MARAGING STEELS

THE INFLUENCE OF THE ALLOYING ELEMENTS ON THE PROPERTIES OF STAINLESS MARAGING STEELS AT LOW TEMPERATURE

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In this work* an investigation was made of the influence of the alloying elements on the properties and structure of stainless maraging steels at room and low temperatures. The investigation was made on low carbon steels with 12% Cr and varying contents of nickel, titanium, copper, and molybdenum. The composition of the steel was made more complicated in steps. At the optimum nickel content the influence of titanium, molybdenum, copper, and other alloying elements was studied (Table 1).

All heats contained 0.4–0.5% Mn and Si, 0.020–0.025% S, and 0.015–0.020% P.

The laboratory heats were melted in an open 25 kg induction furnace. The steel was cast in 17 kg ingots. Bars for the samples were forged at 1150–850°C and then hardened in air from 880°C. The samples were then cut from the bars and tempered.

To determine the critical points use was made of a UVD dilatometer with heating of the samples at a rate of 200 deg/h. After cooling to room temperature the samples were further cooled to the temperature of liquid nitrogen. The heating and cooling curves were recorded by a differential method. The quantity of the magnetic phase was determined with an accuracy of ±3% by the magnetic saturation method on a type BU-3 ballistic unit. In studying the character of failure of impact samples use was made of the standard technique for preparing replicas [1]. The replicas were studied on an EM-7 electron microscope.

Nickel (1%) in the investigated concentrations reduces the Ms and Mf temperatures by 50°C (Fig. 1). Increasing the nickel content over 9.6% completely prevents the martensite transformation in cooling to −196°C.

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Fig. 1. The influence of alloying elements on the critical points and the quantity of austenite after hardening.

### TABLE 1

<table>
<thead>
<tr>
<th>Series</th>
<th>Chemical composition, %</th>
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<tbody>
<tr>
<td></td>
<td>C</td>
</tr>
<tr>
<td>Cr—Ni</td>
<td>0.02—0.03</td>
</tr>
<tr>
<td>Cr—Ni—Ti</td>
<td>0.02—0.03</td>
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<tr>
<td>Cr—Ni—Ti—Cu</td>
<td>0.01—0.03</td>
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<tr>
<td>Cr—Ni—Ti—Cu—Mo</td>
<td>0.02—0.03</td>
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Fig. 2. The relationship of phase composition and the hardness of the steels to the temperature of heating in the area of the $\alpha \rightarrow \gamma$ transformation.

The quantity of austenite fixed by hardening increases with an increase in the nickel content (Fig. 1). This occurs as the result of the reduction in the martensite points. Subsequent heating to 500°C does not change the quantity of austenite. Starting with 500°C there is a reverse $\alpha \rightarrow \gamma$ transformation based on the martensite mechanism. The secondary austenite formed at this time is stable and on cooling to room temperature does not transform to martensite. Above 600°C the mechanism of the $\alpha \rightarrow \gamma$ transformation becomes diffusion and the austenite formed on cooling undergoes the $\gamma \rightarrow \alpha$ transformation (Fig. 2). The maximum quantity of austenite is formed in the steel after tempering at 600°C.

The nickel content has a substantial influence on the quantity of austenite obtained in this manner. The quantity of austenite varies over the widest limits with a nickel content of 8.9—9.6%. For example, for 8.9% Ni the quantity of austenite increases by 32% with a change in the temperature of the heating from 500 to 600°C.

The hardness in the investigated chromium—nickel steels depends upon the content of austenite phase (Fig. 2). The minimum hardness corresponds to heating at 600°C, where the maximum quantity of austenite is obtained.

Therefore, changing the quantity of nickel in the steel and the temperature of the heating in the area of the $\alpha \rightarrow \gamma$ transformation it is possible to change the phase composition and, consequently, the properties of the steel.