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CHANGE IN THE DUCTILITY CHARACTERISTICS OF AUSTENITIC STEELS DURING DEFORMATION AT DIFFERENT RATES

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It is widely believed that an increase in strain rate leads to an increase in ductility. This is indicated, for example, by the data in [1, 2].

The results of other authors make it possible to suggest that the ductility of steels decreases in the transition from static deformation to dynamic straining [3-6].

The present study investigates the ductility of stable austenitic steels 07Kh13AG19N5 and 12Kh18N22T and metastable austenitic steel 03Kh13AG19.

Aften an austenizing quenching (6- and 7-point grain size), the steels were tested in tension at 20 and −196°C at strain rates from $1.7 \cdot 10^{-4}$ sec^{-1} to $5 \cdot 10^{2}$ sec^{-1}.

The ductility of the steels was evaluated from the quantities ε_ψ and ε_{ψ_p}, which were found from the equations

$$\varepsilon_\psi = \ln\frac{1}{1-\psi}; \qquad \varepsilon_{\psi_p} = \frac{1}{1-\psi_p} \quad [4],$$

where ε_ψ is the total plastic strain (true strain after fracture); ψ is the reduction of area of the specimen after fracture; ε_{ψ_p} is the uniform plastic strain (true strain at the moment necking begins); ψ_p is the reduction of area of the specimen at the moment necking begins.

It was established from the study that the ductility of the structurally stable steels is reduced by a transition from static deformation to dynamic deformation at 20°C (Figs. 1 and 2).

There is a similar change in the ductility of steel 03Kh13AG19 under these conditions. with the $\gamma \to \varepsilon$-transformation occurring in this steel during deformation at rates $\dot{\varepsilon} < 10^{-1}$ sec^{-1} [5].

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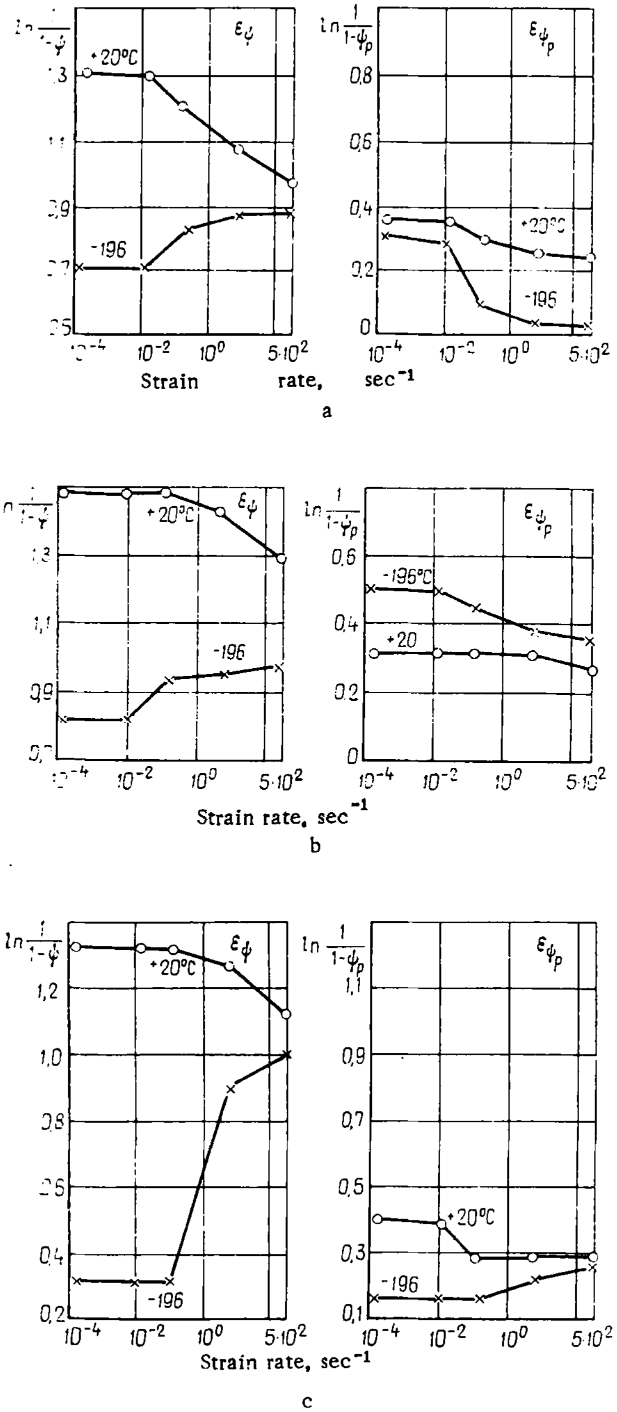

Fig. 1. Effect of strain rate and test temperature on the total ε_ψ and uniform ε_{ψ_p} plastic strain of structurally stable steels 07Kh13AG19N5 (a) and 12Kh18N22T (b) and metastable steel 03Kh13AG19 (c).

A decrease in test temperature to −196°C yields different relations. With an increase in strain rate ($\varepsilon > 10^{-1}$ sec^{-1}), the (total) plastic strain of the stable and metastable steels increases. The increase is greatest (a little more than threefold) for steel 03Kh13AG19.

The uniform plastic strain of the structurally stable steels decreases, while that of steel 03Kh13AG19 increases. This is evidently connected with a redistribution of the deformation zones along the specimen due to phase transformations.

How can one explain the increase in the total ductility of the austenitic steels with high-rate deformation at −196°C?

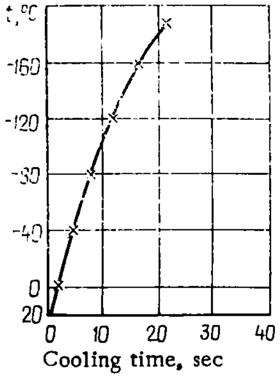

Fig. 2. Change over time in the temperature of the center of a specimen ($\varnothing$ = 4 mm) cooled in liquid nitrogen.

Heating may occur during deformation — especially at high rates. The temperature increase may be due to the strain work being done, 93-95% of which is ultimately converted into heat. Dissipation of the heat into the environment depends on many factors, including the time of deformation. The higher the strain rate, the less time available for heat to be dissipated into the coolant liquid. Thus, other conditions being equal, the final temperature of the specimen must be higher.

If we assume that the specimen temperature (in the deformation zone) does increase, then the actual temperature of the deformed specimen will be different from the temperature of liquid nitrogen.

Calculations showed that the total time of deformation to specimen fracture at rates $\dot{\varepsilon} > 10^0$ sec^{-1} is less than 1 sec. At $\dot{\varepsilon} = 5 \cdot 10^2$ sec^{-1}, t_{def} = 0.0006 sec [5].

Test data on the temperature of specimens cooled in liquid nitrogen shows that the temperature of the central layers of the specimen is —196°C (Fig. 2) 20 sec after the beginning of cooling.

Comparing the total time of deformation and the specimen cooling time, it can be noted that at high rates ($\dot{\varepsilon} > 10^{-1}$ sec^{-1}), the heat released during deformation raises the temperature in the deformation zone and thereby affects the ductility of the steels.

Thus, the ductility of austenitic steels 07Kh13AG19N5, 12Kh18N122T, and 03Kh13AG19 depends on the strain rate in the following manner. There is no change in ductility in the rate interval $1.7 \cdot 10^{-4}$—$1.7 \cdot 10^{-2}$ sec^{-1}. With an increase in the rate ($\dot{\varepsilon} > 10^{-1}$ sec^{-1}), ductility decreases at room temperature and increases in liquid nitrogen.

The increase in the ductility of the steels in liquid nitrogen at $\dot{\varepsilon} > 10^{-1}$ sec^{-1} is connected with a change (increase) in specimen temperature during deformation, which changes not only the thermal conditions for plastic flow of the austenite, but also the conditions for the martensitic transformation.

For metastable steel 03Kh13AG19, these changes have the greatest effect on the increase in ductility at the temperature of liquid nitrogen.

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