THE (Cr) + (NbC) QUASIBINARY EUTECTIC
IN THE Cr – Nb – C SYSTEM

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An experimental investigation of the Cr – Nb – C alloys has shown that in the (Cr) + (NbC) two-phase region there are the fold with maximal solidus temperature and the saddle point \( \text{Cr}_{79.5}\text{Nb}_{12.2}\text{C}_{8.3} \) on the liquidus surface, relating to \( L_e \Rightarrow (\text{Cr}) + (\text{NbC}) \) invariant equilibrium at \( \geq 1640°C \).

Keywords: phase diagram, quasibinary eutectic, solidus, liquidus, Cr – Nb – C.

The Cr – Nb – C system has previously been examined throughout the concentration range at temperatures substantially lower than the solidus temperature: 1050°C [1] and 1350°C [2]. The isothermal sections according to the [1, 2] data do not have any essential differences. Those researches did not confirm the suggestion [3] that the \( \eta \) carbide \( \text{Nb}_3\text{Cr}_3\text{C} \) is formed (structure type \( \text{W}_3\text{Fe}_3\text{C} \)), which is not surprising for researches especially conducted on a substantial number of specimens in the region of possible presence of this doubtful ternary compound. In the opinion of the authors of [2], the \( \eta \) carbide suggested in [3] was formed because of the presence of impurities.

In [4] it was found that there is a quasibinary eutectic \( L_e \Rightarrow (\text{Cr}) + (\text{NbC}) \) with composition \( 76 \pm 5 \text{ mass }\% \text{ Cr and } 24 \pm 5 \text{ mass }\% \text{ NbC}_{1.0} \) formed at \( 1110 \pm 10°C \). That result may appear doubtful, since it conflicts with the [2] data, according to which all ternary alloys in the system at 1350°C are in the solid state. The reason for the error may lie in the deficiencies of the method of determining the temperature for the start of melting used in [4], and thus from the form of the microstructure of specimens annealed at those temperatures.

We have examined the structures of the alloys in the Cr – Nb – C system at the chromium corner of the composition triangle up to 30 at. \% Nb and 30 at. \% C, together with their melting points. We constructed the projections of the solidus and liquidus surfaces and the polythermal section on the 79 at. \% chromium isoconcentrate at high temperatures.

We took the phase diagrams for the Nb – C and Nb – Cr binary systems from [5], while that for Cr – C was taken from [6]. We used the [7, 8] data for the solubility of carbon in chromium.

The initial materials were electrically refined chromium (99.9 mass \% Cr), metallic niobium of grade NbSh-00-12 (99.7 mass \% Nb), and reactor graphite with an ash content of 0.05 mass \%, as well as alloys of compositions \( \text{Cr}_{57}\text{C}_{43} \), \( \text{Cr}_{49}\text{Nb}_{49}\text{C}_{4} \), and \( \text{Cr}_{49}\text{Nb}_{49}\text{C}_{2} \) (as indicated by chemical analysis) made from the same materials under the same conditions. The alloys were prepared in a laboratory arc furnace in argon (gettered in molten titanium for 3 min) on a water-cooled copper substrate, where we used an unconsumed tungsten electrode. The mixtures were initially sintered in a weak arc and then were remelted twice, with turning over between meltings. After that, the castings were ground and melted again in the same way. The cooling rates after switching off the arc were about 100 deg/sec. The specimens in the cast state and after annealing at subsolidus temperatures were examined by x-ray diffraction, optical microscopy, and scanning electron microscopy, as well as by electronprobe microanalysis (EPMA), which was done with a JEOL (Japan) Superprobe 733. The compositions of the alloys are given in Table 1 and Fig. 1.

The temperatures for the onset of melting (solidus) were determined by the Pirani-Alterthum method and by differential thermal analysis (DTA). The alloys were annealed for 30 min directly after the measurement of the solidus temperature by the Pirani-Alterthum method (Table 2), cooling rate 150-200 deg/sec. The method of measuring the melting point has been described in detail in [9]. As the annealing temperatures were only 10-40°C below the solidus temperature, the EPMA and x-ray data for them were considered as referring to the solidus.

Fig. 1. Phase diagram for the Cr - Nb - C system in the region of the quasibinary (Cr) + (NbC) eutectic at the alloy melting temperatures. (1) Two-phase specimens; (2) three-phase ones.

Fig. 2. Polythermal section of the phase diagram for the Cr - Nb - C system on the 79 at. % chromium isoconcentrate: 1) DTA data; 2 and 3) thermal effects \( \lambda_1/\lambda_2 \) of transformation respectively on heating and cooling; 4) positions of phase boundaries on the solidus surface (the height of the rectangle represents the temperature measurement error).

The x-ray data (Table 1) imply that all these alloys fall in the two-phase (Cr) + (NbC) region and in the adjacent three-phase ones (Cr) + (NbC) + (NbCr2) and (Cr) + (NbC) + (Cr23C6); as at 1050 and 1350°C [1, 2], the two-phase region is fairly narrow at the solidus temperatures. For example, with 79 at. % Cr, it lies between 8 and 10 at. % C. We located the conodes that adjoin the two-phase (Cr) + (NbC) region with a fair degree of accuracy on the basis of the phase compositions and the EPMA data (Table 3). The niobium content in the phase based on chromium in the two-phase alloys range from