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PROPERTIES OF AW 5059 ALUMINIUM ALLOY JOINTS WELDED BY MIG AND FRICTION STIR WELDING (FSW)

Mirosław Czechowski

Gdynia Maritime University
Faculty of Marine Engineering
Morska Street 81-87, 81-225 Gdynia, Poland
tel.:+48 58 6901346, fax: +4858 6901399
e-mail: czecho@am.gdynia.pl,

Abstract

The article presents the results of the mechanical properties of aluminium alloy AW 5059 [AlMg5.5Zn] welded by MIG and friction stir welding FSW. Friction Stir Welding (FSW) – a new technology can be successfully used for butt welding of different types of aluminium alloy sheets. Research results on stress corrosion cracking for the AW 5059 alloy welded joints are presented. Stress corrosion cracking was examined via the slow-strain-rate-testing (SSRT) according to EN ISO 7539-7. The following parameters were measured: time-to-failure, obtained max. load, strain energy (the diagram surface under the stress-elongation curve), relative elongation of the specimen, tensile stress and reduction-in-area. The fractures were analysis by scanning electron microscope of Philips XL 30 type. Tests were carried out in the air and in a 3.5% water solution of NaCl – artificial sea water.

On the basis of obtained test results, it can be said that 5059 alloy joints welded by FSW are resistant to stress corrosion in sea water. Tests have shown that the 5059 alloy, welded by FSW, has superior strength properties compared to the FSW 5083 alloy, along with comparable, good resistance to stress corrosion. Original value are received results of the mechanical and corrosion properties of a new method friction stir welding used for joining AW 5059 alloy sheets.

Keywords: *Friction Stir Welding (FSW), mechanical properties, aluminium alloys, stress corrosion cracking*

1. Introduction

Combining aluminum and its alloys welding methods is difficult because of its unique properties. The main difficulties that occur during welding of aluminum alloys due to: the high affinity of aluminum to oxygen and the formation of refractory (2060°C) oxide Al_2O_3, high thermal conductivity, high expansion alloys, high shrinkage casting (the cause of stress and strain welding), significant declines in strength welding temperatures, the loss during the welding of alloy elements such as magnesium, zinc or lithium

These briefly the main difficulties associated with welding aluminum alloys tend to look for other methods of joining these materials. Such an alternative to joining the butt plate of FSW (Friction Stir Welding) method.

Welding technology of friction stir welding (FSW) was invented and patented in 1991 in The Welding Institute (TWI) in Cambridge in the UK [1]. In this method, the heating and plasticization of the material applied to a rotatable tool spindle located at the joint pressed against the sheets. After putting the tool in rotation with the mandrel, heating and friction heat plasticized sheet material in the immediate vicinity thereof, there is free movement of the entire system along the contact line [2]. Friction stir welding is a method in the solid state, yet mainly aluminum and copper. The main advantage of this method is the ease of obtaining connections for high and reproducible properties [2, 3, 5, 6]. Since this is a welding method in the solid state below the melting point of the material, the mechanical properties obtained by the connectors can be higher than that for arc welding techniques.

Al-Mg alloys, especially their welded joints, may be subject to various forms of damage during use, depending on external factors. The most common form of damage taken from the environment, and the most discussed in literature, often leading to destruction (cracking) of the material, is stress corrosion.

Susceptibility to damage by the environment clearly increases in the area of the joint and the adjacent area. Degradation of welded joints depends on the type of additional material and welding technology. Results of stress corrosion resistance, fatigue strength, as well as fatigue-and-corrosion resistance tests for Al-Mg alloys welded using traditional MIG and TIG methods, can be found in literature. There is, however, no information regarding damage to Al-Mg alloys welded using modern methods, such as friction stir welding (FSW). Available literature offers a few elaborations on resistance to corrosion in a water solution of NaCl for Al-Cu alloys (from the 2xxx group) or Al-Zn alloys (from the 7xxx group) welded using the FSW method [5-7]. There are no elaborations comparing the stress corrodibility of FSW-welded Al-Mg joints (from the 5xxx group) with joints obtained using traditional welding methods (MIG). The purpose of this paper is to compare the stress corrodibility of the 5059 alloy MIG and FSW welded. This will allow us to find an optimal welding method which will ensure high strength and resistance to stress corrosion.

2. The research methodology

The testing used EN AW 5059 [AlMg5.5Zn] H321 aluminium alloy (supersaturated and artificially aged). The chemical composition of the alloy in % of weights was given in Tab. 1.

Tab. 1. Chemical composition of the tested AW 5059 aluminum alloy (wt. %)

Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Zr	Ni	Al
0.037	0.092	0.011	0.767	5.411	0.003	0.570	0.024	0.114	0.004	rest

Some plates made from 5059 alloy were butt-welded in inert gas (argon) shield using MIG method, while others were butt-welded using friction stir welding (FSW) method. The welding technologies and parameters have been presented in earlier publications [2]. The study of mechanical properties of aluminum alloy welded by FSW carried out on flat samples taken in accordance with PN-EN 895:1995.

Hardness HV5 made to PN-EN 6507 using a load of 49 N. Hardness measurements cover the whole width of the welded plate test in order to reveal the distribution of hardness depending on the distance from the axis of the weld. Location of measurement points in a butt joint specified in PN-EN 1043-1:2000

Stress corrosion cracking was examined via the slow-strain-rate-testing – SSRT (10^{-6} s^{-1}) according to EN ISO 7539-7. The following parameters were measured: time-to-failure – T [h], obtained max. load – F [N], strain energy (the diagram surface under the stress-elongation curve) – E [MJ/m^3], relative elongation of the specimen – $A_{11.3}$ [%], max. tensile stress – R [MPa] and narrowing – Z [%]. The tests were carried out on cylindrical notch-free specimens with diameter $d = 5$ mm and measured length of $L_0 = 50$ mm. Before testing, the specimens were deoiled. The fractures were analysed by electron scanning microscope of Philips XL 30 type.

3. The research results

The mechanical properties of 5059 alloy and its joints welded by FSW and MIG are shown in Tab. 2 and they are presented graphically in the chart (Fig. 2).

All the samples tested friction welded aluminum alloy cracked weld line separating the native material of plastically deformed material. Breakthroughs welded samples of alloy 5059 friction stir welding of a mixed character with visible ductile areas on the tops of the turn, deep gorges trans-crystalline visible grains (Fig. 3).

Tab. 2. Mechanical properties of 5059 alloy welded by FSW and MIG

Welding method	UTS [MPa]	YS [MPa]	EL [%]	$\frac{UTS_{FSW/MIG}}{UTS_{Native\ material}}$
Native material	401	280	16.2	—
FSW	367	277	12.7	0.92
MIG	296	192	7.6	0.74

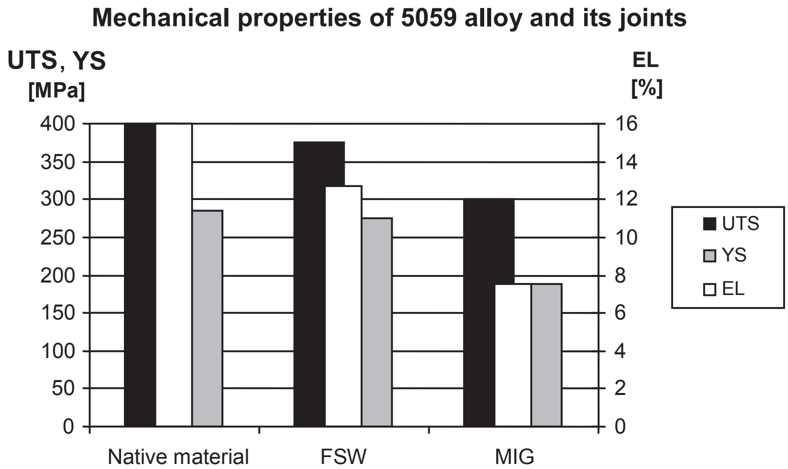

Fig. 2. Graphic interpretation of mechanical properties of 5059 alloy and its FSW and MIG welded joints

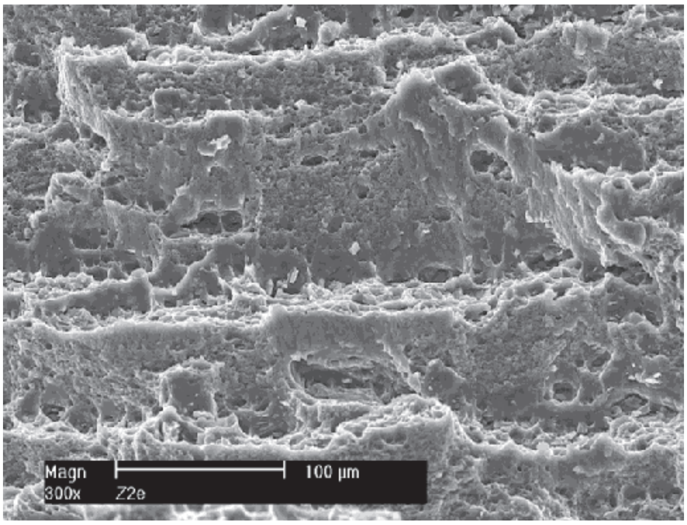

Fig. 3. Fracture of 5059 alloy joined by FSW

Figure 4 and 5 show graphically the distribution of hardness in the face and ridge MIG weld and FSW.

The Stress corrosion cracking tests were performed in air and 3.5% aqueous NaCl solution. Results of tensile tests in air (marked – air) and NaCl (marked – NaCl) are shown for each of the measured parameters in Tab. 3 in the form of their average value calculated from 5 measurements.

Tab. 3. Research results concerning the susceptibility to SCC of 5059 aluminum alloys joined by FSW

Alloy/environment	R [MPa]	E [MJ/m^3]	$A_{11.3}$ [%]	Z [%]	T [h]
5059/air	384.8	65.9	19.8	29.5	28.9
5059/NaCl	379.7	63.8	19.5	29.0	28.5

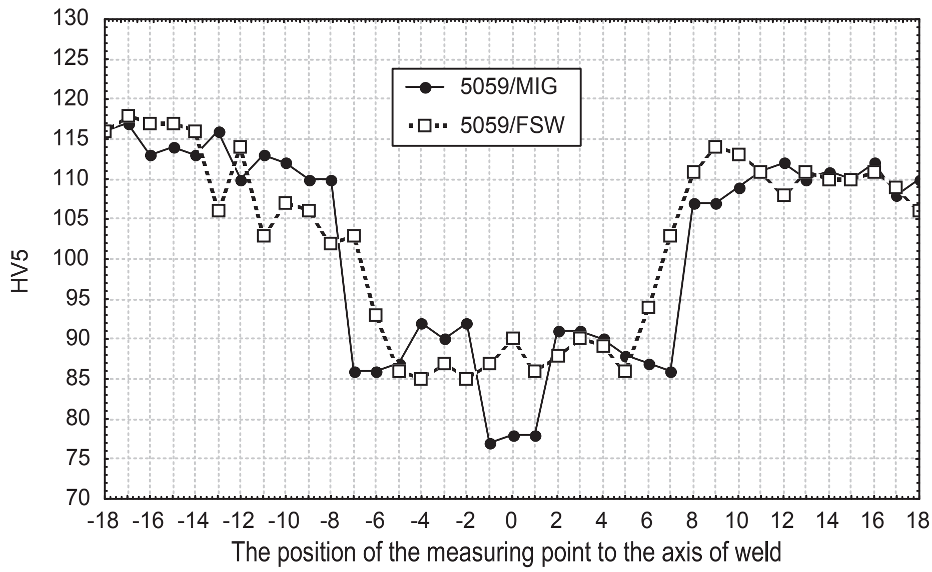

Fig. 4. Influence of the welding method on the distribution of hardness HV5 in the face-seal connections

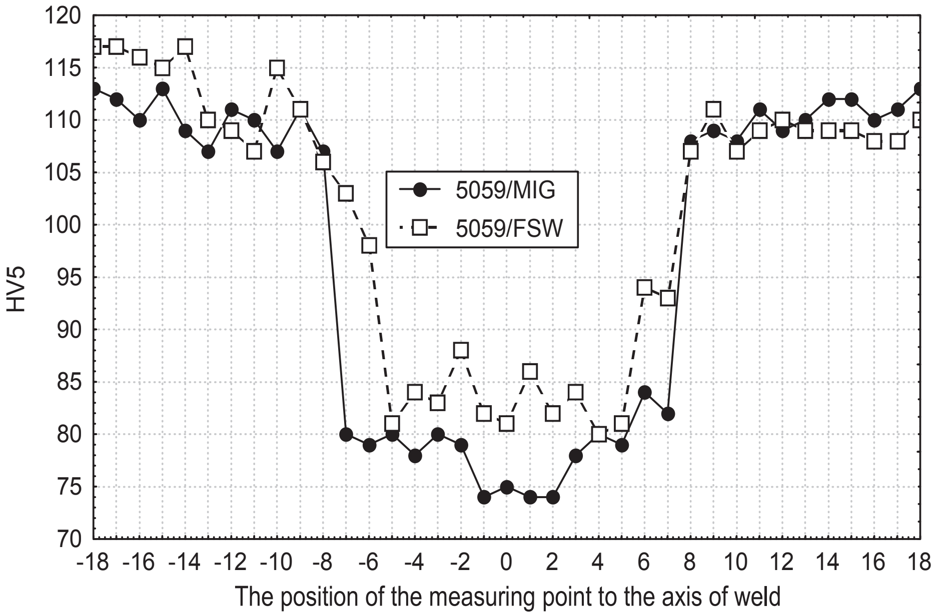

Fig. 5. Effect of welding methods on the hardness distribution in the root HV5-seal connections

4. Summary

Strength properties of studied Al-Mg alloy welded by FSW are higher ($UYS_{FSW}/UTS_{Native\ material}$ = = 0.92) compared with conventional welded joints MIG (Tab. 1). FSW is a method of bonding in the solid state below the melting temperature of welded sheets. The weld is characterized by the absence of a joint porosity and cracks inherent arc processes.

Fractographic studies were carried out on breakthroughs obtained from tensile tests of welded aluminum alloy FSW. In most of the samples were obtained breakthrough mixed with a distinctive character and splintery brittle plastic with distinctive hole (Fig. 3).

Tests Stress corrosion resistance joints of AlMg5.5Zn alloys welded by FSW under a constant low speed tensile (10^{-6} s^{-1}) showed good resistance to this type of environmental degradation. The values of the parameters measured during the tests in air and artificial seawater is slightly different (Tab. 3). Stress corrosion cracking resistance of welded joints using the 5059 alloy FSW is better in comparison with MIG-welded joints of the alloy for.

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