Microstructure and Mechanical Properties of X80/X100 Grade Plates and Pipes

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ABSTRACT
An overview of the manufacturing technology for X80/X100 grade linepipe steel at POSCO was introduced. The microstructure and mechanical properties of X80/X100 steel plates and pipes were analyzed and discussed. Microstructure of plate steel was observed with optical microscope, scanning electron microscope (SEM), transmission electron microscope (TEM), and electron back scattered diffraction (EBSD). Through the UOE simulator, the changes of mechanical properties after pipe forming from plate to pipe were tested and understood. The microstructure of X80 steel was composed of acicular ferrite containing M/A (Martensite/Austenite Constituent) phase. Tested X80 steel plate and pipe were found to have excellent DWTT property. DWTT 85% SATT of X80 steel was about −60°C in plate and −40°C in pipe. In case of X100 steel, bainitic ferrite exhibiting lath and granular type morphology was major phase and M/A existed as second phase. It was shown that the developed X100 steel can be realized to have appropriate properties for UOE pipe. DWTT 85% SATT of the tested 19mm thick X00 steel pipe was below −40°C.

KEY WORDS: Linepipe; API-X80, X100, plate, pipe, UOE Simulator

INTRODUCTION
In order to increase transport efficiency with higher pressure and transmission rate for long distance pipeline, the high grade steel having high strength and excellent low temperature toughness is needed recently. API-X70 grade steel is widely applied and API-X80 grade steel is also used at several projects. Futhermore, many researches and trial productions of X100 and X120 steel are being undergone to develop materials and pipe making, construction, etc. [Petersen et al., 2005; Sanderson et al., 2005]. Many efforts to develop plate and pipe making technology for X80 and X100 steels have been tried in POSCO since 2003 year [Yoo et al. 2004; Kang 2006]. For making high strength linepipe steel plates, POSCO utilized rolling and cooling facilities enabling heavy reduction and fast cooling. In order for customer’s satisfaction, POSCO established Linepipe Steel Application Research Center in which pipe can be produced by UOE simulator and mechanical properties and sour resistance of plate and pipe can be evaluated. UOE simulator having maximum load of 40,000 kN can make pipe of 1 meter length.

In the present paper, microstructure and mechanical properties of X80/100 grade plate and pipe are discussed. Microstructure of plate steel was observed with optical microscope, scanning electron microscope (SEM), transmission electron microscope (TEM), and electron back scattered diffraction (EBSD). Tensile properties of plates and pipes were analyzed and discussed. The changes of mechanical properties after pipe forming from plate to pipe were tested and understood. The microstructure of X80 steel was composed of acicular ferrite containing M/A (Martensite/Austenite Constituent) phase. Tested X80 steel plate and pipe were found to have excellent DWTT property. DWTT 85% SATT of X80 steel was about −60°C in plate and −40°C in pipe. In case of X100 steel, bainitic ferrite exhibiting lath and granular type morphology was major phase and M/A existed as second phase. It was shown that the developed X100 steel can be realized to have appropriate properties for UOE pipe. DWTT 85% SATT of the tested 19mm thick X00 steel pipe was below −40°C.

PRODUCTION OF PLATE
The X80 and X100 steel slabs were manufactured by oxygen converter and continuous cast process. Phosphorus and sulfur contents as impurity were controlled below 100ppm and 10ppm, respectively. Centerline segregation in slab was minimized by applying soft reduction during continuous casting. Table 1 shows typical chemical composition level of X80/X100 steels.

<table>
<thead>
<tr>
<th>Steel</th>
<th>C</th>
<th>Si</th>
<th>Mn</th>
<th>P</th>
<th>S</th>
<th>Others</th>
<th>Ceq</th>
</tr>
</thead>
<tbody>
<tr>
<td>X80</td>
<td>0.05 ~ 0.07</td>
<td>0.25</td>
<td>≤ 1.8</td>
<td>≤0.01</td>
<td>≤0.001</td>
<td>Mo, Ni, Cu, Ti, Nb, V</td>
<td>0.42 ~ 0.44</td>
</tr>
<tr>
<td>X100</td>
<td>0.05 ~ 0.07</td>
<td>0.25</td>
<td>≤ 2.0</td>
<td>≤0.01</td>
<td>≤0.001</td>
<td>Mo, Ni, Cu, Ti, Nb, V</td>
<td>0.46 ~ 0.48</td>
</tr>
</tbody>
</table>

Carbon equivalent value and alloying addition of X80 steel were lower than those of X100 steel, while carbon contents of two steels were in the similar level.

The steel plates of 15~25 mm thickness were manufactured from 250mm thick slab. Thermo-mechanical control process (TMCP)