CHARACTERIZATION OF BUTT WELD JOINT BY MIG WELDING PROCESS ON THE EXAMPLE OF ALUMINIUM ALLOY EN AW 6082

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Abstract – The paper presents the test results of butt welded Al alloy joint EN AW 6082-T651 (10mm). Filler wire was S-Al 5183. The purpose was to evaluate the achieved quality of the welded joint as a function of the applied technological parameters of the MIG welding process. Complying with all the standards, mechanical tensile tests (Rp0.2, Rm and A50), bending and hardness measurement HBW2.5 / 62.5 / 20 in base material (BM), heat affected zone (HAZ) and weld metal (WM) were performed. Macrostructural and microstructural analysis was performed on the cross section of the welded joint specimen after appropriate metallographic preparation. The results of microstructural analysis and mechanical tests showed that cracks and slag were present in WM. This can also be seen on fractured surfaces after tensile and bending tests. The presence of these defects significantly affected the weakening of the welded joint, more precisely the lower values of mechanical properties. It can be concluded that the applied technological parameters of the welding process do not provide a quality joint that meets the requirements of the standard.

Keywords – welding, Al alloy, MIG, mechanical properties, macrostructure, wagon.

1. INTRODUCTION

It is known that the mechanical, physical and chemical properties of Al alloys depend on the chemical composition and the microstructure resulting from the applied thermomechanical processing [1, 2]. Thanks to a unique combination of properties such as precipitatioelectrical and thermal conductivity, low specific weight, strength, corrosion resistance, deformability, weldability and recyclability, Al and its alloys have become indispensable in the railway industry. This primarily applies to alloys series 5xxx (Al-Mg) and 6xxx (Al-Mg-Si). In the production of rail vehicles, these two series of alloys are widely used due to their good mechanical properties, good weldability and the ability to obtain large profiles by pressing, rolling or extrusion. Selected alloy 6082 T651 belongs to the group of medium strength alloys that can be regulated by precipitacion hardening and deformation [3]. Since in the field of rail vehicles this alloy is used for very responsible parts and load-bearing structures, obtained by welding, special attention is given to the control of welded joints that must meet strict quality criteria. Butt-welded joints of 10mm thick aluminum profiles are used, in the rail industry, most often for the construction of the wagon floor. Due to the load that this joint is subjected to, excellent mechanical and metallurgical characteristics are necessary, not only of the base material but also of the weld and heat affected zones.

Precisely, the purpose of this paper was to present a complete quality check of the welded joint of alloy 6082 T651 as a function of the parameters of the MIG welding process, in accordance with the requirements of existing standards [4].

2. TESTING PREPARATION

Experiment was done according to standard SRPS EN ISO 15614-2 Specification and qualification of welding procedures for metallic materials — Welding procedure test - Part 2: Arc welding of aluminium and
its alloys.

2.1. Welding procedure specification

According to the preliminary welding procedure specification, the sample was welded with welding process 131 (MIG), type of joint and weld are BW, 10V. Base material is EN AW 6082-T651 with the thickness of 10mm, added material is SA 5183 and welding position is PA.

2.2. Experiments done for qualification

For one qualification of BW aluminium joint to pass, all of the requirements made by the standard need to be checked. For the NDT Visual examination (ISO 17637), Penetrant test (EN 571-1), Radiographic test (ISO 17636) and for the DT: macrostructure and microstructure (ISO 17639), hardness test as an addition request (ISO 9015-1), tensile test (ISO 4136) and bend test (ISO 5173).

2.3. Specimen preparation

Sample of the welded joint must be at least 300x300 mm from which the specimens are extracted. From each side 25mm is discarded because of the beginning and the end of the weld is not tested. One specimen is needed for each of the tests (macrostructure, macrostructure and hardness), for tensile tests 2 specimens and for the bend test 4 specimens (Fig. 1).

Dimensions of the specimens and their preparations are chosen according to the relevant standards.

3. TESTING MACHINES AND CONDITIONS

Testing conditions for all the experiments done are chosen according to standards. Testing temperature was 23±5°C.

Machines that were used for testing were:
- Microscope Leica DM4 M
- Macroscope Struers StructureExpert Weld 5
- Universal testing machine Shimadzu AG-X plus 300kN
- Brinel hardness tester Echolab HTB 625Z

4. DESTRUCTIVE TESTING

Once all of the specimens were cut or milled out of the sample plate the testing could start.

4.1. Macrostructure examination

Specimen preparation was done on the machine for grinding and polishing Buehler Automet 300 and etched by 15% NaOH.

Fig. 2. Macrostructure

All the dimension that needed to be tested according to standard ISO 17639 for the quality level listed in SRPS EN ISO 15614-2 are good and there were no defects on the specimen.

4.2. Microstructural examination

Specimens was grinded, polished and etched and specific parts of the sample, where defects were noticed, were examined.

Fig. 3. Microstructure figure position
Microstructure examination showed porosity in the narrow HAZ and zone of columnar structure in weld metal, Fig. 4, a, c. between weld and HAZ. Behind the columnar zone in WM cracks can be seen, most likely hot cracks and slag, Fig. 4, b, d. Fig. 4, a, d show that the fusion line stands out more than the HAZ.

4.3. Hardness testing

Hardness testing was done according to standard ISO 9015-1 for hardness testing of welded joints. This test showed no irregularities. Fig. 5 shows measurement places and Fig. 6. and 7. show diagrams of measured hardness and position.

Method used was 2.5/62.5/20 (2.5 mm ball, 62.5 kgF for the duration of 20s).

![Fig. 5. Measurement places](image)

![Fig. 6. Diagrams of measured hardness and position](image)

![Fig. 7. Diagrams of measured hardness and position](image)
4.4. Tensile testing

Tab. 1. Data collected from the tensile test

<table>
<thead>
<tr>
<th>No.</th>
<th>$R_{p0.2}$ MPa</th>
<th>$R_m$ MPa</th>
<th>$A_0$ %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>134</td>
<td>218</td>
<td>7.16</td>
</tr>
<tr>
<td>2</td>
<td>138</td>
<td>217</td>
<td>8.17</td>
</tr>
<tr>
<td>Average value</td>
<td>136</td>
<td>217.5</td>
<td>7.66</td>
</tr>
</tbody>
</table>

Tensile test was done according to standard (ISO 4136). This test showed the tensile characteristics of the welded joint, which has a lower limit on the tensile strength.

According to standard EN ISO 15614-2 the tensile strength of the welded joint needs to be as strong as the tensile strength of the material multiplied by the joint efficiency factor $T$. (1)

$$R_{m}(w) = R_m (p m) \times T$$

where
- $R_{m}(w)$ is the tensile strength of the welded test specimen in the as post-welded condition;
- $R_m (p m)$ is the specified minimum tensile strength of the parent material required in the relevant standard;
- $T$ is the joint efficiency factor.

Factor $T$ for EN AW 6082-T6 is 0.7 from which we can determine that the lower limit for $R_m$ for this welded joint is 217 MPa which means the test just barely passes. The stress-strain diagram for the first sample is shown in Fig.8.

![Fig. 8. Stress-strain diagram for the first sample](image)

Break occurred in the heat affected zone which is shown in the Fig. 9. an the detail look of the broken surface can be seen in the Fig. 10.

![Fig. 9. Specimen failure site](image)

![Fig. 10. Surface area of the specimen after tensile test](image)

4.5. Bend test

Bend test according to ISO 5173 was done. All the testing conditions were chosen according to this standard (distance between rollers, tool diameter, specimen dimensions, bend angle...)

Bend test was done on 4 specimens, 2 on the face side of the specimen (TFBB) and 2 on the root side of the weld (TRBB). Fig. 11. shows 1 specimen after the bend test. All of the bent specs failed in the HAZ.

5. CONCLUSION

All of the results, especially microstructure and bend test, show that these welding parameters were not adequate for this material. Microstructure showed presence of hot cracks and slag. Surface area of the breaking point after tensile test showed slag and porosity and bend test confirmed that the HAZ is weak to pass the qualification. This welded joint would not withstand the forces on the floor of the wagon.

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REFERENCES