HEAT RESISTANT STEEL AND ALLOYS

CENTRIFUGALLY CAST PIPE OF STEEL Kh20N35
WITH DIFFERENT AMOUNTS OF CARBON

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Equipment used in producing hydrogen and ammonia employs centrifugally cast pipe of steels* of the Kh20N35 type operating at temperatures of 750-980°C and pressures up to 30-35 kg/cm². The recommended carbon content of these steels is 0.15-0.50%. Changing the carbon content within these limits must affect the properties of the pipe, thus determining its working capacity, and therefore we investigated the structure and properties of centrifugally cast pipe with different amounts of carbon in the steel.

The investigation was conducted on experimental centrifugally cast pipe with dimensions of 140 × 30 × 590 mm of steels 11Kh20N35, 15Kh20N35, and 20Kh20N35, and dimensions of 324 × 19 × 3100 mm of steels 25Kh20N35 and 45Kh20N35. The chemical composition of the steels is given in Table 1.

The macrostructure of the pipe was investigated on etched transverse sections. Pipe of steels with 0.11 and 0.15% C was characterized by a columnar structure throughout the section (Fig. 1a), while pipe of steels with 0.20-0.45% C had equiaxed crystals in sections adjoining the surface along with columnar crystals (Fig. 1b).

The microstructure consisted of austenite and carbides. In the steel with 0.11% C the carbides were located in grain boundaries (Fig. 2a). Sections of carbide eutectic were observed in steels with 0.20% C or more, which were distributed in the grains and grain boundaries of austenite in the steels with 0.20 and 0.25% C (Fig. 2c) and generally distributed along the axes of dendrites in the steel with 0.42% C (Fig. 2e).

The mechanical properties of the steels at room and elevated temperatures are shown in Fig. 3. Raising the carbon content of the steel from 0.11 to 0.42% increases the proof stress at 20°C somewhat and substantially reduces the ductility in the original condition and after prolonged aging at 800°C (Fig. 4).

With increasing temperatures the strength of all the steels decreases. The ductility of the steels with 0.25 and 0.42% C changes little up to 700-750°C and then increases at 800-850°C. The ductility of the steels with a high carbon content (0.25-0.42%) is higher than that of steels with 0.11-0.20% C at 800-850°C (Fig. 3).

Raising the carbon content of steel Kh20N35 from 0.11 to 0.42% reduces the toughness at all temperatures investigated (20-850°C) (Fig. 5).

*According to GOST 5632-72, steel Kh20N35 is an alloy (< 50% Fe), and should be designated KhN35.

Fig. 1. Macrostructure of centrifugally cast pipe of steel Kh20N35 with 0.15% C (a) and 0.20% C (b).

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Aging at 800° for 24 and 100 h leads to precipitation of carbides, which coalesce during aging for 1000 h (Fig. 2b, d, and f). The composition of the carbide phase varies with the carbon content of the steel and the aging conditions. In the original condition, steels with 0.10–0.20% C have only carbides of the M_23C_6 type, the steel with 0.25% C has carbides of the M_23C_6 and M_7C_3 types, and the steel with 0.42% C has carbides of the M_7C_3 type; after aging at 800° for 1000 and 3000 h these steels contain only carbides of the M_23C_6 type.

The structural transformations resulting from aging induce substantial changes in the mechanical properties (Table 2). The mechanical properties after aging change greatly with increasing carbon concentrations. For the steel with 0.25% C the elongation and reduction in cross sectional area decrease.