ANALYSIS OF STAINLESS STEEL WELDED JOINTS

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Abstract
In this article there are presented the results of the analysis of the quality of the welding joints used for the production of the some parts of the harvester. Tinplates from the low carbon steel are used for production, but increasingly stainless types of the steel are used.

In experimental part was evaluated quality of the butt welds prepared by method 135 with combination of S355 J2 EN10025 and X5CrNi18-10 EN 10088 using light microscopy. Quality of the welds was also tested on the fillet weld of steel tinplates EN 10188 X5CrNi18-10 made by fluctuating welding with method 135. Besides metallographic analysis microhardness was accounted on the vertical sections of the welds.

Key words: weld, microstructure, quality

Weldability Austenitic Stainless Steels
This is by far the largest and most important group in the stainless steel range. These steels, which exhibit a high level of weldability, are available in a wide range of compositions such as the 19/9 AISI 304 types, 25/20 AISI 310 types and 19/12/2 AISI 316 types, which are used for general stainless steel fabrications, elevated temperature applications and resistance to pitting corrosion respectively.

As the name implies, the microstructure of austenitic stainless steel consists entirely of fine grains of austenite in the wrought condition. When subjected to welding, however, a secondary ferrite phase is formed on the austenite grain boundaries, in the heat affected zone and in the weld metal. The extent of the formation of this secondary phase is dependent on the composition of the steel or filler material and the heat input during welding.

While delta ferrite formation can have negative effects on the resistance to corrosion and formation of sigma phase at operating temperatures between 500°C and 900°C, delta ferrite in weld metal is necessary to overcome the possibility of hot cracking.

In general, austenitic welding consumables deposit a weldment containing 4 - 12% delta ferrite. For special applications, i.e. when dissimilar steels are welded under conditions of high restraint, austenitic consumables having weld metal delta ferrite contents as high as 40%, may be required. The delta ferrite can be calculated using the procedure given at the end of this section with the aid of the Schaeffler diagram.

The carbon content of austenitic stainless steels is kept at very low levels to overcome any possibility of carbide precipitation, where chromium combines with available carbon in the vicinity of the grain boundaries to produce an area depleted in chromium, which thus becomes susceptible to intergranular corrosion.

The titanium and niobium stabilised AISI 321 and 347 steels together with ELC (extra low

1. Introduction

Stainless steels is a group of high alloy steels, which contain at least 12% chromium. In general, these steels are alloyed with a number of other elements which make them resistant to a variety of different environments. In addition, these elements modify the microstructure of the alloy which in turn has a distinct influence on their mechanical properties and weldability [1].

Stainless steels can be broadly classified into five groups as detailed below [1]:

- Austenitic stainless steels which contain 12 - 27% chromium and 7 - 25% nickel,
- Ferritic stainless steels which contain 12 - 30% chromium with a carbon content below 0,1%
- Martensitic stainless steels which have a chromium content of between 12 and 18% with 0,15 - 0,30% carbon
- Ferritic-austenitic stainless steels which contain 18 - 25% chromium, 3 - 5% nickel and up to 3% molybdenum
- Martensitic-austenitic steels which have 13 - 16% chromium, 5 - 6% nickel and 1 - 2% molybdenum. The first four of these groups will be discussed in detail below.
carbon) grades are available to further overcome this problem.

As austenitic stainless steels have a coefficient of expansion 50% greater than carbon manganese steels, distortion and warping can be a problem. Welding currents should therefore be kept as low as possible with high travel speeds. Tacking should be carried out at approximately half the pitch used for mild steel and welding should be balanced and properly distributed. Preheating should not be applied and post weld heat treatment of this material is seldom required after welding. Austenitic stainless steels are normally welded with electrodes of matching composition to the base material [1].

In the choice of welding wires for stainless steels welding is often used constitutional Schaeffler diagram that defines the weld structure based on chemical composition of the welding wire [3-6].

![Fig.1 Schaeffler constitution diagram](image)

**2. Methodology of the experiment**

**Tested materials**

Quality of the welding joints was accounted at the samples taken from chosen products. Quality of two types of welding joints was investigated. Figure 2 shows first type of welding joint (sample A). It is a butt weld (BW) welded in position PA.

![Fig.2 Sample A](image)

Weld was made by method 135 (MAG) with the combination of materials S355 J2 EN 10025 and X5CrNi18-10 EN 10088. Tinplates with diameter 2.5 mm were classified as CR ISO 15608 1.2 + 8.1.

<table>
<thead>
<tr>
<th>Table 1 and 2 show chemical composition of used materials.</th>
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<tbody>
<tr>
<td><strong>Tab. 1 Chemical contents of S355 J2 EN 10025 steel</strong></td>
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<tr>
<td><img src="image" alt="Table 1" /></td>
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<tr>
<td><strong>Tab. 2 Chemical composition of X5CrNi18-10 EN 10088 steel</strong></td>
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<td><img src="image" alt="Table 2" /></td>
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<th>Parameters of welding are specified in the Table 3.</th>
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<tr>
<td><strong>Tab. 3 Parameters used for welding of the sample A</strong></td>
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<td><img src="image" alt="Table 3" /></td>
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Figure 3 shows second type of welding joint (sample B). It is an fillet weld (FW) welded in position PB.

![Fig.3 Sample B](image)
Weld was made by method 135 (MAG) with fluctuating mode on the material X5CrNi18-10 EN 10088 classified as CR ISO 15608 1.2 + 8.1. Tinplates with diameter $t_1, t_2 = 2.5 + 3 \text{ mm}$ Table 2 shows chemical contents of used tinplates Parameters of welding are specified in the Table 4.

Tab. 4 Parameters used for welding of the sample B

<table>
<thead>
<tr>
<th>Number of layers</th>
<th>Method of the welding</th>
<th>Average of add. mat. [mm]</th>
<th>Type of polarity</th>
<th>Range of welding flow [A]</th>
<th>Range of intensity [V]</th>
<th>Speed of the welding [cm/mm]</th>
<th>Speed of the wire [cm/min]</th>
<th>Classification of the additional material</th>
<th>Trade mark</th>
<th>Gas</th>
<th>Gas flow – close direct protection</th>
<th>Level of the weld</th>
<th>Program of welding</th>
<th>Exit of the electrode</th>
<th>Angle of the burner</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>135</td>
<td>0.8</td>
<td>DC+</td>
<td>min 75/max 85</td>
<td>min 18/max 19</td>
<td>min 48/max 55</td>
<td>min 7,0/max 7.6</td>
<td>EN ISO 14343 G 19 9 Lsi</td>
<td>OK Autrod 308LSi (ESAB)</td>
<td>EN ISO 14175 M12</td>
<td>10 - 12 l/min</td>
<td>EN ISO 5817 class C</td>
<td>program 126</td>
<td>10 ÷ 12 mm</td>
<td>10 - 15°</td>
</tr>
</tbody>
</table>

Quality of the welding joints was accounted by visual method according to STN EN ISO 17637. Welding joints were classified as suitable according STN EN 5817, they respond to the level B. After the visual control the quality of the welding joints was accounted at the metallographic sections. At the tested sample A and B wasn’t recorded any presence of inner defects.

Figure 5 shows microstructures of sample A. Thermally unaffected base material from the steel S355J2 has ferritic-perlite structure (Fig.5a). Base material from the steel X5CrNi18-10 EN 10088 has fine-grained austenitic structure. In heat affected zone (HAZ), because of input heat, size of grain changed (Fig.5b) and share of the pearlite in ferritic-perlite structure increased. At Fig.5c, there is an austenitic structure of the welding metal without any significant grain’s limits. Inside of the structure of the welding metal we found sporadic carbide inclusion.

Microstructures of the sample B are recorded at the Figure 6. Base material from the steel X5CrNi18-10 EN 10088 has lines austenitic structure (Fig.6a). In the HAZ the size of the austenitic grains changed (Fig.6b). Welding metal made by additional material OK Autrod 308LSi has austenitic structure without any significant grain’s limits (Fig.6c).

Inside of the welding metal there were small amount of carbides.
Results of microstructure evaluation:

Microstructure was accounted on the vertical sections according to the measurement scheme in the Figure 4. Measured values of microhardness from the sample A are marked in the graph in the Figure 7. Maximum values 242 HV 0.1 were measured in the welding metal in the point 5. Base material of the steel X5CrNi18-10 has values of 228 HV 0.1 and base material of the steel S355J2 has values of the microhardness in the interval 172 to 184 HV 0.1.

![Fig.7 Values of the microhardness from the sample A](image)

Highest values of the microhardness in the welding metal were measured also from the sample B, namely 241 HV 0.1, what is recorded in the graph in the Figure 8. Values of the microhardness in the HAZ were in the interval 226 – 230 HV 0.1 and they fluently went down on the minimal values of the microhardness, which were measured in the base material, namely 218 – 221 HV 0.1.

![Fig.8 Values of the microhardness from the sample B](image)

Measured values of the microhardness from both of the samples respond to the used base and additional materials, or to the thermal impact of used welding technology. Welding joints from which the sample was taken weren’t thermally modified after the welding so there weren’t any changes in the structure or in the hardness of the weld.

Conclusion

In the article there was by the destructive tests accounted the quality of the joints taken from the chosen welds, which are components of the agricultural machines.

The quality of the welds was accounted using the visual control; the quality refers to the level B according to STN EN 5817. The quality of the butt welding joint from the combination of low alloyed and stainless steel was accounted. Wire MT 309 L was used as an additional material. Structure of the welding joint was generated from the austenite.

The quality of the fillet weld from the steel X5CrNi18-10 EN 10088 was also accounted. Fluctuating schedule and the thin additional material affected the size of the area HAZ, which was in compare to sample A smaller. Structure of the base material and the welding joint was generated from the austenite.

Based on the presented partial results from all the scale of non-destructive and destructive tests, which are a part of approval processes WPQR that are necessary for the serial production, it is possible to say that used technology, welding parameters and additional materials are suitable for providing the good quality of the welding joints of produced components.

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References


