INVESTIGATION OF ACICULAR FERRITE STRUCTURE IN HOT-ROLLED STEEL INOCULATED BY AL+TI+N

V. Bolshakov\textsuperscript{a}, D. Zotov\textsuperscript{a}, O. Uzlov\textsuperscript{a}, A. Puchikov\textsuperscript{b}

\textsuperscript{a} Pridneprovsk State Academy of Civil Engineering and Architecture, Material Science Department, Chernyshevsky 24-a, 49600 Dniepropetrovsk, Ukraine, oleg.uzlov@gmail.com
\textsuperscript{b} Institute of Ferrous Metals, Starodubova sq. 1, 49050, Dniepropetrovsk, Ukraine, puchikov@ukr.net

Abstract
In current work features of acicular ferrite structure formation in rolled steel (0.18-0.2 % C inoculated by Al+Ti+N system) have been investigated. It has been shown that inoculation of steel by Al+Ti+N leads to acicular ferrite structure formation during bainite transformation at subsequent cooling. Structure and properties of hot-rolled steel with acicular ferrite structure after various tempering processes have been presented. Structural steel inoculated by Al+Ti+N has been shown to possess high complex of strength and ductility properties and could be used in metal constructions and railway freight cars' production.

1. Introduction
As it is well known, Acicular ferrite (or intragranular bainite) structure is far from being organized and can be better described as chaotic. The plates of acicular ferrite nucleate heterogeneously on uniformly dispersed fine non-metallic inclusions and radiate in many different directions from these point nucleation sites. Propagating cracks are then deflected on each encounter with a differently oriented acicular ferrite plate. This gives rise to superior mechanical properties, especially toughness. Inclusions promote intragranular nucleation of acicular ferrite plates and hence improve toughness without comprising strength. But non-metallic inclusions are also responsible for the nucleation of voids during ductile fracture or cleavage cracks during brittle fracture. The inclusions microstructure is particularly important in this respect [1].

As it is known firstly acicular ferrite was observed at arc-weld seam and heat-affected zone (HAZ). Typical bainite transformation at arc-weld deposit occurred at quasi-isothermal conditions. Most of investigators use isothermal treatment to obtain acicular ferrite structure [2]. This approach is difficult to realize in industry practice. Moreover allotriomorphic ferrite net along the austenite grain surfaces can be harmful for mechanical properties.

Most of works, devoted to acicular ferrite properties investigations, have showed increase of both strength and toughness due to interlocking nature of acicular ferrite structure. But some investigators have not found any significant increasing of toughness compared with packet bainite structure [3].

The purpose of the present work is to characterize acicular ferrite nucleation ability of Al-Ti-N alloying system and compare properties of acicular ferrite obtained in a C-Mn-Al-Ti-N steel with properties of other steels with similar alloying system.

2. Experimental Technique
Two 20 ton ingots of low carbon-manganese steel inoculated by Al-Ti-N have been melted in electric furnace. Chemical composition of investigated steels is presented in Table 1.
Table 1. Chemical composition of the investigated steels

<table>
<thead>
<tr>
<th>Steels</th>
<th>Wt. %, Fe-balance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>C  Mn  Si  P  S  Cr  Cu  V  Al  Ti  N</td>
</tr>
<tr>
<td>Steel 1</td>
<td>0.19 0.63 0.28 0.015 0.014 0.18 0.20 - 0.029 0.003 0.019</td>
</tr>
<tr>
<td>Steel 2</td>
<td>0.20 0.71 0.3 0.016 0.010 0.22 0.18 - 0.028 0.016 0.018</td>
</tr>
<tr>
<td>Steel 3</td>
<td>0.17 0.50 0.25 0.018 0.009 0.18 0.15 - 0.034 0.001 0.007</td>
</tr>
</tbody>
</table>

Ingots have been rolled into 60 mm square semi-finished product and then specimens with thickness up to 12 mm have been cut off. Specimens were cut along as well as across the direction of rolling. Specimens were subjected to austenitizing at 1000–1150°C for 30 minutes, and then cooled to room temperature in oil. Treatment parameters were based on results of previous work [4]. The impact tests with U-notch specimens machined in accordance with standards have been made over the temperature range from +20°C to –80°C in order to determine impact toughness of the steels with acicular ferrite structure. Specimens of 10 mm in gauge diameter and 80 mm in gauge length have been used to determine the tensile properties. The microstructures of the specimens have been examined by optical microscopy after polished and etched in 4% Nital. SEM investigations have been made using Jeol 840A LGS scanning electron microscope.

3. Results and Discussion
Size of austenite grain depending on austenitizing temperature is presented at Fig. 1.

As it is shown at Fig. 1 increasing of austenitizing temperature leads to austenite grain growth. It should be mentioned that inoculation of steel by Al+Ti+N (Steel 1 and Steel 2) leads to decreasing of grain grow rate. Steel 1 and Steel 2 have smaller austenite grain compared to Steel 3 (Steel 3 has similar chemical composition but not inoculated by Al+Ti+N). It corresponds with other investigations (Fig. 3, Fig. 4)
Content of acicular ferrite depending on austenitizing temperature has been measured. As it is shown at Fig. 5 maximum of acicular ferrite content is at 1150 °C.

Decreasing of acicular ferrite content higher of 1150 °C can be explained by dissolution of non metallic inclusions (especially AlN). The dissolution process starts at temperature range...
higher than 1150 °C [5]. It should be mentioned that no significant distinction in acicular ferrite content in Steel 1 and Steel 2 at same reheating temperature has been found.

4. Conclusions
As it has been established inoculation of structural steel by Al+Ti+N composition leads to formation acicular ferrite structure under continuous bainitic transformation. Reheating temperature has significant effect on acicular ferrite content. Maximal acicular ferrite content has been observed at reheating temperature of 1150 °C.

Bibliography