INVESTIGATION OF EFFECT OF TEXTURE ON COLD RESISTANCE OF NEW GENERATION STEELS FOR BUILDING STRUCTURES

ИССЛЕДОВАНИЕ ВЛИЯНИЯ ТЕКСТУРЫ НА ХЛАДОСТОЙКОСТЬ СТАЛЕЙ НОВОГО ПОКОЛЕНИЯ ДЛЯ СТРОИТЕЛЬНЫХ КОНСТРУКЦИЙ

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Abstract:
Due to technological particularities of low carbon low alloy API 5L X80 steels producing they have strong texture and its inhomogeneity on plate thickness. Charpy impact tests at ambient and negative temperatures and investigation of texture of samples of API 5L X80 steel were performed. By the method of X-ray structural analysis DPF, IPF and ODF were obtained. Texture components and their volume fraction were determined. It was shown that correlation between volume fractions of main texture components, misoriented grains fraction and DBTT exists. As a result analysis of texture parameters allowed characterization of effect of texture on cold resistance of low carbon low alloy API 5L X80 steel.

KEY WORDS: LOW CARBON MICROALLOYED API 5L X80 PIPE STEELS, TEXTURE, MICROSTRUCTURE, IMPACT TOUGHNESS, COLD RESISTANCE.

1. Introduction
At present, the API 5L X80 grade pipe steels are widely used for building structures, thereby reducing the metal and energy consumption [1-3]. This is associated with a unique set of mechanical and processing properties of low carbon microalloyed steels: combination of high strength, plasticity, ductility, weldability, seismic resistance, and fire resistance [4, 5]. Typically building construction units made of sheet >25 mm in thickness are used. In such thick sheets strong structural inhomogeneity can be formed, induced by chemical inhomogeneity, nonuniformity of deformation and temperature over sheet sequence in the rolling process and heat treatment. This structural inhomogeneity leads to inhomogeneity of mechanical properties and anisotropy [6]. One of the factors that affect the mechanical properties and cold resistance of these steels is the texture formed during rolling and transformation [7]. It is believed that the formation of austenite deformation texture components {110} <1-12> leads to the formation of the ferrite texture {332} <113>, which is preferred for achieving high strength and toughness. Austenite recrystallization causes the formation of the texture component {100} <001>, which transforms into the ferrite texture {100} <011>, that is highly undesirable, since it coincides with the cleavage plane of the ferrite [8]. The problem of the impact of a texture on cold resistance and fracture of steels is not still clear. For example, in [9] it was found that the increasing of volume fraction of the {001} <110> components is accompanied by the decrease of DBTT. So this work is devoted to determination of the role of texture in cold resistance of the API 5L X80 grade pipe steels.

2. Preconditions and means for resolving the problem

2.1 Material and procedures
The materials under the study represented API 5L X80 low carbon low alloy steels after thermo-mechanical processing, produced in manufacturing conditions. The chemical compositions of the steels are presented in Table 1. The mechanical properties of the steels are given in Table 2. The samples under the study were cut from pipes of 1420 mm in diameter and 27,7 (steels #1, 3, Table 1) and 33,4 mm (steel #2, Table 1) in wall thickness.
Samples for impact bending tests were cut at a depth of 2 mm from the pipe surface, and the notch was oriented perpendicularly to the rolling direction. To study the effect of structural nonuniformity over the sheet thickness on cold resistance, the samples were also cut from the central region of the pipe wall of the steel #2. Standard V-notch samples of 10x10x55 mm in size were tested with instrumented impact test machine Roell Amsler RKP-450 (Zwick/Roell) at temperatures of +20, -20, -40, -60, -80, -105, -120, -160, and -196°C. The experimental temperature dependence of toughness was approximated by the function $F(T) = A + B \tanh(T - T_0)/C$, where A and B are the half-sum and half-difference of the levels of the upper and lower shelves of serial curves, respectively, $F(T_0) = A$, and the C parameter was determined graphically [21]. The ductile-brittle transition temperature (DBTT) was taken as $T_0$. The texture of the samples was examined with a Rigaku ULTIMA IV X-ray diffractometer. With usage of MoKα radiation by the divergent beam method inverse pole figures (IPF) were obtained and by the parallel beam method in CoKα radiation direct pole figures (DPF) were plotted. For each sample, the XRD patterns were taken from two planes parallel to the rolling plane and located at a depth of 2 mm from the surface and at center of the pipe wall thickness. With help of software ToolBox MTEX 4.0 from DPF orientation distribution functions (ODF) were calculated, volume fractions of main texture components and misoriented constituent were determined.

### Table 3 – DBTT values for the steels under the study

<table>
<thead>
<tr>
<th>#</th>
<th>DBTT, °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-88</td>
</tr>
<tr>
<td>2</td>
<td>-86</td>
</tr>
<tr>
<td>3</td>
<td>-101</td>
</tr>
</tbody>
</table>

Thus plates for pipe production possess strong inhomogeneity of ductility over plate cross section. Because of deformation and cooling nonuniformity over the plate thickness, the texture also differ at different distances from the rolling surface [29]. Analysis of the results showed that texture in studied steels contained two main components (100) and (211). In all the samples, there is a pronounced texture component (100), due to the austenite recrystallization texture. The study showed heterogeneity of texture components over pipe wall thickness. Comparison of obtained DPF showed their strong difference near the surface and in the center of pipe wall.

### Table 4 – DBTT values of steel samples cut from the center and near the surface of the pipe wall

<table>
<thead>
<tr>
<th>Sample</th>
<th>DBTT, °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pipe wall edge</td>
<td>-86</td>
</tr>
<tr>
<td>Pipe wall mid-thickness</td>
<td>-52</td>
</tr>
</tbody>
</table>

2.2 Results and discussion

As a results of Charpy impact tests values of ductile brittle transition temperature for the steels were determined. Steel #3 had maximal DBTT value. Minimal DBTT value was determined for steel #2 (table 3).
It should be noticed that there is main difference in DPF \( \{100\} \) of center and edge of pipe wall. As it is seen from fig. 1 a, d, g, j pronounced texture components were \( \{112\}(110) \) and \( \{111\}(112) \). Investigation of ODF for the steels under the study showed that edge of pipe wall contained as known misoriented constituent (fig.2). It should be reminded that it is just pipe wall edge has lower DBTT.

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\text{Figure 2} - \text{Volume fractions of texture component } \{100\}-\text{sum of components } \{112\}<001>, \{111\}<110>, \{111\}<112>, \{011\}<011>, \{332\}<113>, \{113\} <011> \text{ and misoriented constituent}
\]

Also steel having lower DBTT possesses maximal sum of total component and misoriented constituent. Analysis IPF showed that growth of DBTT was accompanied by increasing of pole density of \( \{100\} \) component and decreasing of \( \{112\} \) texture component.

3. Conclusion

The study showed that the plates for pipe production possess strong inhomogeneity of ductility and texture over the plate thickness. Steels having a low DBTT value were characterized by low pole density of texture components \( \{100\} \) and increased pole density of orientation \( \{211\} \). Also steel with high cold resistance (low DBTT) has maximal sum of total component and misoriented constituent.

4. Literature


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