Precipitation-hardening Cr–Ni alloys hardened with Ni₃Nb, Ni₃(A1, Nb), and Ni₃(A1, Ti, Nb) have come into wide use in recent years.

It was found that niobium induces the largest hardening effect, increasing the heat resistance and reducing susceptibility to overaging [1, 2].

Alloying of heat-resistant alloys with niobium increases the resistance to crack formation during welding, improves the deformability of welded joints, and substantially reduces oxidation [3].

Niobium also has a favorable effect on other characteristics, reducing the tendency to zonal segregation [4].

We investigated alloy KhN50MBVYu, now undergoing production tests at the Elektrostal’ Plant. The niobium content was 4.5–6.5% [5, 6]. This amount of niobium lowers the high-temperature plasticity and complicates hot pressing.

Production tests of alloy KhN50MBVYu showed low plasticity in hot working, evidently due to over-alloying. The results of determining the plasticity from impact bending tests at deformation temperatures are shown in Fig. 1. The highest plasticity (5–8 kg-m/cm² at 1000–1050°C) is still low. Because of its high resistance to deformation after heating to 1050°C the alloy cannot be forged, and heating to higher temperatures sharply reduces the plasticity (to 2–4 kg-m/cm²), which excludes the possibility of deformation by existing methods (forging, rolling).

Examination of the microstructure in [5, 6] and in the present work showed phases of M₇M₇, M₆C, and NbC types at high temperatures, in clusters of large needles.

The presence of such structural components leads to embrittlement and lowering of the plasticity at elevated temperatures [7, 8], in connection with which deformation occurs by an intergranular mechanism at high temperatures (above 0.4 Tₘ). To obtain the necessary plasticity the quantity of the alloying element must prevent or reduce the formation of such structural components.

There are no data concerning the effect of alloying elements on the high-temperature plasticity of this type of alloy. It is well known that the chemical composition is one of the main factors in plasticity, particularly at high temperatures. An investigation of the plasticity of heat resistant alloys at hot working temperatures is not only of theoretical but also of practical interest, since highly alloyed heat resistant alloys are used mainly in the wrought condition in modern technology.

We investigated the effect of alloying elements (chromium, tungsten, molybdenum, niobium, iron, aluminum, and zirconium) on the plasticity of alloy KhN50MBVYu at hot working temperatures. The concentration of each element was varied within given limits (Fig. 2): the remaining alloying elements were as follows: 14.5% Cr, 4.5% W, 4.0% Mo, 5.5% Nb, 8.5% Fe, and 1.1% Al.

Fig. 1. Effect of testing temperature on impact strength of alloy KhN50MBVYu as-cast.


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The alloys were melted in a 50 kg induction furnace from fresh charge materials by the technique used for similar alloys. Ingots weighing 45 kg were cast, along with trilobed test pieces. After removal of surface defects, the ingots were forged to bars 45 mm in diameter in four passes.

The forging temperature was 1160°C, and the final forging temperature not below 1000°C.

The plasticity was determined from the results of impact bending tests of Mesnager samples at 1100, 1150, and 1180°C in the cast and forged conditions.

The method of impact bending tests of standard samples with a Mesnager notch is fairly simple at high temperatures, which makes it possible to determine qualitatively the high-temperature plasticity of the alloys in relation to their chemical composition [9]. The plasticity was also determined from the deformability of the ingots in forging.

At testing temperatures of 1100 and 1180°C the variation of the plasticity with the concentration of the alloying element is the same as at 1150°C for both the cast and deformed conditions.

With increasing amounts of each element, with the exception of aluminum, the plasticity decreases sharply (Fig. 2). The sharpest reduction of plasticity results from raising the amount of tungsten, molybdenum, and niobium. Raising the niobium content reduces the plasticity of the deformed metal to a greater extent than the cast metal.

It was found that lowering the concentration of tungsten, molybdenum, and niobium to the lower limit of the concentrations investigated makes it possible to obtain plasticity ensuring deformability of the ingots with no special difficulty and does not lead to softening of the alloy. At the same time, a high concentration of any one of these elements along with moderate concentrations of the other elements sharply reduces the plasticity at high temperatures. It follows from this that to obtain satisfactory deformability of the ingots and high operating characteristics (strength and plasticity at room and elevated temperatures) it is necessary that the concentration of the alloying element be kept within strictly defined limits.

It is useful to analyze the effect of the total concentration of the main alloying elements. For this purpose, alloys were melted with moderate, minimal, and maximum total concentrations of alloying elements. The study was conducted by the same method. Figure 3 shows the variation of the impact bending