperature to 950°C σ_t and σ_y increase by 30 and 50 N/mm^2, respectively.

The investigation results showed that with an increase in deformation temperature from 300-500 to 780-840°C the share of ductile constituent in the fractures of specimens with a U-shaped notch tested at normal temperature increases on the average from 65 to 90%.

In analyzing the change in mechanical properties of 10G2S1 steel it was established that in cyclic bending deformation in the 200-500°C range the degree of strengthening is greater than in cold deformation. The maximum increase in σ_t and σ_y, reached at a deformation temperature of 300°C, is 40 and 100 N/mm^2, respectively, greater than after cold deformation. However, with deformation temperatures of 200-300°C the elongation and impact strength of 10G2S1 steel drop to a greater degree than in cold deformation. This must be taken into consideration in selection of warm deformation conditions.

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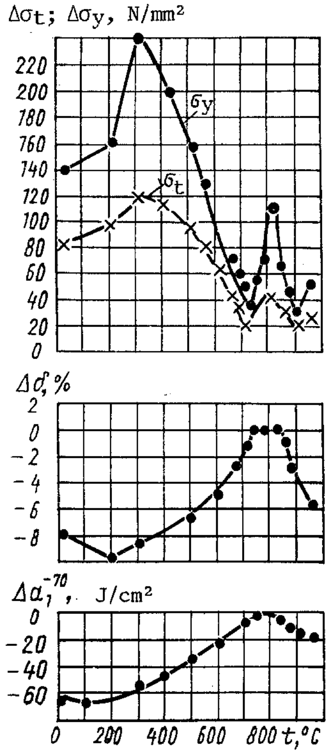

Fig. 1. Influence of cyclic bending deformation temperature on the mechanical properties of 10G2S1 steel.

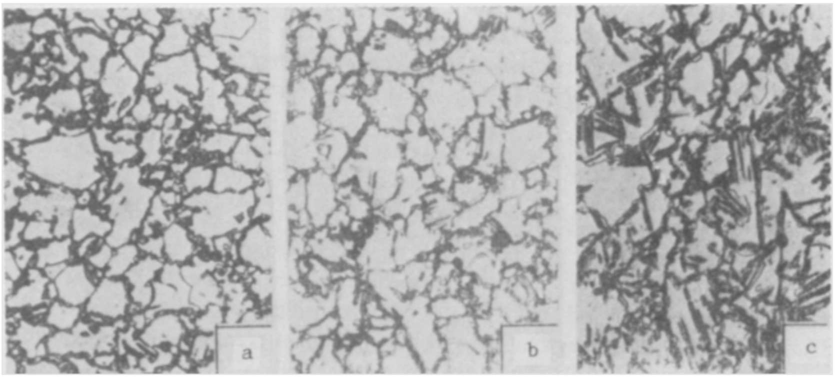

Fig. 2. The structure of 10G2S1 steel after different treatments (400×): a, b) normalized from 780 and 810°C, respectively; c) cyclic bending deformation at 810°C, air cool.

In strengthening in the 780-840°C range the values of elongation of 10G2S1 steel are maintained at the level of the undeformed condition. The impact strength at +20 and −70°C drops by not more than 15 J/cm^2 and the tensile and yield strengths increase by 35-40 and 70-110 N/mm^2, respectively.

The increase in the strength characteristics of the steel at deformation temperatures up to 300°C is caused by formation of a cellular dislocation substructure and by development of the processes of dynamic strain aging [1, 2]. Since the dislocation density is greater in warm deformation than in cold [2], then the degree of strengthening of 10G2S1 steel in warm deformation is greater without a significant reduction in plasticity and impact strength. A further increase in deformation temperature causes an increase in the size of the dislocation substructure cells [7] and accelerates diffusion processes and dislocation mobility. The change in mechanical properties of the steel in deformation in the intercritical temperature range is caused by the change in the ratio of the structural constituents. Earlier we established [8] that at heating temperatures somewhat above Ac_1

austenite is formed at the ferritic grain boundaries in the form of rounded areas, which in cooling decompose according to the intermediate type (Fig. 2a). In heating above 780°C the formation of austenite occurs in certain crystallographic planes in the form of needles (plates) propagating from the grain boundaries inward. Therefore in cooling in air from these temperatures the intermediate structures formed differ in form: rounded in the ferritic grain boundaries and acicular in the bodies of the grains (Fig. 2b). A further increase in temperature leads to merging of the acicular formations.

Deformation at temperatures in the intercritical range causes the formation of an additional quantity of austenite in the form of needles (plates) and an increase in the quantity of acicular intermediate structure after cooling. The greatest quantity of acicular and intermediate structure is formed after deformation at 810°C with air cooling (Fig. 2c). Its volume share increases from 9 to 16% in comparison with the undeformed condition, that is, it almost doubles. The formation of the additional quantity of acicular intermediate structure causes an increase in the strength properties of 10G2S1 steel without reducing its plasticity and impact strength.

Strengthening of the steel at deformation temperatures above Ac_3 (800°C), that is, in the austenitic area, is caused by inheritance by the ferrite of the substructure of hot deformed austenite [1].

Under production conditions cyclic bending deformation of sheets occurs during straightening in sheet straightening machines. In [9, 10] the possibility of use of sheet straightening machines for strengthening treatment of rolled sheet was shown.

Conclusions. 1. In cyclic bending deformation of 10G2S1 steel in the 300-500°C range with subsequent air cooling the tensile and yield strengths increase by 95-120 and 155-240 N/mm^2, respectively, with a drop in the elongation of 7-8.5% and in the impact strength at −70°C of 35-55 J/cm^2. In this case strengthening is caused by the prevailing influence of the processes of formation of a cellular dislocation structure and dynamic strain aging.

2. In deformation in the 780-840°C range the strength characteristics increase by 35-110 N/mm^2 without a reduction in plasticity and impact strength, which is caused by the formation of an additional quantity of intermediate acicular structure.

3. For strengthening of low-alloy thick sheet steel in the warm condition by cyclic bending, roll straightening machines may be used.

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INFLUENCE OF PRELIMINARY COLD DEFORMATION ON THE CAVITATION-CORROSION RESISTANCE OF 12Kh18N9T STEEL

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Certain steels with a structure of unstable austenite, which in loading undergoes the martensitic transformation, possess increased cavitation resistance [1]. This is caused by the simultaneous occurrence of the processes of hardening and stress relaxation in the phase transformations in unstable austenite.

For the martensite formed in unstable steels in deformation a high degree of dispersion and submicrohomogeneity are characteristic. In addition, in contrast to quenching martensite deformation martensite is quite plastic [2, 3]. All of this may provide a high resistance of the steel to cavitation action.

However, in practice as a rule parts operating in chemically active media are subjected to cavitation action. Austenitic steels, which possess low cavitation-corrosion resistance in comparison with martensitic steels close in composition, are normally used for service in such media [4]. In connection with this it was of interest to investigate the influence of deformation martensite formed as the result of preliminary working and also of the $\gamma \to \alpha$ phase transformation on the corrosion resistance of austenitic stainless steels under cavitation conditions.

In this work 12Kh18N9T steel,* which was first deformed at the temperature of liquid nitrogen, was investigated. The completeness of the $\gamma \to \alpha$ phase transformation was controlled by the degrees of deformation, which were from 10 to 52% for the different specimens. The specimens were deformed by tension on a 30-ton tensile machine. From the deformed specimens were prepared specimens for further investigations in such a manner that their working portion corresponded to the zone of deformation of the original specimens. The quantity of deformation martensite in the structure of the steel was determined from the data of x-ray analysis on a URS-50IM instrument in iron K_α-radiation (Table 1).

The cavitation-corrosion tests were made on an experimental unit using the method of [5] at 20°C in an 0.5 M sulfuric acid solution. To imitate cavitation conditions a UZDN-1 ultrasonic generator, the operating conditions of which provided vibrations of the emitter-specimen with a frequency of 22 kHz and an amplitude of 20 μm, was used. The corrosion resistance of the steel under cavitation conditions was determined from polarization curves recorded on a P-5827M potentiostat and from the decrease in specimen weight as the result of electrochemical corrosion calculated according to Faraday's law.

The structure of the 12Kh18N9T steel (Fig. 1) after preliminary plastic deformation with small degrees is a weakly etching austenitic matrix, in the individual grains of which appear slip lines of different planes and twins thickened as the result of precipitation in them of deformation martensite (Fig. 1a, dark portions) [3]. With an increase in the degree of deformation the distribution of the martensite becomes more uniform and it gradually replaces the austenite (Fig. 1b, c).

An analysis of the polarization curves showed that under cavitation conditions in H_2SO_4 solution the electrochemical properties of the preliminarily deformed and undeformed specimens of 12Kh18N9T steel are dissimilar (Fig. 2). The steady potential (φ_{st}) of the specimens with martensite in the structure shifts into the area of more positive potentials in relation

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*V. I. Kocherov participated in discussion of the results of the work and writing of the article.

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