INFLUENCE OF JOINING METHOD FOR HARDNESS DISTRIBUTION IN JOINTS OF AlZn5Mg1 ALLOY

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Abstract

The article presents the research results of hardness values distribution of friction stir welded joint (FSW) alloy AW 7020 (AlZn5Mg1). The joints welded by traditional MIG method of the same aluminium alloy were chosen as reference points. Friction stir welding (FSW) - a new technology can be successfully used for butt welding of sheet metal with different types of aluminium alloys. The parameters of friction stir welding (FSW) and MIG welding used to join metal alloy AlZn5Mg1 (7020) were presented. Metallographic analysis showed the correct structured both MIG welded joints and FSW welded aluminum alloy 7020.

The study was carried out using Vickers hardness HV_5 accordance with the requirements of the Polish Standard PN-EN 1043-1:2000. The study was conducted in three rows, and the indenter load was 50 N.

In order to determine the structural changes in the bonded joints, the samples were polished and then micro-etched KELLER reagent. Metallographic examination was carried out using optical microscope Axiovert ZAISS 25.

Metallographic examination revealed the existence of an explicit heat affected zone of HAZ in case of MIG welded joints and virtually lack thereof, in case of FSW welded joints.

In case of FSW welded joint, maximum hardness was observed in the middle of joint, but at a distance of approximately 25 mm from the middle of the weld there is a hardness decrease of about 10% relative to the base material. In the MIG welded joint lowest hardness of the weld occurred in the middle of the joint.

Keywords: *friction stir welding FSW, welding MIG, aluminium alloys, hardness distribution*

1. Introduction

Aluminium alloys are a material which is widely used in the global industry, including shipbuilding. Aluminium alloys are used more and more widely for building ship and vessel hulls as these alloys allow a significant reduction in ship structure weight compared with the weight of steel structures. The use of aluminium can reduce the weight by approx. 50%, thereby increasing the displacement of the vessel and maintaining the displacement for load or speed increase and stability improvement. For these reasons, aluminium alloys are used, among other things for the construction of hulls and superstructures. Of weldable aluminium alloys for plastic processing, the most popular is still the group of Al-Mg (5xxx series) alloys, with good weldability and relatively good operating properties. The advantage of these alloys is their relative insensitivity to layer corrosion and stress corrosion, the disadvantage – low strength of welded joints, below 300 MPa. In the 90s, Al-Zn-Mg (7xxx series) alloys attracted great interest. They exhibit higher strength properties than the mechanical properties of Al-Mg alloys. The disadvantage of the Al-Zn-Mg alloys is that they are prone to stress and layer corrosion. Many years of research have shown that the resistance of these alloys to stress corrosion is influenced among other things by heat processing, chemical composition and welding technology (welding method, type of fillers, type of connector) [1-7]. Virtually all joints welded using conventional MIG or TIG methods in this group of alloys possess insufficient resistance to stress or layer corrosion and therefore the only materials for hulls of light vessels are still Al-Mg 5xxx group alloys.

An alternative to traditional methods such as MIG of TIG welding may be Friction Stir Welding (FSW). In this method, the heating and plasticization of the material is effected using a tool with a rotating shaft located at the joint of clamped sheets. After the tool has been put in rotation, the sheet material has been heated up with the heat of friction and in its immediate vicinity, the entire system slowly moves along the line of contact (Fig. 1). Because this method consists in welding in the solid state, below the melting temperature of the material, the mechanical properties obtained using this joining method may be higher than those for arc welding techniques (MIG, TIG). The main advantage of this method is that it is easy to obtain joints with high, reproducible properties [7, 9]. Because in the FSW method welding occurs in the solid state, much less heat is supplied to the joined materials than is the case with conventional welding. This significantly reduces the size of the heat-affected zone. Studies of Al-Zn-Mg alloys bonded using MIG and TIG methods exposed to aggressive marine environment have shown a low resistance to stress and layer corrosion occurring just in the heat-affected zone [6, 8].

The industrial applicability of the 7xxx series alloy that is more durable than the commonly used 5xxx series alloys shall be subject to finding a method of bonding which will improve the properties of the whole structure, i.e. also bonded joints and not just the alloy itself. One of the tests performed to determine the mechanical properties of joints between 7xxx series alloy sheets, bonded using various methods, is the hardness test in the joint's cross-section.

The aim of this study was to determine the distribution of hardness in the cross-section of joints bonded using FSW compared with traditional MIG welding. AlZn5Mg1 (AW-7020) alloy joints were used for the study.

2. Research methodology

The study uses EN AW-7020 T6 aluminium alloy. The chemical composition of the alloy is given in Tab. 1.

Tab. 1. Chemical composition of 7020 aluminum alloy

Chemical composition (%)									
Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Zr	Al
0.30	0.35	0.10	0.24	1.30	0.14	4.70	0.08	0.07	other

Butt joints of sheets plates with a thickness g = 10 mm were made with the use of FSW. The sheets were welded on both sides using the same parameters.

The diagram of friction welding with the commingling of weld material (FSW) is shown in Fig. 1 and the parameters are shown in Tab. 2.

Studies of the weld's structure have shown its correct structure without visible discontinuities in the area of the plastically deformed material.

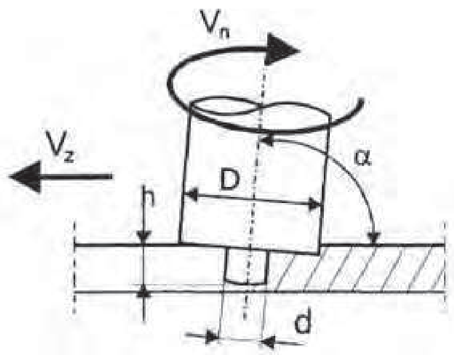

Fig. 1. The diagram of FSW

Tab. 2. FSW parameters of 7020 aluminum alloy sheets

Tool dimensions			Angle of tool deflection, α [°]	Tool rotating speed, V_n [rev/min]	Welding speed, V_z [mm/min]
D [mm]	d [mm]	h [mm]			
25	10	5.8	88.5	450	180

For the comparison, butt joints were used between sheets with a thickness g = 12 mm, made of the same alloy (7020), MIG-welded. The preparation of welded joints was made in accordance with the procedures required by the shipbuilding industry. Edges were cut and (Y) bevelled using mechanical processing. Before welding, the surfaces of the groove and those located in its immediate vicinity were cleaned of oxides using rotating brushes made of stainless steel and then degreased using extraction naphtha. AlMg5 (Nertalic AG5 made by SAF) alloy wire was used for the welding, and argon gas with a purity of 99.99% was used as shielding. Sheet metal welding parameters are presented in Tab. 3

Tab. 3. MIG welding parameters of 7020 aluminum alloy sheets

Welding electrode diameter [mm]	Welding current [A]	Number of layers	Argon consuption [m^3/h]
1.6	190-230	4 + pre-welding	16-18

The welds were checked using X-ray flaw detection and showed no welding defects.

Hardness testing was carried out using Vickers HV_5 as required by the Polish Standard PN-EN 1043-1:2000. The indenter load was 50 N. The hardness was measured in three parallel rows, from the centre of the weld through the SWC heat affected zone through to native material.

Samples for testing were polished and etched using Keller reagent. This allowed to precisely determine zones occurring in the welded joint, such as: weld, heat affected zone or unchanged material – native, and then making exact measurements exactly in the aforementioned areas.

3. Test results

The results of hardness tests in the FSW welded joint are shown graphically in Fig. 2.

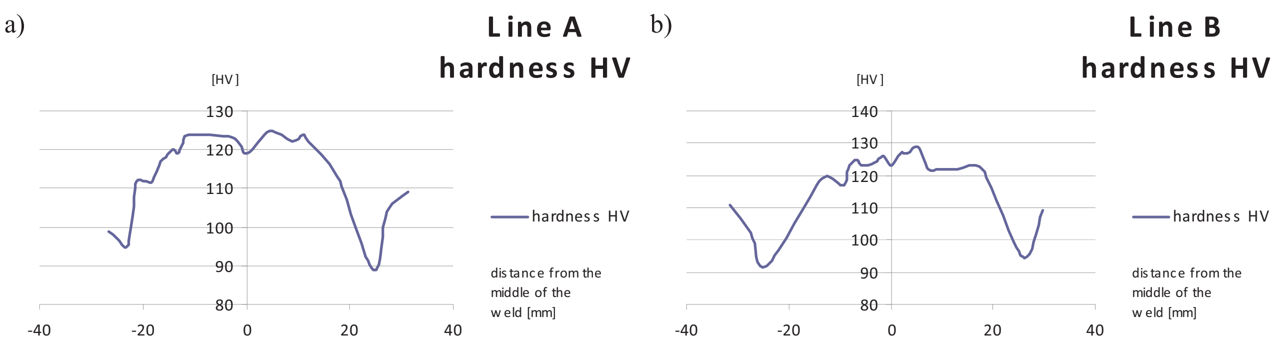

Fig. 2.Hardness distribution of FSW welded joints: a) near the surface, b) in the middle of the specimen

Figure 2a labelled "Line A" shows hardness distribution at a distance of 2 mm from sample surface. The test was carried out symmetrically on both sides (on the ridge and root side), and there were no significant differences in the results. For this reason, only one graph is presented. The second one, designated as "Line B" shows the distribution of hardness in the middle of the sample. The width of the weld in the middle of the sample was approximately 10 mm, and it expanded gradually to about 25 mm at the surface.

Based on the tests carried out, it was found that the highest hardness was obtained over the entire weld surface. This is probably associated with the strengthening of the material due to mechanical impact of a plasticizing tool on the material joined. The hardness drop, present at approximately 25 mm from the weld axis, suggests a change in the microstructure in this area. Tests performed using a light microscope did not confirmed this. Possible changes to the microstructure of 7020 supersaturated and aged (T6 state) alloy should be monitored using electron microscopy (TEM).

Hardness distribution in the MIG-welded joint is shown in Fig. 3.

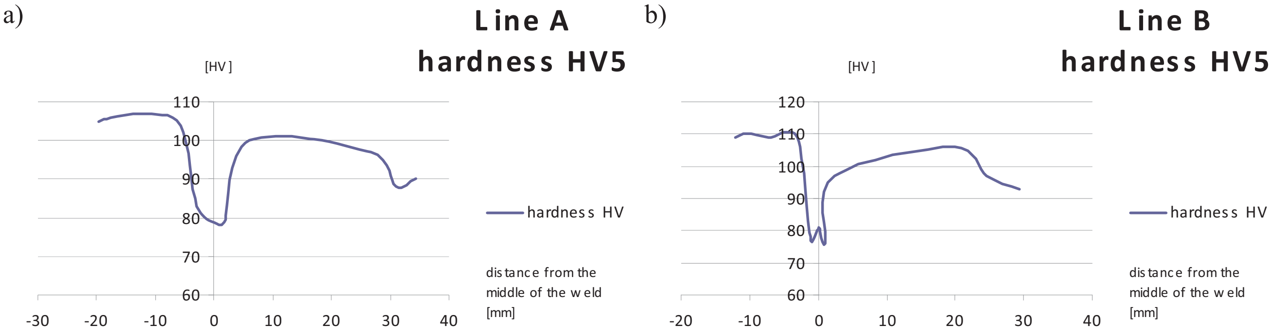

Fig. 3. Hardness distribution of MIG welded joints: a) near the surface, b) in the middle of the specimen

Figure 3a labelled "Line A" shows average hardness values obtained from measurements in two rows at a distance of 2 mm from sample surface. Differences in the findings, both from the weld ridge and root side were slight enough to make it possible to present the results in one chart. "Line B" located in Fig. 3b shows the distribution of hardness in the middle of the sample. At this point, the weld has the smallest dimension of about 5 mm, while its width at the surface reaches about 12 mm.

After analyzing the results obtained, it was found that in contrast to the welded samples, the weld shows the lowest hardness that increases with increasing distance, from weld axis to hardness characteristic of the native material. The weld material is created in the process of crystallization from the liquid phase, it exhibits a cast structure with lower hardness than that of the precipitation hardened native material.

4. Microscopic examination

In order to determine the effect of the bonding method on the change in the structure of the material, microscopic examinations were performed using a ZAISS Axiovert 25 optical microscope. The samples were etched using Keller reagent. Fig. 4 shows typical microstructures of bonds made using FSW and MIG methods.

a) b)

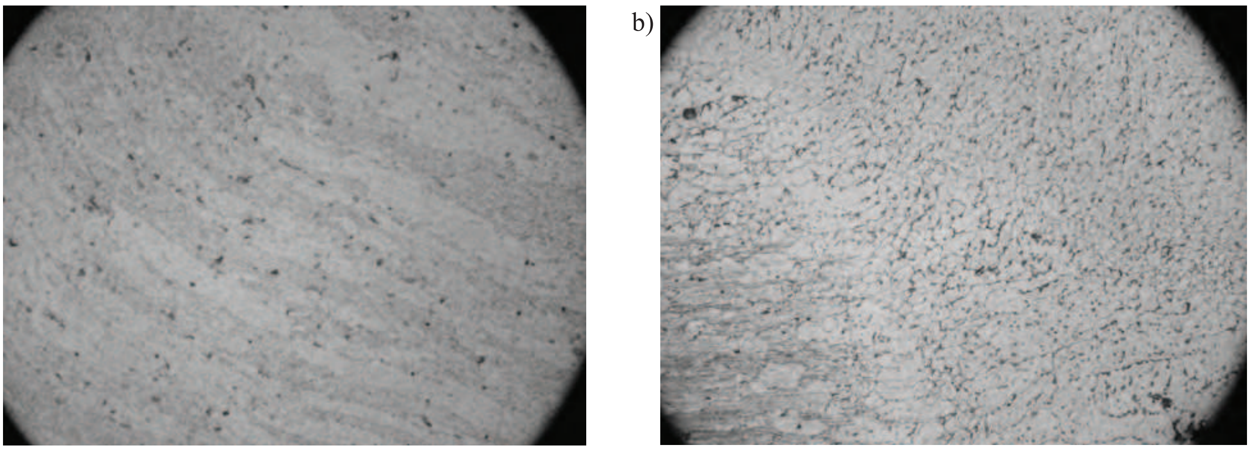

Fig. 4. Microstructures of joint: a) welded by FSW, b) welded by MIG

For joints made using traditional MIG method, a dendritic structure of the cast material can be clearly distinguished in the weld, an adjacent zone of SWC heat impact, with characteristically overgrown grains of the overheated zone, down to the fine-grained structure of the native material.

The structure of joints welded using the FSW method shows traces of mechanical plasticization with characteristic traces of material flow. The microstructure of friction-welded joints exhibits fine grain and limited heat affected zone.

5. Summary and conclusions

The study of friction welded joints showed an average hardness increase of 25% occurring in the weld, compared to the hardness of the native material. This increase averaged 25% relative to the base material. Within approximately 25 mm from the weld axis, there is a noticeable decrease in hardness, both in the middle of the sample and at the surface. Hardness in the area was on average 10% lower than the hardness of the native material. This indicates microstructure changes as a result of the welding heat. Over the entire weld surface, there is a fine-grained structure with visible traces of plasticization by the welding tool. The characteristic mingling lines can be seen there.

For joints made using conventional MIG arc welding method, the lowest hardness value was observed in the joint itself. The hardness decrease compared to the native material was approx. 20%. The structure of the bonded joint was typical of arc welded joints, with a dendritic weld, a SWC heat impact zone, with a characteristic overheating zone, where overgrown grain and fine-grained native material structure occurred.

The lowest hardness value recorded for FSW welded joints was higher by 12% compared with the hardness obtained in MIG-welded joints. Based on the tests carried out, it can be concluded that with the hardness criterion in mind, a better method of bonding of the 7020 alloy is the friction welding method.

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