The 56th International October Conference on Mining and Metallurgy
22-25 October 2025, Bor Lake, Bor, Serbia
www.ioc.tfbor.bg.ac.rs

DOI: 10.5937/IOC25434M
Original scientific paper

STRUCTURAL CHARACTERIZATION OF WELDED JOINTS OF AlSiMg ALLOYS

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Abstract

The structural characterization of welded joints is described in the standard SRPS EN ISO 17639. The purpose of these tests is to evaluate the crystal structure, morphology, and orientation, as well as the presence of precipitates and inclusions, independently and/or in correlation with various cracks, voids, and other phenomena in metallic materials. The paper presents the results of metallographic examinations of welded joints of 6082 T6 and 6005A alloys. Al 5087 alloy was used as the filler metal. The characteristics of macro and microstructural examinations are presented in terms of detecting irregularities (defects) in the welded component, along with an assessment of the sensitivity of the optical microscopy method in microstructural analysis.

Keywords: *Macrostructure, microstructure, welded joint, aluminum*

1. INTRODUCTION

Aluminum alloys from the 6000 series, due to their low specific weight, high strength, and good corrosion resistance, are used in almost all industries. Compared to the EN AW 6005 alloy, the EN AW 6082 alloy contains significantly more Mn, which improves the crystal structure and provides greater strength and corrosion resistance. However, the 6005 alloy has better formability in the extrusion process.

Both alloys can be successfully joined by arc welding. The quality of the welded joint depends on several factors. The choice of appropriate filler material, welding technique and procedure, as well as the knowledge of the base material's sensitivity to the occurrence of critical defects during welding (cracks, voids, pores, etc.), represent some of the factors that must be considered to achieve a good welded joint [1].

Hot cracks and voids are two negative phenomena that may occur during the welding process. The mechanisms of their formation different. Hot cracks (solidification/liquation cracks) can occur during the solidification of the welded metal or of the partially melted base metal. The occurrence of these cracks may be caused by a wide solidification range of the welded metal and/or the presence of low-melting eutectics (Al-Mg_2Si, Al-Si, Al-Fe-Si). Voids (shrinkage cavities) form due to the difference in shrinkage between the liquid and solid metal. This phenomenon can also induce crack formation under stresses (if present) that are lower than the material's strength limit [2].

The described defects in the welded material may be localized on the surface and/or in the interior and may affect the quality of the joint. Standard EN ISO 10042 defines the limits of these phenomena for quality levels D, C, and B.

This paper presents the micro- and macrostructural characterization of a welded joint of two aluminum alloys, with special emphasis on the microstructure of the heat-affected zone.

2. EXPERIMENTAL

The MIG welding process (equipment – Kemppi X5) was used to join the aluminum alloys EN AW 6082 and EN AW 6005. A V-groove butt joint of two profiles, each 14 mm thick, was made, with welding performed from one side and with the use of a metallic backing. The material was preheated to a temperature of 100–120 °C, and a forward welding technique without weaving was applied. A schematic of the joint preparation is presented in Figure 1.

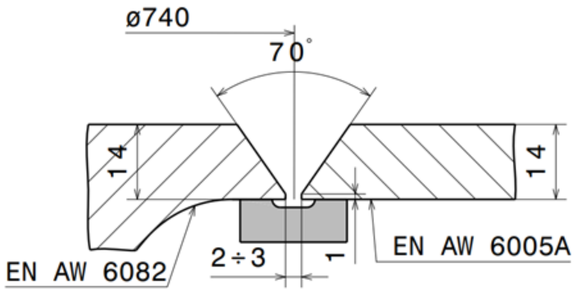

Figure 1. Joint preparation layout

Metallographic examinations of the welded joint were carried out using a Leica DM4 microscope, while macrostructural examinations were performed on a Struers device with magnification up to 50x.

3. RESULTS AND DISCUSSION

The macrostructure of the cross-section of the welded joint of aluminum profiles is shown in Figure 2.

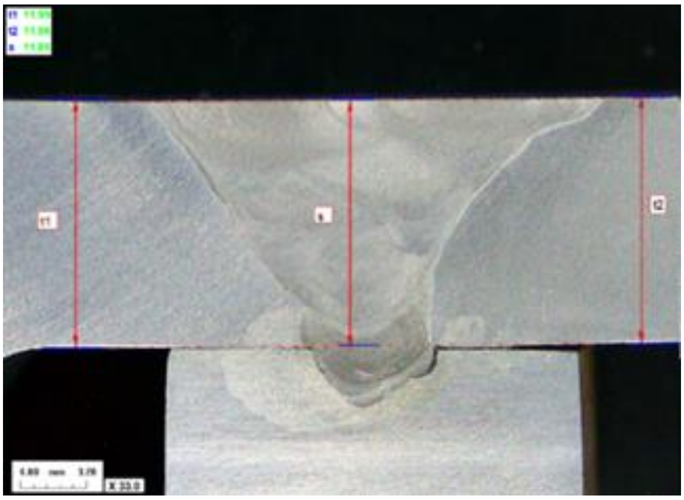

Figure 2. Macrostructure of the welded joint

Table 1 presents the measured characteristics of the welded joint.

Table 1. Thickness of the Al profiles and the welded joint

Marking	Description	Value (mm)
t1	Thickness of base material 1	11.99
t2	Thickness of base material 2	11.96
s	Thickness of butt welded joint	11.89

The quality of the achieved joint can be assessed based on macroscopic and/or microscopic examinations. To a large extent, almost all metallographic characteristics of welded metallic materials can also be evaluated through macroscopic inspection. From the macrograph of the welded Al alloy joint obtained at 30x magnification, it is possible to assess the absence of defects such as lack of fusion, incomplete root penetration, excess weld metal, excessive penetration, or overlap of the base metal, etc. However, the morphology of the metal structure (appearance, shape and size of grains, structural orientation, precipitates, presence of inclusions) necessarily requires microscopic examination.

Furthermore, surface and internal defects such as cracks, microcracks, pores (individual or localized in lines or clusters, evenly distributed), and cavities can be properly assessed only through metallographic investigations.

In the examined welded joint of aluminum profiles, the microstructure image (Fig. 3) reveals the presence of a defect which, according to the categorization given in ISO 6520-1, can be classified as a type 100 defect [3].

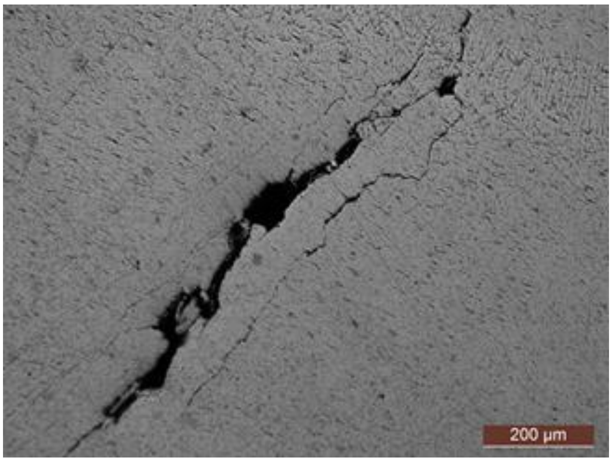

Figure 3. Root crack in the weld

The microstructure of the welded joint (for the 6082 alloy) in the heat-affected zone (HAZ) is shown in Figure 4. In the lower right corner of the image, the base metal structure can be recognized.

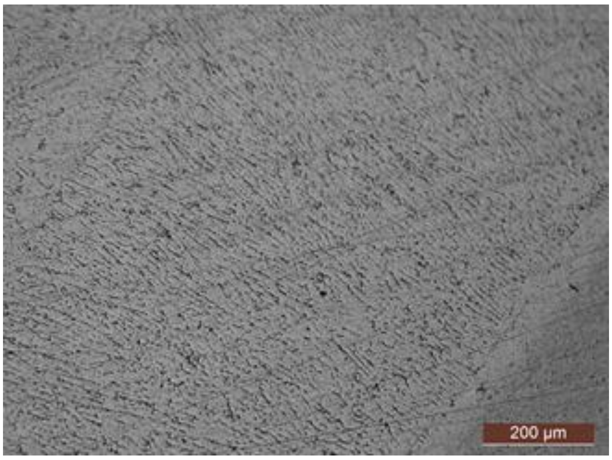

Figure 4. Microstructure of the HAZ, base material 6082 alloy

The transition zone is clearly evident, featuring columnar crystals with oriented alignment in the direction of intense heat dissipation, and the area where the weld structure changes into a cellular structure. On the other side of the welded joint, the microstructure of the HAZ (for the 6005A alloy) is shown in Figure 5.

Significant differences in the morphology of the welded joint between the 6082 and 6005A alloys cannot be observed. The structural morphology is quite similar. Here, the columnar crystal zone is also present, although it appears less pronounced and less developed compared to the HAZ microstructure shown in the previous figure [4].

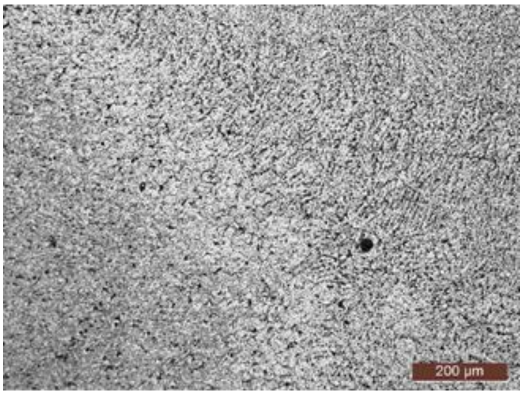

Figure 5. Microstructure of the HAZ, base material 6005A alloy

4. CONCLUSION

In this study, the micro and macrostructure of the welded joint of two aluminum alloys with different compositions was investigated. Structural characterization of the joint was carried out with particular emphasis on the presence of defects identified and categorized according to standard ISO 6520-1. Additionally, the sensitivity of the optical microscopy method was examined regarding its ability to detect fine differences in the microstructure of the HAZ. The following conclusions can be drawn:

1. Macrostructural examinations can fully determine welding flaws (defects) resulting from the welding technique itself, such as lack of fusion, incomplete root penetration, excess weld metal, excessive penetration, etc.
2. Microstructural examinations are indispensable when it is necessary to determine the morphology of the microstructure (grain shape and size, structural orientation, cellular or dendritic type, etc.). More detailed and accurate assessment of the presence of defects (surface and internal), such as cracks of various origins, pores, shrinkage cavities, inclusions, etc., can be performed using optical microscopy for microstructural analysis of metals and alloys.
3. The sensitivity of the optical microscopy method is defined by its ability to resolve fine elements within the microstructure. More detailed investigation of microstructural features (precipitates, specific inclusions, eutectics, etc.) can be achieved using other complementary techniques, such as SEM-EDS and XRD, which supplement the capabilities of optical microscopy.

ACKNOWLEDGEMENTS

The research presented in this paper was done with the financial support of the Ministry of Science, Technological Development and Innovation of the Republic of Serbia, with the funding of the scientific research work at the University of Belgrade, Technical Faculty in Bor, according to the contract with registration number 451-03-137/2025-03/200131.

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