EFFECTS OF CARBURIZATION OF Kh16Ni15M3B STEEL IN SODIUM ON MECHANICAL
CHARACTERISTICS IN VARIOUS STRUCTURAL STATES

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It has been found that fuel-pin sheaths in fast reactors sometimes become carburized because carbon-bearing substances have entered the sodium coolant [1, 2]. As Kh16Ni15M3B austenitic stainless steel is widely used in these sheaths, it was of interest to examine the effects of carburization in sodium on its mechanical characteristics.

We report tests on short-term stretching for carburized flat tenfold specimens (thickness 0.5 mm, width 3 mm, working length 15 mm). The specimens were carburized in sodium by the method of [3], which provided a carbon distribution over the thickness corresponding to that given in [4]. The tests were performed at 293-973 K with a strain rate of 0.8 x 10^-4 sec^-1 at a pressure ≤ 10^-3 Pa.

The steel was tested in the austenitized and cold-deformed states (carbon contents at the surfaces of the material, correspondingly 0.240, 0.850, and 0.85% and 0.240, 0.650, and 0.850%).

As the specimens were carburized at 923 K in sodium for 230 h [4], we also examined parallel specimens after aging in argon at the same temperature for the same time. Also, some of the cold-deformed specimens were aged at 823 K before carburization to 0.650%.

Austenitized State (Figs. 1a, 2a, and 3a). The value of σ₀.₂ increased with the carbon content (substantially for C = 0.850% and less substantially for C < 0.240%). Aging after austenization reduced the yield and strengthsomewhat (curve A). The most marked effect from carburization was the considerable reduction in the relative extension (Fig. 3). Increasing the carbon content at the surface to 0.80% reduced the plasticity by about a factor of five.

Cold-Deformed State (Figs. 1b, 2b, and 3b). Cold deformation increases σ₀.₂ and σₜ considerably; but reduces the plasticity substantially (curve o). Carburization of the cold-deformed material has effects on the mechanical properties somewhat different from those for the austenitized specimens. At low degrees of carburization (up to 0.085%), there is a reduction in the nominal yield point and also in the ultimate strength (curve +), and only for C = 0.850% do both of these characteristics exceed the initial values (curve ▽). The values of σ₀.₂ for carbon contents of 0.250 and 0.650% were similar throughout the temperature range.

The carburized aged specimens showed an unambiguous picture: σ₀.₂ and σₜ increased with the carbon content, while the relative elongation decreased. It has previously been shown [4] that keeping Kh16Ni15M3B steel for long periods at 923 K (aging) causes the carbon to coagulate and form carbides, along with the deposition of secondary phases. At the same time, the dislocation structure is rearranged and the internal stresses relax completely (recovery), as these are produced by preliminary cold deformation (curve ▽).

The increase in carbon concentration during aging in cold-deformed steel probably hinders internal-stress relief on account of the deposition of carbides and the formation of stable atmospheres at the dislocations, which prevents redistribution of the latter. The dislocations introduced by cold strain are blocked so extensively that they cannot move under the external stresses and represent major barriers for fresh dislocations (curve ▽) [4].

While σ₀.₂ and σₜ are reduced by carburizing the cold-deformed material (low carbon contents), the dominant process is a weakening one (curve +); on the other hand when these characteristics increase (high carbon contents), then hardening predominates (curve ▽).
Fig. 1. Temperature dependence of the yield point for Kh16N15M3B steel specimens in the austenitized state (a) and in the state of cold deformation by 20% (b) after heating to 923 K in argon for 230 h (Δ and ▼), after carburization in sodium to surface concentrations of 0.083% (+); 0.240% (●, ■); 0.650% (▲) and 0.850% (☆, ▼).

The $\sigma_{0.2}$ (T) curves for carbon contents of 0.240 and 0.650% come together because the material in the cold-deformed state before carburization to 0.650% had been aged at 773 K for 230 h, which had partly relieved the internal stresses, which led to softening.

The U-shaped $\sigma$(T) curves occur for the material in all the states probably because carbides are deposited at the grain boundaries, which hinders accommodation of deformation, and consequently leads to a transition from intragranular failure to intergranular [4].

These results show that carburization in sodium to $C = 0.850\%$ at 923 K causes Kh16N15M3B sheath steel to have catastrophically low plasticity in the working temperature range in fast reactors. Then the critical carbon activity at 923 K can be taken as 0.14.

The specimens in both states show similar relative elongations as the carbon contents at the surfaces increase, so it is preferable to use sheaths in the cold-deformed state on account of the much higher resistance to minor plastic strain.