METALLURGICAL ASPECTS OF WELDABILITY OF MULTIPHASE STEELS FOR AUTOMOTIVE INDUSTRY

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Abstract:
This paper presents some of technical aspects of the twin-spot laser welding of multiphase steels for automotive industry. The dual beam was obtained using a special optical system that divides a laser beam. The investigation was carried out in two main areas of welds, which are fusion and heat affected zones. The results show that in case of analyzed steels the use of twin-spot laser welding leads to changes in martensite morphology compared to single spot laser welding in both zones. The defragmented morphology suggests that tempering-like processes occur during the welding. This phenomenon causes the decrease in weld hardness compared to single spot laser welding.

1. INTRODUCTION

The automotive industry places very high requirements on safety and mass reduction of the car body construction. The mass reduction is related to decrease of petrol consumption that leads to lower amount of pollution created by cars. To fulfil these requirements it is necessary to use multiphase steels of high strength. These steels allow manufacturing of the thin-wall elements that decrease the total mass of car body and at the same time fulfil safety requirements [1-3]. The most important feature of the multiphase steels is their microstructure that brings a high work strengthening potential. In the case of a car body manufacturing, the joining of elements requires welding methods. One of the commonly used joining methods is laser welding. During the laser welding the initial microstructure is destroyed (melting of material and crystallization into new phases) [4-6]. This destruction leads to increase in hardness of weld compared to a base material. The difference of hardness may lead to fracture of construction elements near the weld. To decrease the difference of hardness between the base material and a weld a twin-spot laser welding method may be used [7-9]. The twin-spot laser welding allows decrease of the weld hardness by increasing the cooling time (two laser beams) [10]. There are two methods for obtaining two laser spots. In the first method two different laser heads are combined, whereas the second method uses the special optical system [7]. The twin-spot laser welding is the method used in the case of welding of aluminum and titanium alloys, coated steels and advanced high strength steels, because of its positive effect on mechanical properties of the weld [11-13].

2. EXPERIMENTAL

The twin-spot laser welding is characterized by complex thermal cycles that may be changed in a wide range. The most important parameters that influence the thermal cycle are: distance between laser beams, power distribution between beams, linear energy and the position of the weld pools. All the parameters that influence the thermal cycle are presented in Fig. 1. Using all these parameters it is possible to obtain various properties of welded steels. This work presents some results of the twin-spot laser welding of advanced high strength steels. The chemical composition of analyzed steels is presented in Tab. 1. The welding tests were carried...
out using a robotic system for laser processing in Welding Institute in Gliwice (Poland). The laboratory satisfies the requirements of most advanced rigs and is equipped with the TruDisk 12002 – a Yb:YAG solid-state laser (Trumpf) with the maximum power of 12 kW. The two beams were obtained by a special optical system (the D70 head) that includes special optical lens which enable dividing the laser beam. The welding parameters for each steel are presented in Tab. 2.

![Diagram of weld pools](image1)

**Fig. 1** Schematic presentation of parameters that influence the thermal cycles of twin-spot laser welding

**Table 1.** Chemical composition of analyzed steels

<table>
<thead>
<tr>
<th>Steel</th>
<th>Elements</th>
<th>C</th>
<th>Mn</th>
<th>Si</th>
<th>Al</th>
<th>Ti</th>
<th>Nb</th>
<th>Cr</th>
<th>Mo</th>
<th>Cₚ</th>
</tr>
</thead>
<tbody>
<tr>
<td>DP</td>
<td>[wt.%]</td>
<td>0.13</td>
<td>1.50</td>
<td>0.20</td>
<td>0.04</td>
<td>-</td>
<td>0.015</td>
<td>-</td>
<td>-</td>
<td>0.22</td>
</tr>
<tr>
<td>CP</td>
<td></td>
<td>0.08</td>
<td>1.72</td>
<td>0.56</td>
<td>0.29</td>
<td>0.125</td>
<td>0.005</td>
<td>0.34</td>
<td>0.016</td>
<td>0.46</td>
</tr>
<tr>
<td>TRIP</td>
<td></td>
<td>0.24</td>
<td>1.55</td>
<td>0.87</td>
<td>0.40</td>
<td>0.023</td>
<td>0.028</td>
<td>-</td>
<td>-</td>
<td>0.54</td>
</tr>
</tbody>
</table>
Table 2. Welding parameters of each steel sheet

<table>
<thead>
<tr>
<th>Steel</th>
<th>Beam power [kW]</th>
<th>Power distribution [%]</th>
<th>Linear energy [kJ/mm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>DP</td>
<td>6</td>
<td>50:50</td>
<td>0.048</td>
</tr>
<tr>
<td>CP</td>
<td>6</td>
<td>50:50</td>
<td>0.048</td>
</tr>
<tr>
<td>TRIP</td>
<td>6</td>
<td>50:50</td>
<td>0.048</td>
</tr>
</tbody>
</table>

Fig. 2 Microstructure of fusion zone for investigated steels; RA - retained austenite, MA - martensitic-austenitic islands

After the laser welding the microstructure investigation was carried out. The samples were prepared by grinding on abrasive papers (80, 320, 1000 and 2500) and polishing (diamond and corundum slurry). The microstructure of specimens was revealed by etching in 3% Nital and then in aqueous solution of sodium pyrosulphate for retained austenite observation. The microstructure investigations were performed using MeF4 light microscope (Leica).

3. RESULTS AND DISCUSSION

The microstructure investigations were carried out in both fusion and heat affected zones. The microstructures of the fusion zone for DP, CP and TRIP steels are presented in Fig. 2.

The microstructure of the fusion zone for dual phase steel is composed of lath martensite. In the case of complex phase steels the microstructure is composed of the low-carbon lath martensite and small fraction of retained austenite in shape of thin-films between martensite laths. The morphology of this lath martensite is defragmented (Fig. 2d) what indicates that tempering-like processes could take place during the welding. The microstructure of the fusion zone of the TRIP steel was composed of the lath martensite with some fraction of blocky martensite and retained austenite. In this case the defragmentation of martensite can be seen as well. The retained austenite was presented as films [14]. Additionally, the fusion zone of the TRIP steel
includes harmful non-metallic inclusions because of the highest amount of alloying elements with the high affinity to oxygen. Recently, Grajc et al. [14] investigated the non-metallic inclusions in this steel. They found out that there are large and small non-metallic inclusions of globular shape. Depending on their size, the particles contain Al, Si and Mn (large size) or just Al (small size). The total amount of the alloying elements for each steel is presented in Tab. 3. Figure 3 presents the microstructure of the heat affected zone for each steel. The microstructure of the heat affected zone of dual phase steel is composed of the fine-grained martensitic-bainitic mixture with small fraction of retained austenite. Similar situation occurs in the case of complex phase steel. The morphology of the martensite shows that tempering-like processes could occur in the case of HAZ, as well (Fig. 3d). The microstructure of the TRIP steel is composed of the fine-grained martensitic-bainitic mixture. Unlike in the fusion zone, the morphology is mainly lath-like. The retained austenite is embedded in the microstructure of the heat affected zone in shape of thin films between martensitic and bainitic laths [14]. The HAZ of all steels is free of non-metallic inclusions.

### Table 3. Sum of alloying elements with the high affinity to oxygen for each steel

<table>
<thead>
<tr>
<th>Steel</th>
<th>Elements [wt.%]</th>
<th>Mn</th>
<th>Si</th>
<th>Al</th>
<th>Total content</th>
</tr>
</thead>
<tbody>
<tr>
<td>DP</td>
<td></td>
<td>1.50</td>
<td>0.20</td>
<td>0.04</td>
<td>1.74</td>
</tr>
<tr>
<td>CP</td>
<td></td>
<td>1.72</td>
<td>0.56</td>
<td>0.29</td>
<td>2.57</td>
</tr>
<tr>
<td>TRIP</td>
<td></td>
<td>1.55</td>
<td>0.87</td>
<td>0.40</td>
<td>2.82</td>
</tr>
</tbody>
</table>

![a) dual phase steel](image1)

![b) complex phase steel](image2)

![c) TRIP steel](image3)

![d) SEM photo of CP steel](image4)

**4. CONCLUSION**

The use of the twin-spot laser welding increases the cooling time of welded material, what affects positively the microstructure and mechanical properties of the welded joints. The FZ and HAZ martensitic microstructures of the dual phase, complex phase and TRIP steels show the effects of tempering-like processes caused by the second
beam. This phenomenon decreases the hardness of welds and, finally, it prevents cracking during exploitation. The martensite of the HAZ is more fine-grained and blocky-like compared to the tempered martensite occurring in the fusion zone. The FZ of TRIP steel includes complex and pure non-metallic inclusions due to the highest amount of elements with the high affinity to oxygen.

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REFERENCES


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