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STRENGTH OF WELDED JOINTS MADE OF AW-5754 ALLOY UNDER STATIC LOAD CONDITIONS

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Abstract: *The most commonly used method of aluminum welding is gas arc welding using a fusible electrode (MIG method) and a non-fusible electrode (TIG method). In machine construction aluminum alloys are commonly used, which the 5xxx series alloys are characterized by high strength and corrosion resistance. The work presents the properties of EN AW-5754 alloy, which is a material that allows joining elements by welding. The aim of the paper is to present mechanical properties test results of EN AW-5754 alloy welded joints with the 131 method for various values of linear welding energy: Q = 70 kJ/mm and Q = 1280 kJ/mm. The obtained results indicate a significant influence of linear welding energy on the strength of the welded joint.*

Keywords: Welded joint, Aluminum welding, Joint strength, Aluminum alloy EN AW-5754, Welding method 131.

1. Introduction

Pure aluminum has little use, the addition of one or more elements to pure aluminum leads to an alloy that often has significantly different properties than the unalloyed material. While the addition of alloying elements to aluminum sometimes deteriorates certain pure metal characteristics (such as corrosion resistance or electrical conductivity), which is acceptable in some applications because other properties (such as strength) can be significantly increased. An example of a change in the aluminum properties due to the addition of alloying elements is a materials belonging to the 5xxx series group. The 5xxx series alloys contain magnesium, which makes them very durable and corrosion resistant. Alloys from this group are used in ship hulls and other marine applications, welding wire and welded storage tanks (Graczewski et al., 2019). The strength of the alloys in this series is directly proportional to the magnesium content, which is up to about 6 %.

The basic and most commonly used method of aluminum welding is gas arc welding using a fusible electrode (MIG method) and a non-fusible electrode (TIG method). This method is based on the use of alternating current with a sinusoidal waveform and a frequency of the supply voltage 50/60 Hz. During one half-period, when the electrode is an anode and the cathode becomes a welded material, the phenomenon of "cathodic cleaning" can be observed in the joint zone (Woźny et al., 2016). During the second half-period, when the electrode is a cathode, it is cooled and intensively heated the weld pool, which contributes to the melting of the material. To ensure the arc re-ignition in the half-periods, high-frequency current arcs and voltages of 9000 – 15000 V are used. Due to these pulses, the ionization of the space in which the arc is ignited takes place, which makes it possible to re-ignite the arc with a slight delay.

The main problem during welding turns out to be the need to remove the aluminum oxide film. Welding problems can be caused by a large difference in the melting temperature of Al and Al_2O_3 (660 and 2060 °C respectively) and a higher specific gravity of aluminum oxide (4 g/cm^3) than liquid aluminum (2.4 g/cm^3). As a result, Al_2O_3 particles fall to the bottom of the weld, being the porosity cause. The high

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hydrogen solubility in liquid aluminum and the practical solubility lack in the solid state can be formed in the presence of gas bubbles in welded joints.

The next problem is the high thermal conductivity of aluminum, which on the one hand contributes to heating the metal to the melting point, and on the other is the cause of the material rapid cooling. Such a property leads to the fact that welding stresses can be found in the weld, which can cause damage to the joint. The high thermal aluminum conductivity is the reason for the need for increased welding energy. When conventional welding methods for aluminum alloys (MIG, TIG) are used, this is the reason for the wide heat-affected zone within the weld. It also has a negative effect on the aluminum strength at temperatures higher than about 500 °C and is the cause of hot cracks and high thermal expansion resulting in significant stresses and welds cracking (Woźny et al., 2017).

Aluminum alloy is increasingly used in the construction of machine components (Ligaj et al., 2018). This is due to the lower density of the aluminum alloy (2.65 - 2.85 g/cm^3) compared to the density of steel (7.86 g/cm^3). This allows reducing the weight of the structure, which has an impact on decreasing the energy consumption of machines (Mańka et al., 2018). Their proper operation requires appropriate diagnostics using non-destructive methods, i.e. vibration measurement (Muślewski et al., 2015), assessment of temperature distribution (Łukasiewicz et al., 2018), assessment of defects (Wirwicki et al., 2014), etc.

The aim of the paper is to present the mechanical properties test results of welded joints of EN AW-5754 alloy by selected welding methods.

2. Experimental research

2.1. Aluminum alloy properties AW-5754

The aluminum alloy EN AW-5754 (AlMg3) was adopted for testing, according to PN-EN 573-3:2010 and PN-EN 573-3/AK:1998 standards. The main components of the alloy are aluminum (Al) and magnesium (Mg). In order to improve its properties, other alloying additives have been introduced such as: chromium, manganese. The detailed chemical composition of the alloy is given in Tab. 1.

Tab. 1: Chemical composition of the AW-5754 aluminum alloy.

	Selected alloying elements marked according to the periodic table									
	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Inne	Al
	Elemental concentration in %									
Experimental research	0.21	0.34	0.04	0.27	2.73	0.05	0.02	0.02	0.10	rest
According to PN-EN 573-3	max. 0.40	max. 0.40	max. 0.10	max. 0.50	2.60 ÷ 3.60	max. 0.30	max. 0.20	max. 0.15	max. 0.15	rest

The EN AW-5754 alloy has excellent corrosion resistance also in seawater. The material is used as a construction material in construction and the maritime industry, in the construction of pressure vessels, in transport and the automotive industry as a decorative anodized material in facade applications, construction material in railways, in the construction of car body elements, packaging elements.

2.2. Geometric features of the samples

Tests under static load were carried out on samples (Fig. 1) with dimensions in accordance with PN-84/H-04334. The strength of AW-5754 aluminum alloy sheet was carried out on the samples shown in Fig. 1a. The geometrical form of welded joint samples is shown in Fig. 1b.

The welding process of sheets from which samples were made was carried out by the following methods:

a) welding option A – method 131 mechanized:
- voltage U = 25 V,
- current intensity I = 160 A,
- linear welding speed v = 400 mm/min,
- coefficient k = 0.8,
- linear welding energy Q = 1280 kJ/mm,

b) welding option B – method 131 semi-automatic:
- voltage U = 13.5 V,
- current intensity I = 140 A,
- linear welding speed v = 62 mm/min,
- coefficient k = 0.6,
- linear welding energy Q = 70.3 kJ/mm.

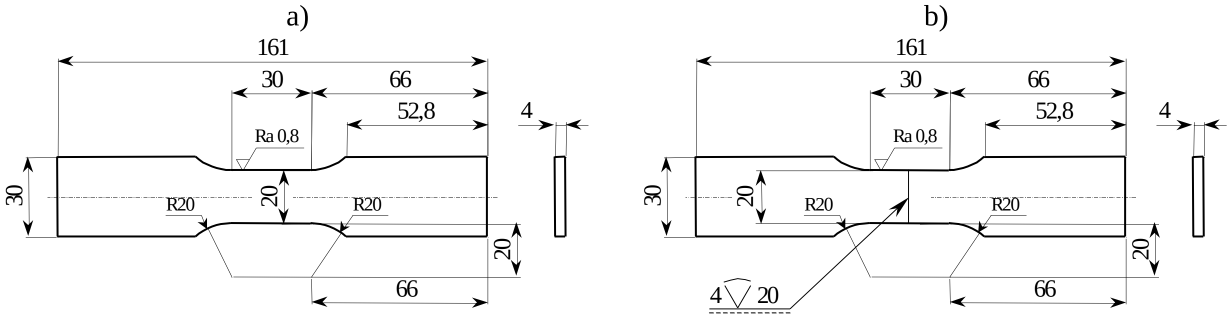

Fig. 1: Geometric features of the sample for testing under static loads: a) AW-5754 aluminum alloy sheets; b) AW-5754 aluminum alloy welded sheets.

Welded joints were subjected to material macrostructure analysis to assess their correctness (Fig. 2). Analysis of the presented macrostructure photographs shows no welding defects. Samples can be used in experimental studies.

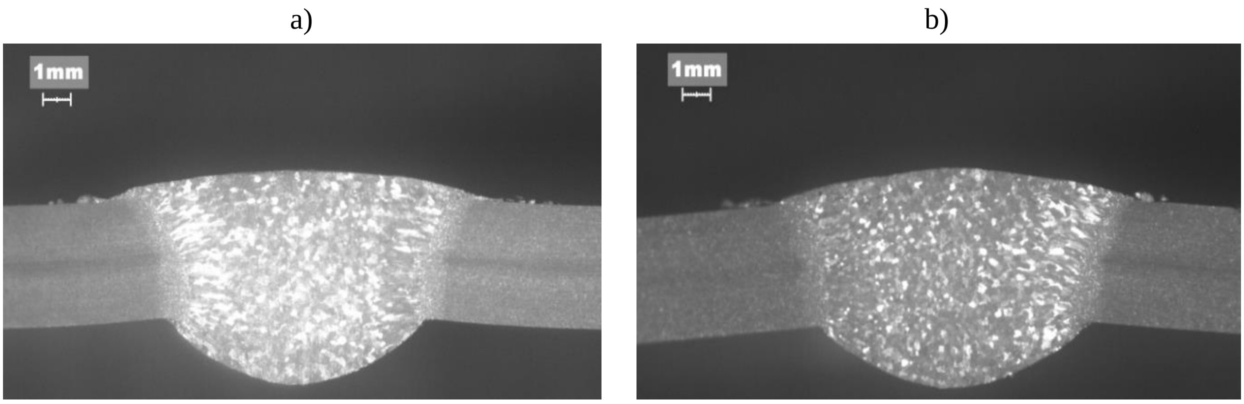

Fig. 2: Macrostructure of the welded joint from EN AW-5754 sheet metal made by the method: a) 131 mechanized, b) 131 semi-automatic.

2.3. Test results under static loads conditions

The tests were carried out on the Instron 8502 testing machine. Sheet strength was determined on samples cut along the rolling direction and transverse to the rolling direction. The results of the tests are presented in Tab. 2. The tests results of the welded joints are presented in Tab. 3. Fig. 3 shows examples of damaged samples.

Tab. 2: Mechanical properties of AW-5754 alloy sheet.

Sheet metal rolling direction	Statistical parameter	Mechanical properties			
		$S_{y0.2}$ [MPa]	S_u [MPa]	E [MPa]	A [%]
Longitudinal	Average value	150.4	310.5	71 896	25.6
	Standard deviation	2.4	7.1	554	3.5
Transverse	Average value	111.9	218.3	68104	27.2
	Standard deviation	2.3	1.4	274	1.8

Tab. 3: Mechanical properties of welded joints made by specific methods.

Welding method	Statistical parameter	Mechanical properties		
		$S_{y0.2}$ [MPa]	S_u [MPa]	A [%]
Method 131 mechanized	Average value	137.0	310.4	12.9
	Standard deviation	8.7	3.2	0.9
Method 131 semi-automatic	Average value	139.6	314.5	19.1
	Standard deviation	0.9	0.2	0.6

a) b)

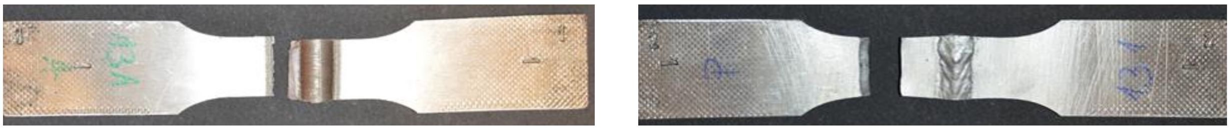

Fig. 3: Form of damage to welded joints samples made using the method: a) 131 mechanized; b) 131 semi-automatic.

3. Analysis of tests results and conclusions

Based on the results of the research, it was found that:

a) the adopted welding energy has an effect on changing the mechanical properties of welding joints made using the 131 method,

b) there was a decrease in the yield strength $S_{y0.2}$ welded joints in relation to the parent material ($S_{y0.2}$ = 150.4 MPa) by: about 9.0 % for method 131 mechanized, about 7.8 % for method 131 semi-automatic,

c) the plasticity of the material decreased, which is manifested in a change in the value of welded joint samples elongation A in relation to the parent material (A = 25.6 %) by: about 49.6% for method 131 mechanized, about 25.4 % for method 131 semi-automatic,

d) a change in the mechanical properties of welded joints, resulting from a change in process parameters, affects the performance of strength and durability structural elements calculations (Lewandowski et al., 2018).

References

Graczewski, A., Ligaj, B., Gietka, T. (2019) Influence of the Welding Method on the Strength of Structural Elements of Machines Made of Aluminum Alloy EN AW-5754, Scientific Session on Applied Mechanics X, Book Series: AIP Conference Proceedings, vol. 2077, Article Number: UNSP 020023, doi:10.1063/1.5091884.

Lewandowski, M., Ligaj, B., Gietka, T. (2018) Calculations of Fatigue Life of Welded Construction Elements made of Aluminum Alloy AW-5754, Engineering Mechanics 2018 Proceedings, vol. 24, pp. 505-508, doi:10.21495/91-8-505.

Ligaj, B., Wirwicki, M., Karolewska, K., Jasinska, A. (2018) Experimental studies of glued Aluminum-glass joints, 3rd International Conference on Science, Technology, and Interdisciplinary Research (IC-Star), Book Series: IOP Conference Series-Materials Science and Engineering, vol: 344, no. UNSP 012014, doi:10.1088/1757-899X/344/1/012014.

Łukasiewicz, M., Falęcki, P., Kałaczyński, T., Żółtowski, B., Musiał, J., Wilczarska, J., Kostek, R. (2018) Analysis of the thermovision diagnostics potential in the light system elements. 24th International Conference on Engineering Mechanics, vol. 24, pp. 513-516.

Mańka, E., Słomion, M., Matuszewski, M. (2018) Constructional features of ropes in functional units of mining shaft hoist. Acta Mechanica et Automatica, vol. 12, Iss. 1, pp. 66-71.

Muślewski, Ł., Pająk, M., Grządziela, A., Musiał, J. (2015) Analysis of vibration time histories in the time domain for propulsion systems of minesweepers Journal of Vibroengineering, vol. 17, Iss. 3, pp. 1309-1316.

Wirwicki, M., Topolinski, T. (2014) Zirconium dioxide - static test on glued connections, Book Series: Engineering Mechanics, pp. 724-727.

Woźny, P., Błachnio, J. (2016) Assessment of the quality of welded joints of aluminum alloys by computed tomography methods, Studies & Proceedings of Polish Association for Knowledge Management, no. 80, (in Polish).

Woźny, P., Błachnio, J., Dragan, K. (2017) Quality of welds on Al alloys of military aircraft made by arc welding, Journal of KONBiN, no. 44, (in Polish).