Effect of High Heat input on CTOD Property of the Thick Steel Plate for Offshore Engineering

Joon Sik Park, Boyoung Jung and Jong Bong Lee

1. Introduction

Fracture toughness of the steel plate is an important factor for the integrity of offshore structures. Among the various parameters for the evaluation of fracture toughness, CTOD has been widely used in the offshore engineering within the welding heat input range of 0.7–4.5 kJ/mm. As a result of CTOD tests, high nitrogen steel containing TiN particle showed HAZ CTOD values over than 0.38 mm at 55 kJ/mm, however the weld metal did not satisfied the required value. The effect of HAZ microstructure was analyzed to explain the superior CTOD properties even under the high heat input condition.

Key words : CTOD, high heat input, electro gas welding

2. Experimental

Chemical composition of two steels for this study was given in Table 1. It is noticeable that steel B contains higher Ti, N and B content. Flux cored arc welding (FCAW), submerged arc welding (SAW) and electro gas welding (EGW) processes were used with the range of heat input from 7 to 55 kJ/mm. Special interest was focused on HAZ CTOD values at the heat input higher than 10 kJ/mm to improve that property.
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CTOD tests were performed in accordance with British standard BS 7448, employing the B × B type specimens at -10°C. Fractured surface and microstructure were observed by the scanning electron microscope and optical one.

3. Results and Discussions

Mechanical properties of the steels are summarized in Table 2 which indicates that they have the similar tensile properties. Both steels are composed of ferrite and pearlite microstructures where the volume fraction of pearlite is larger in steel A since it contains more carbon content. Fig. 2 shows the CTOD test results with the variation of welding heat input for steel A. SCHAZ and CGHAZ were defined based on the API RP 2Z rule. Steel A obtained high CTOD values in SCHAZ over the whole range of heat input from 0.7~4.5 kJ/mm. However, it failed in satisfying the API requirement (0.38 mm) in CGHAZ at the heat input over 4.5 kJ/mm. To find the reason why CTOD values of CGHAZ decreased at the heat

Table 2 Mechanical properties of the steels.

<table>
<thead>
<tr>
<th>Steels</th>
<th>Thickness(mm)</th>
<th>YS(MPa)</th>
<th>TS(MPa)</th>
<th>EL(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel A</td>
<td>80</td>
<td>431</td>
<td>543</td>
<td>28</td>
</tr>
<tr>
<td>Steel B</td>
<td>80</td>
<td>434</td>
<td>533</td>
<td>24</td>
</tr>
</tbody>
</table>

Fig. 1 Microstructures of base metal for steel A and B.

Fig. 2 CTOD test results of steel A with the variation of heat input.
input of 4.5kJ/mm in steel A, microstructural observation was performed at the crack initiation site in the fractured specimen as shown in Fig. 3.

When CTOD value is high (Fig. 3(a)), the crack tip was blunted before the fracture showing the plastic metal flow. However, Fig. 3(b) shows the brittle fracture at crack tip due to the formation of brittle upper bainite which caused the deterioration of CTOD property. Therefore, it was considered that steel A is applicable under the condition of heat input lower than 4.5 kJ/mm in order to satisfy the CTOD requirement.

Fig. 4 shows the CTOD test results at the heat input of 55 kJ/mm for steel B. Since the definitions of SCHAZ and CGHAZ are available at the heat input lower than 4.5 kJ/mm in API RP 2Z rule, the CTOD values were measured from the fusion line with the interval distance of 1 mm.

As shown in Fig. 4, all the CTOD values satisfied API requirement (0.38 mm) in HAZ, but weld metal showed the lower CTOD value of 0.06 mm. Fig. 5 shows the microstructures of EGW welds for steel B at the heat input of 55 kJ/mm. The figure indicates that HAZ microstructure is composed of ferrite and pearlite phases and there is no local brittle zone such as upper bainite. It was known that steel B contained the high nitrogen TiN particles to improve the HAZ microstructure and toughness. Since the prior austenite grain was restricted to the small size by TiN particles even at the high heat input, the hardenability was to be lowered which prevented the formation of brittle phase such as upper bainite. Also, B element is
regarded to be useful in reducing the amount of free nitrogen by the formation of boron nitride, which improves the HAZ toughness. Therefore, steel B containing high nitrogen TiN particles is applicable at the heat input as high as 55 kJ/mm in order to obtain the HAZ CTOD requirement.

However, as shown in Fig. 6, the weld metal contained grain boundary ferrite and upper bainite which are poor in toughness which decreased CTOD value in the weld metal region (Fig. 5). The welding consumables were DWS50GTF and DWS50GTR commercially manufactured by KOBELCO for high efficient EGW welding process. They showed the superior Charpy impact energy at low temperatures, but failed in obtaining proper CTOD values at -10°C. Further study is required to develop the welding consumables for the improvement of CTOD property in weld metal.

4. Conclusions

The effect of high heat input on CTOD properties of the thick steel plate for offshore engineering was investigated. Although the conventional steel just obtained proper HAZ CTOD value under the heat input lower than 4.5 kJ/mm, the high nitrogen steel containing TiN particle showed HAZ CTOD values over than 0.38 mm at 55 kJ/mm restricting the formation of brittle phase such as upper bainite. However, even for the high nitrogen steel, it was difficult to satisfy the required CTOD value for the weld metal. Further study is required to develop the welding consumables for the improvement of CTOD property at high heat input.

5. References

