SURFACE HARDENING OF AUSTENITIC STEELS

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Austenitic steels are surface hardened mainly by nitriding and mechanical strain hardening [1], in which case the thickness of the hardened layer does not exceed 0.2-0.3 mm.

In this connection it is of interest to surface harden austenitic steels by heat treatment,* with changes in the depth of the hardened layer within wide limits. The same metastable austenitic steels of the Fe–Ni–Ti system (2-4% Ti) used for phase strain hardening in [1] were used in this work. A hard surface layer on austenitic steels is obtained due to the martensitic transformation to the desired depth and subsequent aging of the martensite. The permeability of the sample increases due to the ratio of the volumes of the ferromagnetic surface layer and the paramagnetic austenitic core. It can be assumed that for massive parts, in which this ratio is small, the total change of the magnetic field would be negligible.

The simplest method of surface hardening of metastable steels is cold treatment of the surface. However, the thickness and hardness of the layer cannot be strictly controlled in this case. To obtain high hardness (HRC 45) it is necessary to have a fairly large amount of martensite (over 40%). Consequently, it is necessary that the surface be cooled far below M_s or that the isothermal $\gamma \rightarrow \alpha$ transformation occur. However, this leads to development of the martensitic transformation in deep layers of the part due to the high thermal conductivity of metals and alloys. Furthermore, the distribution of martensite in the surface layer is uneven because of the temperature gradient.

In the method of hardening proposed the martensitic transformation in the surface layer results not from the creation of a temperature gradient but from the complete and even cooling of the piece after preliminary preparation of the structure of the core and the surface layer.

The preparation of the structure consists of a substantial reduction of M_s of the entire piece (stabilization) in the range of negative temperatures and subsequent raising of M_s (destabilization) only in the surface layer (by means of heating by high-frequency current, for example). Further cooling of the piece to temperatures between the M_s of the surface and the core leads to a martensitic transformation only in the destabilized surface layer despite the identical temperature of the surface and the core.

The use of precipitation-hardening Fe–Ni–Ti steels for surface hardening permits additional hardening of the surface by aging of the martensite (a hardness >HRC 60 can be obtained [2]).

The austenitic core is hardened either by aging or by phase strain hardening, and the thickness of the hardened layer is controlled by changing the frequency of the current and the solutioning time.

This method can be used after intensive stabilization of austenite in the first stages of aging of Fe–Ni–Ti alloys [3]. Figure 1 shows the effect of the aging temperature and time for carbon-free steels N27T3, N21T3M3, and N21T3M2 on the position of M_s. The stabilizing effect of aging is so large that M_s drops more than 100°C. Aging at 475° for 6 h of steels N27T3 and N21T3M3 quenched from 1100° permits retention of the stability of austenite down to temperatures below −196° (original $M_s = -80°$). The austenite is stabilized, and holding for 3 h at −60 to −196° does not lead to the martensitic transformation, whereas 40-50% martensite is formed during cold treatment of the quenched steels. With increasing amounts of titanium in the steel up to 4-5% the quantity of γ phase precipitated during aging increases and also stabilization – holding for 1 h at 450-500° is sufficient for complete stabilization of γ phase.

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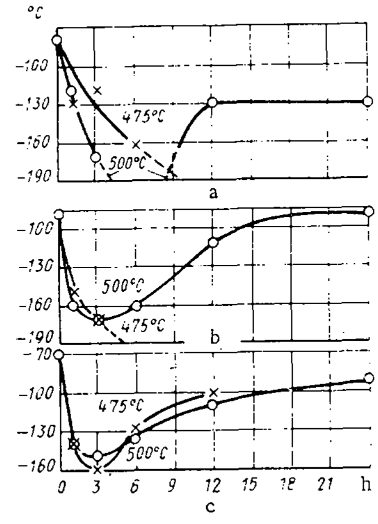

Fig. 1

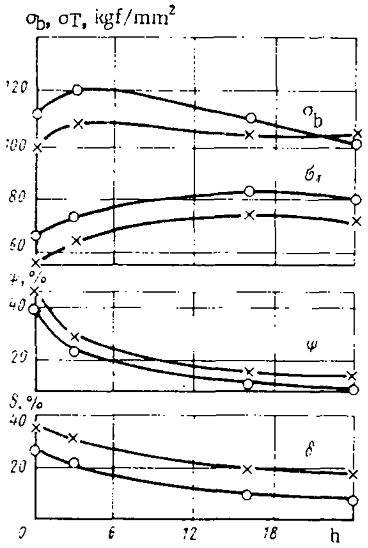

Fig. 2

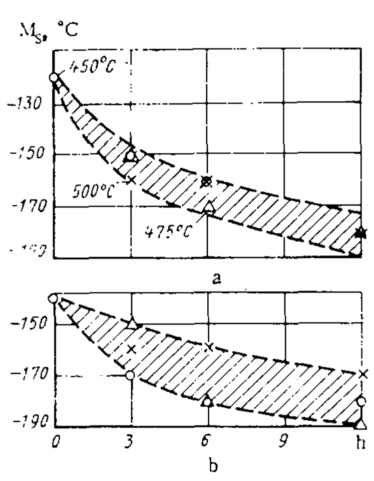

Fig. 3

Fig. 1. Position of M_s for steels N27T3 (a), N21T3M3 (b), and N21T3M2 (c) in relation to aging time at 475 and 500°.

Fig. 2. Mechanical properties of steel N21T3M2 after phase strain hardening at different temperatures and subsequent aging at 500°. ○) Phase strain hardening at 800°; ×) at 850°.

Fig. 3. Effect of phase strain hardening at 850° (a) and 800° (b) and aging time on M_s of steel N21T3M2. Aging temperatures are given on the curves.

According to [4], the stabilizing effect of γ' phase in steels with 23-26% Ni and 2-5% Ti is due to reduction of the critical size of α-phase nuclei. Also, the reduction of M_s after aging can be explained by the barrier effect of the precipitating particles or the creation of stress fields preventing nucleation of martensite [5]. Stabilization was associated with an increase of the energy spent on the formation of martensite in [6] when particles of γ' phase with a fcc lattice undergo the transformation along with austenite and are transformed to a new metastable condition with a bcc lattice.

Stabilizing aging, particularly in steels with a high titanium content, can be a hardening treatment at the same time. The core of the piece can be hardened to a still greater extent by phase strain hardening and aging. Phase strain hardening of austenite occurs in the steels investigated due to the direct martensitic $\gamma \rightarrow \alpha$ transformation during cooling in liquid nitrogen of steels previously quenched from 1100° and the reverse $\alpha \rightarrow \gamma$ transformation during heating to 800-850°.

Figure 2 shows the mechanical properties of steel N21T3M2 hardened by phase strain hardening in relation to the heating temperature during the $\alpha \rightarrow \gamma$ transformation (temperature of phase strain hardening) and subsequent aging time at 500°. The yield strength of austenite can be raised to 80 kgf/mm². Considerable stabilization of austenite is observed in steel N21T3M2 (Fig. 3), which permits the surface hardening treatment to be conducted.

The second stage of hardening consists of destabilization of the surface layer and the martensitic transformation in the surface layer. Destabilization of austenite occurs with solution of previously precipitated γ' phase in the surface layer, for which purpose it is heated to temperatures exceeding 800-850° by means of high-frequency current. The simplest conditions for surface heat treatment of steel N21T3M2 are as follows:

1) Stabilization of austenite (aging at 475° for 3 h of steel quenched from 1100°).

2) Destabilization of the surface layer as the result of induction hardening (current frequency 3 kHz).

3) Martensitic transformation of the surface layer – cooling to −120° (holding 3 h). In this case 50% martensite is formed in the surface layer, while the core remains austenitic.

4) Aging at 450° for 1 h.

The hardness of the surface layer after this treatment is HRC 48 and the depth of the layer is 4 mm. The structure of the martensite in the surface layer and the austenite in the core is shown in Fig. 4. The hardness

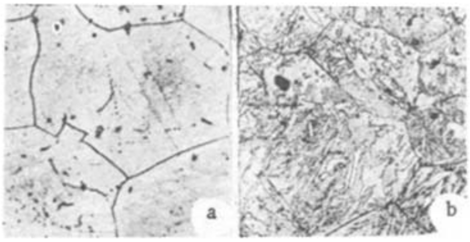

Fig. 4. Microstructure of steel N21T3M2 (×500). a) Austenite in core; b) martensite in surface layer.

is constant throughout the entire layer. The boundary zone where the transition from martensite to austenite occurs, the hardness decreasing to the original level, is 0.5 mm deep.

It is possible to eliminate the cold treatment if the composition of the steel is selected so that M_S is at 60-100°, while stabilization aging makes it possible to lower M_S to negative temperatures.

CONCLUSIONS

1. A method is proposed for surface hardening of austenitic steels (N27T3, N21T3M2, and others) that includes stabilization of austenite throughout the entire piece due to aging, destabilization of the surface layer by heating with high-frequency current, the martensitic transformation in the surface layer during cooling of the piece to temperatures between M_S of the surface layer and M_S of the core, and aging of the martensite.

2. This treatment produced a hardened layer 4 mm thick with a hardness of HRC 48 on austenitic steel N21T3M2.

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