Influence of Initial Residual Stress by the Rolling Process on Welding Distortion of Stiffened Plates

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ABSTRACT
When building ships and assembling marine structures, straightening and reworking steel accounts for approximately 5% of the total manufacturing costs and about 25% of the welding processes. To achieve high productivity, it is essential to minimize cutting and welding deformations. Furthermore, the unevenness of deformation makes straightening difficult. To minimize these problems, stress controlled steel is developed. In this study, the influences of initial residual stress on welding distortion are investigated by comparing stress controlled steel to conventional steel. To clarify this effect, cutting and welding experiments are performed to fabricate a stiffened panel.

KEYWORDS: initial residual stress; dispersion; welding distortion; fillet welding, cutting

INTRODUCTION
During ship and marine construction, welding is extensively used to join stiffeners to plates, a process that often causes deformation. One of the more common welding deformation modes is out-of-plane deformation of plate fields. When this deformation exceeds permissible limits, it must be eliminated by means of a straightening process. However, straightening welding deformations is an expensive and time-consuming process because it is done manually (Itoh, Nakata, Chimura, Serizawa and Murakawa, 2007). Therefore, minimizing welding deformations and their associated straightening costs is required (Mochizuki, Yamasaki, Okano and Toyoda, 2006; Okano, Mochizuki, and Toyoda, 2008).

It has previously been reported that the dispersion of welding distortion is large during construction stages, (Tani, Ueda, Ohe, Miyazaki and Nakashima, 2001). This makes the straightening process more difficult. Reducing this dispersion by predicting potential welding deformation with appropriate accuracy is, therefore, a key to achieving high productivity. One of the factors affecting the welding deformation is residual stress. Because of this, stress-controlled steel, which is manufactured through an improved rolling process, has been developed (Tani, Okada, Ohe and Miyazaki, 2001; Tani, Kobayashi, Ohe, Ueda, Okada and Miyazaki, 2002). In this study, the influences of initial residual stress on welding distortion were investigated by comparing stress-controlled steel with conventional steel. To clarify these influences, a series of experiments were conducted involving the fillet welding of stiffened plates.

EXPERIMENTS AND MEASUREMENTS
Figure 1 shows the two processes used to manufacture the flange panels used for large structures, such as bridges and ships. The first is a cutting process that creates a rib from the skin plate. The second is an attachment process, in which five ribs are welded to the flange plate. After each process, distortion is measured. Although both stress controlled and conventional steels were tested, in this study, the same steel was used for both the ribs and the flanges. The chemical components and the material properties of the steels are shown in Table 1.

Table 1 Chemical composition and mechanical properties of developed and conventional steel.

<table>
<thead>
<tr>
<th></th>
<th>Chemical composition (%)</th>
<th>Mechanical properties (N/mm²)</th>
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<tbody>
<tr>
<td></td>
<td>C</td>
<td>Si</td>
</tr>
<tr>
<td>Stress controlled</td>
<td>0.15</td>
<td>0.38</td>
</tr>
<tr>
<td>Conventional</td>
<td>0.16</td>
<td>0.20</td>
</tr>
</tbody>
</table>

Fig. 1 Method of fabricating flange panel.