EFFECT OF RETAINED AUSTENITE ON THE PROPERTIES OF CAST STAINLESS STEELS

V. I. Nikol'skaya, L. M. Pevzner, and N. G. Orekhov

Retained austenite may have different effects on the toughness and other mechanical properties of wrought steels, depending on the composition of the austenite, its morphology, fine structure, and stability, and also on the composition and properties of the surrounding martensite matrix and other factors [1-6]. In some wrought stainless steels retained austenite increases the toughness, particularly at cryogenic temperatures [1-4]. However, no such effect was observed in maraging steels of the N18K9M5T type [5-6].

This work* concerns the possibility of reducing the susceptibility to brittle fracture with retention of high strength (σb ≥ 170 kg/mm²) in cast stainless maraging steel of the Cr–Ni–Co–Mo type by retention of austenite.

The study was conducted on maraging stainless steel melted in a vacuum induction furnace: ≈ 0.03% C, 11-12% Cr, 4-6% Ni, 11-13% Co, 5.5-6.5% Mo.

The amount of martensite was determined after final heat treatment from the saturation magnetization. The saturation magnetization of pure martensite is about 17,000 G for this steel.

Data concerning the effect of austenite obtained by different treatments on the mechanical properties of the steel are given in Table 1.

Heat 1, with a martensitic structure after aging (A < 5%), has high strength (σb = 190 kg/mm²) and ductility, although the toughness and crack sensitivity (αD and K1c) are very low.

The retention of around 30% austenite in the direct martensitic transformation increases the toughness and reduces the tendency to crack (K1c almost doubled). The ultimate strength decreased somewhat, but remained fairly high (over 170/mm²).

*Yu. A. Zhmurina and V. G. Sukhorukov took part in this work.

| Heat No. | Method of obtaining austenite | Heat treatment | σb| kg/mm² | ϕ| % | σ170| kg-m/cm² | αD| mm | K1c| mm²
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</thead>
<tbody>
<tr>
<td>1</td>
<td>—</td>
<td>1150°C 4 h + 1000°C 1 h + 550°C 1 h &lt;3</td>
<td>170</td>
<td>12.5</td>
<td>45</td>
<td>1.5</td>
<td>0.65</td>
<td>0.2</td>
<td>172</td>
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<tr>
<td>2</td>
<td>Thermal stabilization</td>
<td>1150°C 4 h + 1000°C 1 h + cooling to 100°C holding 1.5 min + 550°C 1 h</td>
<td>~20</td>
<td>149</td>
<td>170</td>
<td>12.5</td>
<td>52</td>
<td>8.0</td>
<td>6.9</td>
<td>3.5</td>
<td>317</td>
</tr>
<tr>
<td>3</td>
<td>Reverse transformation</td>
<td>1150°C 4 h + 1000°C 1 h + 550°C 2 h</td>
<td>~20</td>
<td>142</td>
<td>175</td>
<td>11.8</td>
<td>50.5</td>
<td>3.2</td>
<td>1.0</td>
<td>0.5</td>
<td>185</td>
</tr>
<tr>
<td>4</td>
<td>Quenching + cold treatment</td>
<td>1150°C 4h + 1000°C 1h + cold treat at -70°C 2 h + 550°C 1h</td>
<td>~20</td>
<td>155</td>
<td>180</td>
<td>15.5</td>
<td>52</td>
<td>6.9</td>
<td>5.4</td>
<td>3.4</td>
<td>315</td>
</tr>
</tbody>
</table>

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The effect of retained austenite from the direct transformation after thermal stabilization (treatment 2 in Table 1) and after standard quenching and cold treatment (treatment 4, heat 2) on the properties proved to be identical.

With the same amount of austenite (30%) obtained in the reverse $M \rightarrow \gamma$ transformation the properties of heat 1 improve hardly at all. The strength decreases slightly and the toughness increases, while the values of $a_p$ and $K_{IC}$ remain practically the same as for the steel with a martensitic structure (treatment 3).

X-ray analysis of fractures by the method described in [7], physicochemical phase analysis of hardening phases, and transmission electron microscopic analysis led to the following conclusions on the reasons for the difference in the effects of austenite from the direct and reverse transformations.

The positive effect of retained austenite is due not only to its original high ductility but also to an increase in the ductility resulting from the $\gamma \rightarrow M$ transformation, which leads to an increase of the energy absorbed in impact tests by about 500% [6, 8].

Measurements of the amount of austenite in fractures of Cr–Ni–Co–Mo steel showed that with the same original amount of austenite from the reverse transformation and from the direct transformation (~30%) the amount of austenite in the fracture is about 19% in the first case and only 8% in the second case. It follows that austenite from the reverse transformation is more stable. This may be one of the reasons for its small effect.

The positive effect of austenite formed in the reverse transformation may be due also to characteristics of its morphology (interlayers in the boundaries of martensite crystals), with an increase of the proof stress due to enrichment in nickel and chromium [9], and also to the more brittle condition of the martensite matrix, impoverished in nickel and containing large precipitates of brittle R phase [10].

It is technologically complicated to obtain austenite by special stabilizing heat treatment, and it does not ensure uniform properties of cast machine parts. Therefore the magnetic method of checking the melting process (with use of the MKL apparatus) is used to obtain austenite in the steel after standard quenching (or quenching + cold treatment).