RESISTANCE TO BRITTLE FRACTURE OF LOW CARBON ABRASION RESISTANT STEELS

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1. Introduction

Today, low carbon steels produced by using advanced technology of manufacturing, achieve very good mechanical properties together with reasonable price. Especially more and more popular become steels with boron which are belonged to group of abrasion resistant steels. Applying of these steels can extend the lifetime of expensive machining construction in many industries such as mining, auto industry, agriculture industry [1]. High values of mechanical strength and abrasion resistant is achieved after heat treatment, it means hardening and tempering. However, these steels are supplied by the manufacturers in different states (often not covering the heat treatment), as suggested by the customer tailored to its needs. In this article two grades of steels B27 and 28MCB5 manufactured by two well known in Europe companies – Rautaruukki Corporation (Finland) [2] and Zerneri Acciai Company (Italy) [3] were examined. Impact strength of the steels at different temperatures and with three different states (delivered state and after typical heat treatment normalization, hardening and tempering at 200 °C) was investigated and fractographic analysis was carried out.

2. Material investigated

Chemical composition of the two grades of boron steels B27 and 28MCB5 given by the manufactures is presented in Table 1.

<table>
<thead>
<tr>
<th>Grade of steel</th>
<th>C</th>
<th>Mn</th>
<th>Si</th>
<th>Cr</th>
<th>P</th>
<th>S</th>
<th>B</th>
</tr>
</thead>
<tbody>
<tr>
<td>B27</td>
<td>0.27</td>
<td>1.2</td>
<td>0.25</td>
<td>0.3</td>
<td>*</td>
<td>*</td>
<td>0.02</td>
</tr>
<tr>
<td>28MCB5</td>
<td>0.25-0.30</td>
<td>1.0-1.30</td>
<td>0.15-0.33</td>
<td>0.25-0.70</td>
<td>0.019</td>
<td>0.020</td>
<td>0.0011-0.01</td>
</tr>
</tbody>
</table>

AI and/or Ti are used as micro alloying elements for binding of nitrogen.

*not been included by producers

| Tab. 1: Chemical composition steels tested |

Heat treatment of tested steels was provided at Institute of Material Science and Applied Mechanic Wroclaw University of Technology. Some structures of the examined steels are showed in Figures 1 and 2. Structure in delivery state of B27 is characterized by band distribution of ferrite and pearlite. In grade 28MCB5 pearlite colonies are surrounded by ferrite precipitates. Normalized structures of both steels are similar with band distribution of ferrite and pearlite. Structures after hardening and tempering consist of martensite tempered.

Fig. 1. B27, hardened and tempered state, etched with Mi1Fe. Light microscopy.

Fig. 2. 28MCB5, hardened and tempered state, etched with Mi1Fe. Light microscopy.

3. Results of examination and analyses

3.1 Results of impact test

Impact strength of tested steels were provided by using standard Charpy – V notch impact strength. Steels were examined at temperature from 20 to -40 °C - characteristic work temperature for most devices. Average values impact strength measured, in three analyzed states, are presented in Table 2.

<table>
<thead>
<tr>
<th>Grade of steel</th>
<th>As delivered</th>
<th>After normalization</th>
<th>After hardening and low tempering</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>20</td>
<td>-20</td>
<td>0</td>
</tr>
<tr>
<td>B27</td>
<td>35</td>
<td>25</td>
<td>15</td>
</tr>
<tr>
<td>28MCB5</td>
<td>30</td>
<td>20</td>
<td>10</td>
</tr>
</tbody>
</table>

Tab. 2. Average values of toughness steels tested at temperature range of 20 - -40 °C

A common criterion of transition from ductile to brittle fracture is the adoption of some arbitrary value of the impact strength. Often for structural steels it is amount equal to 35 J/cm². Such defined ductile to brittle transition is present, in the analyzed steels B27 and also 28MCB5, in delivered state above 0°C. After normalization it is observed at temperatures about 0 °C. Only the state after hardening and tempering shows it at -20 °C,
and even for the steel grade B27 less than -40 °C.

3.2 Results of fractographic analyses

Another way to determine the temperature of ductile to brittle transition is a direct analysis of the fracture nature. It is assumed that the criterion of impact corresponds to the occurrence the mid-brittle and mid-ductile fracture. Analysis of the fractures shows the differences in the assessment of the fragility according to these two criteria. Impact strength at 20 °C, in all states, is higher than the mentioned criteria. Participation brittle fracture, however, far exceeds the value of 50% in delivered state and is at 20 °C 72% for steel B27 and 61% for steel 28MCB5. At 0 °C, participation brittle fracture exceeds 80%.

In normalized state, when the values of impact strength are higher, surfaces of brittle fracture exceed 50% for steel B27 and 40% for steel 28MCB5 at room temperature (but at 0 °C exceed 75%). In this case transition from ductile to brittle fracture takes place at temperatures similar or higher than 20 °C. Ductile narrow zone under mechanical notch, (Fig. 3 and 4), provides a low resistance of steel to initiation of brittle fracture.

Different fracture is provided in tested steels after hardening and tempering.

At temperature 20 °C, the middle zone of steel B27 (Fig. 5) presents ductile-cleavage character of fracture. A similar kind of grade occurs in the steel 28MCB5 (Fig. 6).

Fracture surfaces of both steel is not changed dramatically at lower temperatures. Significant ductile side zone is continued and in addition, the central zone still retains significant share of the ductile fracture (Fig. 7 and 8). Occurring in this zone facets are plastically deformed. It provides the relatively high impact strength at low temperatures.

4. Summary

Analyzed low carbon steel with boron are in the group of abrasion resistant steels, but manufacturers make them available after various treatments. These steels containing different structures, characterized by different impact strength and different transition from ductile to brittle fracture which in many applications is essential. Analysis of steels in the state of delivery and after normalization shows that transition from ductile to brittle fracture already occurs at room temperatures. Although values of impact strength of the former steels at 20 °C are relatively high, mainly brittle character of fracture is occurred. Other properties are showed by the test steels in the hardened and tempered condition. Ductile to brittle transition takes place at much lower temperature. The steels after hardening and tempering present relatively high impact strength to temperatures about -40 °C (average value of impact strength 28MCB5 at -40 °C is slightly lower). Kind of fracture is also different from previous states. Central zone contains many ductile areas. This affects to relatively high values of impact strength of these steels.

5. References

[2] Rautaruukki Corporation, P.O. Box 138, FI-00811 Helsinki, Finland.