INCREASING THE DUCTILITY OF CAST NIOBIUM ALLOYS BY HEAT TREATMENT

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At present we have many niobium alloys, the heat resistance of which is created by alloying of the solid solution and precipitation hardening with phases (mainly carbides) formed in decomposition of the supersaturated solid solution. However, an increase in the strength of niobium alloys is accompanied by reduction of the workability, particularly in the cast condition [1], which leads to raising the initial deformation temperature of ingots to 1500-1700°C [2]. After deformation under these conditions there are large surface defects, rods are tapered, and the output of serviceable metal is low. The high resistance of deformed ingots prevents creating high-strength alloys with an elevated concentration of carbide phases.

The effect of heat treatment on the structure and properties of precipitation-hardening alloys in the deformed condition was investigated in [3, 4]. No systematic studies were made of the effect of heat treatment on the structure and properties of precipitation-hardening niobium alloys with over 0.08% C in the cast condition.

We investigated the effect of heat treatment on the structure and properties of Nb-Mo-Zr-C alloys in the cast condition. The studies were made on domestic alloys VN3 (4.7-5.2% Mo, 1.3-1.6% Zr, 0.1-0.16% C) and VN4 (9-10.2% Mo, 1.5% Zr, 0.25-0.3% C, and 0.01% Ce). The ingots contained 0.01-0.2% O and 0.02-0.03% N.

Fig. 1. Microstructure of alloy VN3 obtained by arc melting (a) and electron beam melting (b), and alloy with VN4 obtained by arc remelting (c) in the cast condition.

Fig. 2. Microstructure of alloy VN3 in the cast condition obtained by arc melting. a) Axis of dendrite (7500 X); b) between axes of dendrites (7500 X).
The ingots of alloy VN3 with a diameter of 150 mm were subjected to vacuum arc remelting or electron beam remelting at melting rates of 10-13 and 3-5 mm/min respectively; the ingots of alloy VN4 were subjected to vacuum arc remelting at a melting rate of ~7 mm/min.

We examined the macrostructure of the ingots and also determined the mechanical properties in the longitudinal and transverse directions. The ingots were heat treated at 1000-2000°C with holding for 0.5-20 h. The cooling rate was varied from 10 to 700 deg/min down to 1000-1100°C with further cooling at the rate of 50-100 deg/min.

The samples were heat treated in the TVV-4 and TVV-5 furnaces, and ingots 150 mm in diameter in the MVD3 vacuum furnace.

Metallographic analysis was conducted on microsections obtained by the chemomechanical method, with subsequent etching in a mixture of concentrated HF, HNO₃, and H₂SO₄.

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The electron microscopic investigation was conducted with double silver-carbon replicas shadowed with chromium.

The lattice constant was determined by photographing the samples in the RKE camera with copper radiation from lines (411), for which \( \theta = 83° \). Cast samples with large crystals were subjected to rotation and vibration simultaneously; the accuracy of the measurements was ±0.0005 Å.

Line (400), for which \( \theta = 67° \), was recorded with copper radiation in the URS-501M diffractometer to calculate the microstresses in cast alloys. The phase analysis was made by electrochemical separation of the phases with subsequent chemical and x-ray analysis.

The mechanical properties of the samples were determined in tension on the Gagarin press at a speed of 0.8 mm/min; the microhardness was determined in the PMT-3 apparatus under a load of 200 g.

The short term heat resistance was tested in tension at 800-1500°C in the PRV-203 machine in vacuum. The red hardness was measured in the MIF-1 apparatus.

Alloys VN3 and VN4 are characterized by microheterogeneity and a dendritic structure. The extent to which the dendritic structure develops depends on the composition of the alloy and the solidification and cooling conditions of the ingot. The dendritic structure is pronounced in ingots of VN3 produced by vacuum arc remelting (Fig. 1a). In ingots of VN3 produced by electron beam remelting and in ingots of VN4 obtained by arc remelting, which solidify and cool at a slow rate, there is no dendritic microheterogeneity, although there is selective etching of the grains (Fig. 1b, c).