EFFECT OF EB-WELD AND COLD-ROLLING ON LOW TEMPERATURE STRENGTH AND TOUGHNESS OF AUSTENITIC STAINLESS STEELS

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INTRODUCTION

Austenitic stainless steels are widely used for cryogenic applications as structural materials because of their excellent toughness at low temperature and nonmagnetic property. Recently, the higher strength austenitic stainless steels have been required for the development of superconducting technology. There are several ways to strengthen the austenitic steels, i.e. solution hardening, work hardening and precipitation hardening. Cold-rolling is one of the available methods; it increases particularly the proof stress. However, the structural materials are joined commonly by fusion welding, which brings about the decrease in strength at weld zone. The strengthened base materials are remelted and heat-affected. There are many reports on welding the stainless steels, but few reports about welding the cold-rolled austenitic stainless steels.

The purpose of this study is to estimate the effect of the welding on low temperature strength and toughness of the cold-rolled stainless steels. The experiments were carried out on SUS304L and 316L as candidate materials for cryogenic applications and SUS310S as fully stable austenitic steels.

EXPERIMENTAL PROCEDURE

Materials and welding

The stainless steels used in this investigation were commercial hot-rolled and heat-treated plates of 25mm thick. They were cold-rolled to 20 and 15mm in thickness (20 and 40% in reduction) parallel...
Table 1. Chemical composition of the steels (wt%)

<table>
<thead>
<tr>
<th></th>
<th>C</th>
<th>Si</th>
<th>Mn</th>
<th>P</th>
<th>S</th>
<th>Ni</th>
<th>Cr</th>
<th>Mo</th>
</tr>
</thead>
<tbody>
<tr>
<td>SUS304L</td>
<td>.012</td>
<td>.69</td>
<td>1.69</td>
<td>.034</td>
<td>.026</td>
<td>10.24</td>
<td>18.10</td>
<td></td>
</tr>
<tr>
<td>SUS310S</td>
<td>.07</td>
<td>.77</td>
<td>1.65</td>
<td>.021</td>
<td>.003</td>
<td>19.76</td>
<td>24.50</td>
<td></td>
</tr>
<tr>
<td>SUS316L</td>
<td>.019</td>
<td>.52</td>
<td>.86</td>
<td>.031</td>
<td>.004</td>
<td>12.75</td>
<td>16.55</td>
<td>2.15</td>
</tr>
</tbody>
</table>

...to the hot-rolling direction. The cold-rolled plates were machined to a thickness of 13.3mm. The chemical composition of the steels is given in Table 1.

The bead-on-plate electron beam welding (beam voltage: 50kV, beam current: 170mA, travel speed: 125cm/min) was carried out. The direction of the travel was parallel to that of the rolling. The axes of mechanical test specimens were perpendicular to the direction and the weld bead was located in the center of gauge length in tensile specimen and at the tip of notch in impact one, as shown in Fig. 1.

Test methods

The mechanical tests were made on the base metal specimens and the welded ones at 293K (room temperature), 77K (boiling liquid nitrogen) and 4.2K (boiling liquid helium). The dimensions of tensile specimen were 6.25mm in diameter and 25mm in gauge length. The tensile tests were conducted at a strain rate of $3.3 \times 10^{-4} \text{s}^{-1}$, and 0.2% proof stress, ultimate tensile strength, total elongation and reduction of area were obtained.

The impact tests were performed to evaluate the toughness from the absorbed energy with standard Charpy V-notch specimens (10x10x55mm). The impact tests at liquid helium temperature were achieved using the newly developed method which was described elsewhere.

The measurement of Vickers microhardness number, observation of microstructure, fractography, and X-ray analysis at weld zone were carried out.

EXPERIMENTAL RESULTS AND DISCUSSION

Aspect of weld zone

Photo 1 shows optical microphotographs of the weld zone etched by the nitrohydrochloric acid (50 pct/50 pct nitric acid/hydrochloric acid). In 304L there was no weld defect, but there were observed solidification crackings in 310S and rarely a microscopic hot cracking in heat-affected zone in 316L. The width of weld fusion zone of each steel is about 1mm.

The content of Cr and Ni at the center part of weld fusion