EFFECT OF THE DEOXIDIZING TECHNIQUE ON THE PROPERTIES OF LOW-HARDENABILITY STEEL

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Costly chemicothermal treatments to increase the strength and working life of machine parts are being replaced by the progressive method of surface quenching after deep induction heating [1]. However, this method of heat treating parts (gears, for example) requires the use of low-hardenability steel for a combination of high surface hardness and adequate strength and ductility of the core.

As is well known [2], the hardenability of steel, depending on the critical quenching rate, is determined by the composition of the steel, homogeneity of the austenite, the grain size, and the metallurgical procedures used in the production of the steel (particularly the method of deoxidation).

It was found in [3, 4] that by deoxidizing steel without the use of silicon (for example, with aluminum or aluminum and titanium) it is possible to attain specific properties — high ductility in the quenched condition, low susceptibility to cracking during quenching, lower hardenability.

The expediency of using silicon-free deoxidation in the production of low-hardenability steel was noted in [5]. The effectiveness of this technique in melting low-hardenability (PP) steel in open hearth furnaces was confirmed in [6].

The present experiments were conducted with four experimental heats of low-hardenability PP steel with 0.53-0.54% C, which were melted in a basic 20-ton arc furnace and deoxidized by two methods.

<table>
<thead>
<tr>
<th>Composition, %</th>
<th>C</th>
<th>Mn</th>
<th>Si</th>
<th>S</th>
<th>P</th>
<th>Cr</th>
<th>Ni</th>
<th>Cu</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat A</td>
<td>0.54</td>
<td>0.14</td>
<td>0.15</td>
<td>0.027</td>
<td>0.025</td>
<td>0.06</td>
<td>0.13</td>
<td>0.13</td>
</tr>
<tr>
<td>Heat B</td>
<td>0.53</td>
<td>0.18</td>
<td>0.16</td>
<td>0.025</td>
<td>0.024</td>
<td>0.06</td>
<td>0.08</td>
<td>0.12</td>
</tr>
<tr>
<td>Heat C</td>
<td>0.54</td>
<td>0.16</td>
<td>0.16</td>
<td>0.025</td>
<td>0.022</td>
<td>0.10</td>
<td>0.12</td>
<td>0.09</td>
</tr>
</tbody>
</table>

Fig. 1. Hardenability of PP steel deoxidized by methods A (1) and B (2).

Fig. 2. Sulfide inclusions in PP steel of low hardenability (method A). × 600.

In method A, which is used for most steels, the heats were deoxidized in the reducing period with ground coke (2.0 kg/ton) and 75% ferrosilicon (3.0 kg/ton) in the slag along with deoxidation of the metal in the furnace with 45% ferrosilicon (2.0 kg/ton), 28% ferrotitanium (0.98 kg/ton), and lump aluminum (0.57 kg/ton) before pouring.

In method B the silicon content of the metal was limited to 0.08% in the process of diffusion deoxidation of the steel with ground coke and 75% ferrosilicon. Deoxidation in the furnace was conducted with lump aluminum (0.31 kg/ton) and 1–2 min before tapping with 28% ferrotitanium (1.0 kg/ton of liquid steel); the steel was deoxidized in the ladle with lump aluminum (0.30 kg/ton) and 45% ferrosilicon (3.5 kg/ton of liquid steel) [4].

In the first method the steel was deoxidized in the furnace with ferrosilicon, ferrotitanium, and aluminum; in the second method the deoxidation in the furnace was conducted without silicon, using aluminum and ferrotitanium. Silicon, however, was added along with the aluminum in the ladle, when the steel was already deoxidized.

To exclude the effect of the chemical composition of the steel on the hardenability, all the experimental heats had the same chemical composition (see Table 1).

The inherited austenite grain size was grade 5-6 in the heats deoxidized by both methods.

The experimental heats were siphon-cast in square ingots weighing 1100 kg which were rolled in a universal mill to strips 37 × 275 mm in section.

The hardenability of the PP experimental heats was determined by end quenching of cylindrical samples 25 mm in diameter from 820 ± 10°C (GOST 5657-51).

The hardenability was characterized as the hardness at a distance of 3 mm from the quenched end, which according to the technical specifications should not exceed HRC 45.

A procedure giving more precise test results, described below, was used.

After quenching of the samples, two parallel flat bands about 0.5 mm deep were ground on opposite sides along the length of the sample. The HRC hardness under a load of 150 kg was measured on both sides at distances of 1, 2, and 3 mm from the quenched end, and then every 1.5 mm up to a distance of 15 mm from the end. The distances of the first four points from the end were measured with the aid of a magnifying glass with a precision of 0.1 mm. The hardness at each point was taken as the average from tests on two or four sides.

If the measurement of the hardness did not coincide exactly with the distance of 3 mm from the end, then the hardness at this point was determined graphically from the test results at other points.

Hardenability bands were then plotted from the test results for the different heats (Fig. 1).