Development of Thick Steel Plates for Shipbuilding Having High Strength and Good Weldability

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ABSTRACT

Thick steel plates having good combination of strength, toughness and weldability have been required for building large container ships. EH36 steel plates with heavy gauge were developed using newly installed accelerated cooling equipment. In order to develop EH40 grade steel, the hardenability of boron were carefully utilized, along with optimizing TMCP processing variables to obtain good mechanical properties and to lessen inhomogeneity in the thickness direction. These thick steel plates showed high strength and good toughness, even at the mid-thickness region, and excellent properties of welded joints at high heat input.

KEY WORDS: Thick steel plate; Boron; Weldability; Thermo-mechanical control process, Inhomogeneity.

INTRODUCTION

The foreign trade between countries has been growing and has been globalized at the very fast pace. This trend has accelerated the need for container ships and in turn the number of container ships has been increasing very fast. Also, the container ships are getting larger in order to enhance the transportation efficiency. In other words, larger container ships could reduce delivery cost per a container, compared to smaller ones. Nowadays, the container ships around 9000~10000 TEU (Twenty feet Equivalent Unit) are being manufactured in the shipyards.

It is well known that the container ship has an open upper deck structure to load as many containers as possible. Its structural characteristics require heavy thickness steel plates having high strength and toughness, such as very thick EH36 or EH40 grade steels. These steel plates are used to construct an upper deck and a hatch coaming. These steel plates also need excellent weldability and welded joint properties which could lead to improvement of productivity in the shipyards by alleviating the restriction on preheating and short bead, and enabling high heat input welding which is around 300 kJ/cm.

Thermo-mechanical control process (TMCP) is effective to achieve high strength and good toughness of thick steel plates, even with low carbon equivalent (Ceq) (Imai, 2002; Toyosada, 2002). Thick steel plates of EH36 and EH40 grades for shipbuilding applications were developed by optimizing chemical compositions and applying TMCP, with the assistance of the newly established MULPIC (multi-purpose interrupt cooling) facility. For the EH40 steel plate, a small amount of boron was added to achieve required strength level, without adding more expensive alloying elements, like Cu and Ni. In the present paper, the basic concept of development and mechanical properties of base metals and welded joints are introduced.

DEVELOPMENT CONCEPTS

Target Properties

Development targets and detailed aiming properties are shown in Table 1. EH36 and EH40 steels were designed to enable high heat input up to 300 kJ/cm. The target properties of strengths and Charpy impact toughness of base plate are in accordance with IACS (International Association of Classification Societies) specification. A combined welding process of FCAW (Flux Cored Arc Welding) and EGW (Electro-Gas Welding) with the maximum heat input around 300 kJ/cm was considered for vertical-up welding of side shell, longitudinal bulk head and hatch coaming in the container ship. Thus, the target for maximum heat input is around 300 kJ/cm. Properties of welded joints also follow IACS specification.

Table 1. Target Properties of developed steels

<table>
<thead>
<tr>
<th>Steel Grade</th>
<th>Base metal properties</th>
<th>Welded joint properties</th>
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<tbody>
<tr>
<td></td>
<td>YS (MPa)</td>
<td>TS (MPa)</td>
</tr>
<tr>
<td>EH36</td>
<td>≥ 355</td>
<td>490~620</td>
</tr>
<tr>
<td>EH40</td>
<td>≥ 390</td>
<td>510~650</td>
</tr>
</tbody>
</table>

*Charpy V-notch specimens are extracted from transverse direction.

Alloy Design

Generally, lowering C and Si contents as well as Ceq is needed to obtain good toughness in the welded joint. Since C and Si contents also