Effect of Microstructure on the Yield Ratio and Strain-aged Low Temperature Toughness of Offshore Structural Steels

Jong Chul-Kim, Byung-Jun Park, Ki-Jung Park, Sung-Doo Hwang, Yong-Chan Suh
Hyundai Steel Company, Technical Research Center
Dangjin-Si, Chungnam, Korea

ABSTRACT

Despite its short business history in heavy plate production which began its first operation 2010, Hyundai Steel has been developing high quality steel plates for offshore applications. Since 2013, the state-of-the-art technology of rolling, HART (Hyundai’s Advanced Rolling Technology), has been applied to produce high strength and extra heavy gauge steel plates for applications such as ship-building, offshore structure and construction. Owing to its capability to exquisitely controlling of hot rolling passes schedule, HART allows the production of high strength, heavy gauge steel plates with refined microstructure compared with conventional TMCP (Thermo-Mechanically Controlled Processed) steel plates. The present study aims at investigating the effects of rolling condition on Charpy impact toughness of SMYS 460-MPa-class offshore structural steel plates in strain-aged condition. The microstructure of the steel fabricated from HART process is compared with the steel manufactured by conventional TMCP process.

KEY WORDS: Strain-Aging; Mean Flow Stress; Recrystallization

INTRODUCTION

In response to the worldwide increase in demand for energy resources, the areas of crude oil drilling and exploration are being extended to cold regions such as Sakhalin and the North Sea (Tomita et al, 1994). In order to secure the lifetime of structures in extreme weather conditions, it is required to use steels with higher strength and better toughness than conventional steels. Meanwhile, pipe products usually used for structural member to support the loads of facilities. Press bending or roll bending are commonly applied to produce pipe products, and these bending process deteriorates the mechanical properties of steel. In particular, the deterioration of toughness has a significant influence on the integrity of structures, and in order to overcome this problem, demand for strain aging properties of steel is increasing (Torizuka et al, 2006). Grain refinement is the most effective way to improve toughness of steels in harsh environments (Tanaka, 1981). Thermo-mechanically control process is generally used for heavy plate rolling where high strength and toughness are required. In 2013, HYUNDAI STEEL developed a state-of-the-art heavy plate rolling process, HART (Hyundai’s Advanced Rolling Technology), that can make finer and more uniform microstructure than conventional TMCP process by delicately controlling rolling pass schedule, rolling temperature, etc. Through this process, it is possible to manufacture high-strength heavy plates with outstanding strain aging impact toughness and applying them to many offshore projects. In this study, the effect of the rolling conditions on the microstructural change and strain aging impact toughness of the SMYS 460-MPa-class offshore structural steel plates manufactured by conventional and HART process.

ALLOY DESIGN

When bending process introduced, cracks are initiated in the most vulnerable parts of the steels such as segregations, inclusions, and porosities. Cracks easily propagate along with the above defects. If the content of impurity atoms such as phosphorous, sulfur, and nitrogen is high, it increases the possibility of internal defects (Furukimi el al, 1990). For this reason, most specification of heavy plate limits the amount of impurity atoms. Moreover, the addition of a large amount of alloy elements such as copper, nickel, chromium, molybdenum for increasing strength also raises carbon equivalent, which, in turns, lowers the toughness and weldability of steels (Kim el al, 2003). Because the usual as-rolled or normalizing process has a limitation in improving toughness of steels due to the high carbon equivalent, TMCP steel is commonly used for manufacturing high strength steels. TMCP is one of the most effective methods that can improve strength and toughness of steels simultaneously through controlled rolling and accelerated cooling while minimizing the addition of alloy elements which is detrimental to toughness and weldability of steels. In this respect, low carbon alloy steel was designed with carbon equivalent (CE) about 0.40%. Table 1 shows the chemical composition of the steel used in the study.

Table 1. Chemical composition of steel used in the study (Wt. %)

<table>
<thead>
<tr>
<th>C</th>
<th>Si</th>
<th>Mn</th>
<th>P</th>
<th>S</th>
<th>Others</th>
<th>Cu, Nb, Ni, Ti</th>
<th>CE</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.08</td>
<td>0.21</td>
<td>1.58</td>
<td>0.011</td>
<td>0.003</td>
<td>Cu, Nb, Ni, Ti</td>
<td>0.40</td>
<td></td>
</tr>
</tbody>
</table>

CE (%) = C + Mn/6 + (Ni + Cu)/15 + (Cr + Mo + V)/5