ENVIROMENTAL STRENGTH EVALUATION OF WELDED STEEL JOINT IN SEAWATER

PART I : CORROSION FATIGUE CRACK GROWTH BEHAVIOUR FOR HIGH CYCLE

Se-Hi Chung*, Jae-Kyoo Lim** and Eui-Gyun Na***

(Received August 30, 1988)

A study on corrosion fatigue was experimentally conducted for the as-welded and PWHT specimens of the steels, HT80 and SM53B in 3.5% NaCl solution. Submerged arc welding was done. PWHT was carried out at comparatively high temperature of 650°C. Besides, in order to simulate the residual stress in weld HAZ, the stress of 98MPa was applied during PWHT. Corrosion fatigue crack growth was dependent upon the materials and PWHT conditions. In the case of HT80, crack growth in corrosion environment was faster than that in air. However, the crack growth of the main crack for SM53B in 3.5% NaCl solution was decreased in comparison with that in air, unlike HT80. The sensitivity to corrosion environment was reduced due to PWHT. The applied stress in HAZ during PWHT acted to enhance the crack growth compared with that of the PWHT specimen without stress.

Key Words : Post Weld Heat Treatment (PWHT), Heat Affected Zone (HAZ), Corrosion Fatigue, Stress Intensity Factor Range, Crack Growth Rate, Secondary Crack.

1. INTRODUCTION

Post weld heat treatment (PWHT) of the weldments is carried out to remove the triaxial residual stresses and improve the fracture toughness in welds. It is well known that temper embrittlement depends on PWHT conditions, applied stresses during PWHT and microstructure (Lim, 1987). Speidel and Wei (1972) indicated that corrosion fatigue was an important fracture phenomenon for the structures. However, the data of PWHT specimens and the as-welded in corrosive environment are scarce. To establish the design criteria based on the fracture mechanics in designing weldments under the aggressive conditions mechanically and environmentally, it is necessary to evaluate the environmental effect of crack propagation in weld HAZ, and more data are needed.

In this study, the effects of PWHT and stress simulating the residual stress during PWHT in weld HAZ for SM53B and HT80 steels on corrosion fatigue crack growth were evaluated experimentally.

2. EXPERIMENTAL PROCEDURES

The materials used in this experiment were two steels, SM53B and HT80. Table 1 shows the chemical composition and mechanical properties obtained at room temperature. 4mm depth, 60° grooves were machined perpendicular to the rolling direction of the plate, and submerged arc welding was conducted.

Figure 1 represents the locations of specimens which were oriented transverse to the welding direction, and centered on the fusion line. PWHT was done under the following conditions: temperature of 650°C, heating rate of 220°C/hr, holding time of 1/4hr, cooling in furnace. To simulate the residual stress, the stress of 98 MPa was applied to the HAZ during PWHT

Table 1 Chemical compositions, and mechanical properties

(a) Chemical compositions (wt %)

<table>
<thead>
<tr>
<th>SolAI</th>
<th>Ti</th>
<th>Cr</th>
<th>Mo</th>
<th>Ni</th>
<th>Cu</th>
<th>P</th>
<th>S</th>
<th>Mn</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.29</td>
<td>0.20</td>
<td>0.43</td>
<td>0.042</td>
<td>0.005</td>
<td>0.83</td>
<td>0.016</td>
<td>0.46</td>
<td>0.26</td>
<td>0.106</td>
</tr>
<tr>
<td>0.20</td>
<td>0.43</td>
<td>0.042</td>
<td>0.005</td>
<td>0.83</td>
<td>0.26</td>
<td>0.016</td>
<td>0.46</td>
<td>0.042</td>
<td>0.29</td>
</tr>
</tbody>
</table>

(b) Mechanical properties

<table>
<thead>
<tr>
<th>SM53B</th>
<th>HT80</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yield strength (MPa)</td>
<td>413.5</td>
</tr>
<tr>
<td>Tensile strength (MPa)</td>
<td>560.5</td>
</tr>
<tr>
<td>Elongation (%)</td>
<td>27</td>
</tr>
</tbody>
</table>

Fig. 1 Welding plate configuration and extraction of specimen
PWHT. Double edged notches (2mm) located on the fusion line were machined with the cut-off wheel of 0.15mm width as shown in Fig. 2.

The cyclic loading was provided by the out of bending fatigue machine with the cyclic frequency of 30 Hz. The specimens were tested under zero to tension. The applied stress to the center cross section was 196 MPa. When the corrosion fatigue testing was conducted, 3.5% NaCl water solution passed through the acryl cell at a flow rate about 200 ml/min. The measurement of crack growth was performed with the optical microscope (×40).

3. RESULTS AND DISCUSSIONS

Figure 3 and Figure 4 are the semilogarithmic plots of crack growth rate \( (da/dN) \) and stress intensity factor range \( (\Delta K) \) for the as-welded and parent of SM53B as well as HT80 steels in air. The value of \( K \) was calculated using the following equation proposed by Bowie(1967), \( K = 1.005 \sigma a \sqrt{a} \).

Where, \( \sigma \) : applied stress, \( a \) : crack length. Regardless of SM53B and HT80, crack growth rate of the as-welded in air is slower than that of the parent. Kapadia(1987) reported that the compressive residual stress in HAZ resulted in reducing the crack growth rate in comparison with that of the base metal. Figure 5 represents the crack propagation path of the as-welded and the base metal for SM53B. However, the discontinuities of microstructure and irregularities of mechanical properties in HAZ make the crack propagation path complex, so it is reasonable to regard that the reduced crack growth in HAZ is due to the compressive residual stress as well as singularities in welded region.

Figure 6 shows the behaviour of corrosion fatigue crack growth for the as-welded and parent of HT80, including the air data. Crack growth rate of the parent and as-welded in 3.5% NaCl solution is increased in comparison with that in air. Besides, the maximum acceleration factor of \( (da/dN) \) corrosion/ \( (da/dN) \) air for the as-welded is about 2, while that for the parent 1.5. This result can be explained by the following facts. The microstructures of martensite and pearlitic formed at the welded region were very sensitive to corrosion environment. Besides, the microdefects of the welded region in corrosion environment cause to produce the local electric potential difference which promotes the corro-