Evaluation of Tensile Strain Capacity of X80 Line Pipe with CWPT Tests

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ABSTRACT

CWPT (Curved Wide Plate Tensile) and SENT (Single Edge Notched Tensile) tests were carried out to evaluate the TSC (Tensile Strain Capacity) of girth welded X80 line pipes. Two kinds of X80 line pipes were compared, i.e., SBD (Strain-Based Design) and conventional (or non-SBD) X80 line pipes manufactured by POSCO. Round-house type strain-stress curves were obtained from full thickness tensile specimens of SBD X80, while Lüder’s bands were shown in those of non-SBD X80. The overmatch ratio of weld metal to base metal tensile strength were 26% for SBD X80 pipes and 18% for non-SBD X80 pipes. The SBD X80 pipe shows 1~2% higher tensile strain capacity compared with non-SBD X80 pipes where cracking occurred in the HAZ of specimens.

KEY WORDS: X80 line pipe; Tensile strain capacity; Curved wide plate tests; Strain-based design.

INTRODUCTION

With the increasing demand for energy across the globe, resource development has become necessary in hostile environments like polar regions and deep sea areas that were previously considered to have poor economic efficiency and exploitation conditions. Pipelines are the primary means for long-distance transport of crude oil or natural gas collected from the cold locations such as the Arctic coast or Alaska to urban areas. Pipelines must be designed to resist compression and tension that may occur when they pass through seasonally frozen soils or earthquake-prone zones. However, as it is difficult to ensure the economic viability of pipelines in cold locations with the existing Allowable Stress Design (ASD), industrial classification organizations like the Det Norske Veritas (DNV) are considering the Strain-Based Design (SBD), which takes into account plastic deformation after yielding.

In the case of pipelines located in seasonally frozen soils, the soils undergo local heave and settlement due to periodic freezing and thawing, which causes bending moment to be applied to portions of the pipelines. Specifically, the 6 o’clock direction of the girth weld zone is known to be the most likely location of welding defects at the time of on-site pipe welding. When tensile stress is applied to part of such girth welded pipe, the existing CTOD (Crack Tip Opening Displacement) test gives a too conservative evaluation of the tensile strain capacity of pipes due to the different loading mode and crack-tip constraints between the CTOD specimens and the actual pipes. Therefore, the newly designed SENT (Single Edge Notched Tensile) or CWPT (Curved Wide Plate Tensile) tests are now considered alternative test methods. An international standard for the CWPT testing method has yet to be established. However, research has been conducted by R. Denys at the Royal University of Gent, ExxonMobil, JFE, etc. Denys has acquired extensive experience by carrying out Wide Plate Tests from the 1960s through 2000s. His testing methods are summarized in “Fatigue and Fracture Testing of Weldments” of ASTM STP 1058, and “Pipe Girth Joint Testing” of CSM (Denys, 2009). Since 2000, ExxonMobil has performed more than 200 CWPT tests to evaluate the weld zone capacity of line pipes (Fairchild, 2007). Recently, CRES (Dr. Wang), TransCanada Pipelines, C-FER Technologies, etc. have undertaken joint research (Wang, 2006). This study has designed the specimens and conducted CWPT tests by reference to Denys’ test methods and with advice from CRES.

CWPT TESTS of X80 LINEPIPE

X80 Line Pipe Production and Welding

The specifications of the two POSCO-produced API 5L X80 line pipes are shown in Table 1. Each line pipe was produced by the UOE simulator owned by the POSCO Technical Research Laboratory, with GMAW girth welds. For girth welding, LA100 solid wire (1mm) was used. The mechanical capacities of the LA100 solid wire are tensile strength of 780MPa, uniform elongation of 20%, and impact toughness of 160J @ -20°C. Fig. 1 shows the details of welding bevel shape for the two pipes and Fig. 2 exhibits a macro photo of each.

Table 1. Geometry of SBD and non-SBD X80 Line Pipes

<table>
<thead>
<tr>
<th>Pipe/Grade</th>
<th>Thickness</th>
<th>Diameter</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>SBD X80</td>
<td>23.7 mm</td>
<td>48 in</td>
<td>(1219.2 mm)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Thermal coating treatment</td>
<td></td>
</tr>
<tr>
<td>non-SBD X80</td>
<td>25.4 mm</td>
<td>48 in</td>
<td>(1219.2 mm)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Thermal coating treatment</td>
<td></td>
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</tbody>
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