Nickel and chromium–nickel stainless maraging steels are being more widely used as structural materials with a high strength ($\sigma_b \geq 140$ kg/mm$^2$) [1, 2].

In manufacturing large forgings and extrusions of maraging steels of the 000Kh11N10M2T type the steel becomes brittle due to precipitations of titanium carbonitrides in austenite grain boundaries during slow cooling.

Titanium carbonitride goes into solution at 1200°C, and precipitation is suppressed by cooling in water [3]. However, heating at high temperatures induces austenite grain growth, leading to reduction of the ductility and toughness of the steel in the fully hardened condition, and therefore a special heat treatment to refine austenite grains is needed after solution of titanium carbonitride.

In maraging steels the austenite grains are not refined in the process of the $\alpha \rightarrow \gamma$ transformation. Refining occurs at higher temperatures due to recrystallization of phase strain hardened austenite.

A heat treatment has been developed for steel 000Kh11N10M2T that makes it possible to obtain, from the original coarse-grained metal, properties close to those of semifinished products of small section with

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**Fig. 1**

Initial stage of migration of the original austenite grain boundaries. Treatment: 1220°C 2 h, water, and 1015°C 30 sec. 200 X.

**Fig. 2**

Effect of heating temperature on $M_s$ after preliminary austenitizing at 1220°C for 2 h with quenching in water.
a low final deformation temperature, fine grains, and fairly high ductility and toughness at temperatures down to −70°C.

In small sections (round and square up to 30 mm) after hot pressing with a low final deformation temperature (≤ 900°C), quenching from 850°C, and aging at 500°C for 2 h, steel 00Kh11N10M2T has the following properties: \( \sigma_b = 145-170 \text{ kg/mm}^2, \sigma_{0.2} = 140-160 \text{ kg/mm}^2, \delta = 8.5-12.5\%, \psi = 45-60\%, \sigma_{a20} = 5.0-9.0 \text{ kg-m/cm}^2, a_n^{70} = 4.5 \text{ kg-m/cm}^2 \) [1].

The studies were made on commercial heats with 0.019% C, 10.8% Cr, 9.85% Ni, 2.13% Mo, and 1.02% Ti.

The samples were prepared from bars with a section of 16 × 16 mm. The preferred austenite grain size after quenching from 1220°C corresponds to zero on the standard scale.

Austenite Grain Size. The steel was heated to 850-1150°C for grain refining.

With single and multiple heating at temperatures below 910°C the grains are not refined. At higher temperatures the shape and size of the grains change by means of migration of the original boundaries. Individual sections of the original boundaries shift at different rates and in different directions. Figure 1 shows the initial stage of migration of the original boundaries after 30 sec at 1015°C. The uneven migration induces the formation of the characteristic "tongues," the cross sections of which on the micrographs resemble inclusions of fine grains within the original large grains.

The motive force of grain boundary migration is rapidly spent. At 1015°C the movement of boundaries ends after approximately 10 min. With further holding up to 3 h there is no change in the shape or size of the grains. After heating once to 920-1050°C for 1 and 3 h sections of the original grain boundaries are retained. Austenitizing must be repeated for development of the migration process. After repeated heating to 980-1025°C the original boundaries disappear and many tongues are formed in separate grains, but large irregular grains are still retained. Heating to higher temperatures leads to even grains with regular faces, although the average grain size is larger than grade 2-3.

Very fine grains (grade 4-5) are obtained after triple austenitizing at 1010 ± 10°C. A change in the heating rate to austenitizing temperature from 30 to 200 deg/sec has no effect on the austenite grain size.

No additional grain refining is induced with holding for 1-3 h before austenitizing at temperatures between \( A_S \) and \( A_f \) (575-720°C).

Retained Austenite and \( M_S \). After austenitizing at 850-1020°C there is almost no retained austenite in steel 00Kh11N10M2T (not over 3%). The austenite is stabilized with holding in the range of \( A_S-A_f \). According to anisometric data, an increase of holding time at 600°C from 1 to 6 h increases the amount of retained austenite from 13 to 30%; holding for 1 h at 625°C stabilizes 34% of the austenite. Heating to higher temperatures in the range of \( A_S-A_f \) decreases the stability of austenite.

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**Fig. 3.** Effect of austenitizing temperature on the mechanical properties of austenite at 350°C after preliminary quenching from 1220°C (2h) in water.

**Fig. 4.** Microstructure of steel 00Kh11N10M2T with stabilized austenite (after water quench from 1220°C, 2 h, and triple austenitizing at 1010°C for 1 h in air). 1500 ×. a) Directly after holding at 600°C for 14 h; b) same + additional hardening from 850°C (1 h) in air.