DEGRADATION OF MECHANICAL PROPERTIES AFTER WELDING OF HIGH STRENGTH STEEL ARMOX 500

Peter LIPTÁK, Igor BARÉNYI, Ondrej HÍREŠ

Abstract: The Armox steels by SSAB Oxelosund are the most known and most widely used armored plates in European area. Secondary processing of these steels is generally problematic. The paper deal with research of ARMOX 500 steel and its behaviour during welding and consequential change of microstructure and then mechanical properties as is strength. The main topics are to determine the level of degradation and its reason.

Keywords: High strength armoured steels, ARMOX, welding, hardness, toughness, tensile strength, thermo – mechanical processing.

1 INTRODUCTION

ARMOX 500 is the steel form group of high strength armoured steel by Swedish company SSAB Oxelosund. These steels have high strength, hardness and good toughness acquired by application of thermo-mechanical treatment (TMT).

Armox 500 steel has good weldability according to the chemical composition because of its carbon equivalent is relative low (0.65).

\[ CEV = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Cu + Ni}{15} \text{[\%]} \]  

(1)

However, there is a problematic factor also at welding of Armox 500 and other steels of this type. The heat generated during welding process minimalizes the TMT effect and the decrease of mechanical properties level occurs.

The producer recommends to not exceeding the temperature circa 200°C during their secondary processing as is welding. The high temperatures occurring during welding process lead to uncontrolled temperation and then to the degradation of mechanical properties level. Submitted paper study the level of the degradation of mechanical properties during welding process of Armox 500 steel.

2 MATERIAL AND METHODS

Armox 500 steel was used for all experiments. Its basic characteristics including chemical composition and mechanical properties are shown in the Table 1.

Table 1 Chemical composition and mechanical properties of ARMOX 500 [1]

<table>
<thead>
<tr>
<th>Chemical composition [wt. %]</th>
<th>C</th>
<th>Si [0.1-0.4]</th>
<th>Mn</th>
<th>P</th>
<th>S</th>
<th>Cr</th>
<th>Ni</th>
<th>Mo</th>
<th>B</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.32</td>
<td></td>
<td>1.2</td>
<td>0.015</td>
<td>0.010</td>
<td>1.0</td>
<td>1.8</td>
<td>0.7</td>
<td>0.005</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Mechanical properties</th>
<th>Tensile strength (R_m) [MPa]</th>
<th>Yield strength (R_{y0.2}) [MPa]</th>
<th>Impact energy (KU[J])</th>
<th>Hardness (HBW)</th>
<th>Elongation (As[%])</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1450 - 1750</td>
<td>min. 1250</td>
<td>480 - 540</td>
<td>8</td>
<td></td>
</tr>
</tbody>
</table>

Fig. 1 Experimental sample (a=4 mm, b=10 mm, \(L_d=40 \text{ mm}\)
The experimental samples were produced from the steel by using of unconventional cutting methods like laser, plasma and water jet cutting. Selection of cutting technology was secondary experimental topic. The influence of cutting method selection on the basic ARMOX material is described in [2].

Two groups of experimental samples were made. There were samples without weld joint in the first one (basic material only). The second one consisted of samples with weld joint. Welded joint is situated in the middle of the weldment in compliance with STN EN 895 (Fig. 1). The shape of experimental samples with and without weld joint is designed according to STN EN ISO 6892 – 1 standard.

Experimental specimens of second group were welded by using Metal active gas method (MAG). ThermaX X were used as a welding consumable (18 Cr/8 Ni). Protect atmosphere consisted of 80 % Ar and 20 % CO2.

3 EXPERIMENTAL RESULTS

All experimental samples were examined by tensile strength test (STN EN ISO 6892-1). Testing device Instron 5500R with automatic evaluation of mechanical characteristics (Tensile and Yield strength) was used. Results of tensile strength test are presented in Table 2. The results from every presented alternative are average of ten measurements.

<table>
<thead>
<tr>
<th>Group</th>
<th>Type of Armox steel</th>
<th>Cutting method</th>
<th>Yield strength $R_{p0.2}$ [MPa]</th>
<th>Tensile strength $R_m$ [MPa]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 without WJ</td>
<td>500 T</td>
<td>Plazma</td>
<td>1359,60</td>
<td>1539,90</td>
</tr>
<tr>
<td></td>
<td>500 T</td>
<td>Laser</td>
<td>1392,68</td>
<td>1579,15</td>
</tr>
<tr>
<td></td>
<td>500 T</td>
<td>Water jet</td>
<td>1422,09</td>
<td>1614,32</td>
</tr>
<tr>
<td>2 With WJ</td>
<td>500 T weldment</td>
<td>Plazma</td>
<td>593,82</td>
<td>614,65</td>
</tr>
<tr>
<td></td>
<td>500 T weldment</td>
<td>Laser</td>
<td>818</td>
<td>837,35</td>
</tr>
<tr>
<td></td>
<td>500 T weldment</td>
<td>Water jet</td>
<td>750,56</td>
<td>772,60</td>
</tr>
</tbody>
</table>

Fig. 2 ARMOX 500 - Yield strength of basic and welded material
Comparisons of all variants between weld and basic materials bring those results: Yield strength (R\(_{p0,2}\)) decreases about 44 % in the case of plasma cutting, about 42 % in the case of laser cutting and about 45 % in the case of water jet cutting. Decreases are almost equal; therefore cutting method has no influence on the yield strength level.

The highest decrease of tensile strength (R\(_m\)) indicates the alternative with plasma cutting, where the decrease is about 60 %. The decrease is about 47 % in the case of laser cutting and about 52 % in the case of water jet cutting. Significant decrease of R\(_m\) at variant with plasma cutting means that affection by heat is so high to appear even after welding application (in contrast to other two cutting technologies).

4 INFLUENCE ON MICROSTRUCTURE

The main reason of degradation of mechanical properties during ARMOX 500 steel welding are changes in microstructure. The original (un-affected) microstructure is shown on Fig. 4 and it consists of very fine-grained heterogeneous martensitic structure obtained as a result of thermo – mechanical treatment. This structure provides all good features of Armox steel as are high strength, hardness and good toughness.
The microstructure of heat-affected zone (HAZ) is absolutely different in comparison to microstructure of basic material. There is shown the microstructure of HAZ area close to welding metal. It consists of very coarse martensitic needles (Fig. 5).

The needles became finest sequentially in areas farther from weld metal, but structure still remains relative coarse (Fig. 6). Too much martensitic elements and especially big coarse martensitic needle leaves HAZ area of steel brittle. The degradation effect is bigger because of un-wanted change of microstructure specifically obtained by thermo-mechanical processing in this case.

5 CONCLUSIONS

Decrease of both mechanical properties (Rm and Rp0.2) is obvious at welding joints. The weld metal is the weakest place of welding joint where all of experimental specimens is broken. The level of decrease is in relation to the used welding consumable properties.

The study of microstructure of heat-affected zone brings detailed information about affection of ARMOX steels by welding process. Heat affection changes very fine-grained martensitic microstructure obtained by thermo-mechanical treatment to worse one, mostly consisted of coarse martensitic structure.

The subject of experiments was Armox 500 steel, but we can await similar behaviour during welding at all steels from Armox and Hardox groups. Therefore is very important to mind that behaviour in all cases of secondary processing of described steels based on heat transfer as are welding, cutting etc. Ignoring of the over tempering effect may lead to critical components failure and threat of safety. Armox steels are applied as mobile army containers for mobile hospitals or maintenance centers.
References


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