Development of Covered Electrode with Good CTOD Properties for YS 500 MPa Class High-Strength Steel

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ABSTRACT

Offshore structures have recently been constructed with larger designs and operated in colder and deeper seas to explore energy resources. In this trend, higher strength and higher toughness have been required for the component materials including welding consumables. The authors have studied on improvement of the CTOD properties of weld metal for high strength steel to realize the development target: yield strength ≥ 500 MPa, tensile strength ≥ 610 MPa, and CTOD values at –40 °C ≥ 0.1 mm. This report discusses the influences of some dominant factors (oxygen, Mo and Si content in weld metals) on the toughness of the weld metal for high strength steel. Through this research, an advanced covered electrode has been developed with an optimized chemistry formula as introduced in the following.

KEY WORDS: Covered electrode; CTOD (Crack Tip Opening Displacement); offshore structure.

INTRODUCTION

Oil and natural-gas development in the world is activated lately in tandem with the rise of energy demand; thus, offshore structures are constructed increasingly at a high rate, particularly in Southeast Asian countries, South Korea, and China. In recent years, oil and gas exploration has been expanded to colder and deeper seas in such areas as the North Sea and the waters off the Sakhalin seacoast in particular, in order to secure the amount of mining. Fig. 1 shows the transition of the working water depth for various offshore structures in the past 25 years. As shown in the figure, oil and gas exploration to deeper seas has been progressed rapidly since 1990, and the use of such floating offshore structures as tension leg platform (TLP) and floating production storage and offloading (FPSO) vessel has been increased in the working water depth exceeding 1000 m after the second half of the 1990s.

As energy exploration has been expanded to colder and deeper seas, offshore structures have increasingly been required to be constructed with larger designs and lighter materials; for the weld joints, higher strength and higher toughness are required. For steel plates, the capability of arresting the propagation of a brittle crack (brittle crack arreastability) is expected; for weld metals, the capacity of preventing a brittle fracture is expected and CTOD value is also called for to evaluate the fracture toughness.

In this report, clarified is the effect of each dominant factor (oxygen, Mo and Si content in weld metals) on the fracture toughness of the weld metal for YS 500 MPa class high-strength steels expected to be used extensively. Based on this clarification, the authors have developed an advance shielded metal arc welding (SMAW) electrode dedicated for direct current welding, which offers high toughness and other advanced properties as reported below.

EXPERIMENT

Experimental weld metals containing varied amounts of oxygen, Mo and Si (Table 2) were produced with low hydrogen type SMAW electrodes with tailored coverings. The welding conditions are shown in Table 1, and the groove preparation and pass sequence are shown in Fig. 2.

Table 1 Welding conditions

<table>
<thead>
<tr>
<th>Current (A)</th>
<th>Voltage (V)</th>
<th>Speed (mm/min)</th>
<th>Heat Input (kJ/mm)</th>
<th>Interpass Temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>150</td>
<td>24~26</td>
<td>112</td>
<td>2.0</td>
<td>90~110</td>
</tr>
</tbody>
</table>

Fig. 1 Water depth transition of offshore structures

Fig. 2 Groove preparation and pass sequence