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MECHANICAL PROPERTIES OF 5083, 5059 AND 7020 ALUMINIUM ALLOYS AND THEIR JOINTS WELDED BY FSW

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Abstract

The article presents the research results on the mechanical properties of aluminum alloy 7020 and its friction stir welded (FSW) joints. For comparison alloy 5083 – the most currently used in shipbuilding alloy was chosen as well as 5059 - the new high-strength alloy. Besides the native material alloys there were investigated their joints welded by FSW - the same method as alloy 7020. Welding parameters used for the connection of the sheets made of 7020, 5083 and 5059 alloys were presented. Metallographic analysis showed the correct construction of structural bonded joints.

Friction Stir Welding (FSW) – a new technology can be successfully used for butt welding of different types of aluminum alloy sheets. FSW method can be an alternative to traditional arc welding methods i.e. MIG or TIG. The research was carried out using a static tensile test in accordance with the requirements of the Polish Standards PN-EN ISO 4136:2011 and PN-EN ISO 6892-1:2010. Flat samples cut perpendicular to the direction of rolling were used. The research was conducted at the temperature of + 20ºC.

The 7020 alloy has higher strength properties then alloys: 5083 and 5059. The yield stress is higher by 14.8% compared to 5083 alloy, and by 11.7% compared to the alloy 5059. Plastic properties of an alloy 7020 are the lowest, but with reserves meet the requirements of classification societies. The joints welded by FSW of 7020 alloy have higher strength properties then joints of alloys: 5083 and 5059. The yield stress achieves the highest value for alloy 7020 and is 24.2% higher than for 5083 alloy and 11.5% for the 5059 alloy. Despite the strength properties also plastic properties are best for 7020 alloy joints.

Keywords: *Friction Stir Welding (FSW), aluminium alloys, joints, welding, mechanical properties, shipbuilding*

1. Introduction

Aluminium alloys are materials which find worldwide industrial applications, including shipbuilding. Their application to ship hull structures is increasing as the alloys make it possible to lower significantly mass of structures as compared with that of steel structures. By using Al-alloys lowering the mass by about 50% can be obtained, which makes it possible to increase ship buoyancy, or at maintained buoyancy to increase its load carrying capacity or speed, as well as to improve its stability [4]. For that reasons Al-alloys are used i.e. for construction of ship hull and superstructures. Among weldable Al-alloys suitable to plastic working the group of Al-Mg alloys (of 5xxx- series) of good weldability and relatively good service conditions are still the most popular. Their relative insuspectibility to layer and stress corrosion is advantageous, and their disadvantage is low strength of welded joints of elements made of them, not exceeding 300 MPa. In order to more intensive craft of weight Al-Zn-Mg alloys (7xxx series) became more interesting. They are characteristic of higher strength properties as compared with those of Al-Mg alloys. Susceptibility to layer and stress corrosion is a disadvantage of Al-Zn-Mg alloys. Multi-year research has revealed that thermal working, chemical composition and welding technology (welding method, kind of fillers, type of joint) are responsible for stress corrosion susceptibility of the alloys [1-4]. Practically all welded joints made of alloys of this group by means of traditional MIG or TIG methods do not show sufficient resistance to stress or layer corrosion, hence only Al-Mg alloys of 5xxx- series are the only materials applicable to hull structures of light-weight ships.

However, the higher strength alloys are used in ship design elements that have no direct contact with sea water, or are secured by suitable paint coatings.

An alternative to traditional methods such as MIG or TIG welding may be Friction Stir Welding (FSW). In the method a tool fitted with rotary mandrel located in the place of welding the pressed-down plates is used to heat and plastify the material. After putting the mandrel-fitted tool into rotation, friction heating and plastifying the plate material in its direct vicinity occurs, and slow sliding the entire system follows along contact line (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 [5, 6]. 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.

The aim of this paper is to determine the mechanical properties of the alloy AlZn5Mg1 (AW-7020) and its joints welded by FSW compared to 5xxx series alloys and their joints made by the same method. As a reference point were chosen alloys: 5083 – the most often currently used in shipbuilding and the new alloy 5059 - with improved strength.

2. The research methodology

The testing used EN AW-7020 T6 aluminium alloy (supersaturated and artificially aged). For a comparative study was carried out using aluminum alloy EN AW-5083 (AlMg4.5Mn0.7) and AW-5059 ALUSTAR (AlMg5Mn0.7). The chemical composition of alloys are given in Tab. 1.

Tab. 1. Chemical composition of 7020, 5083 and 5059 aluminum alloys

Alloy	Chemical composition [%]									
	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Zr	Al
7020	0.30	0.35	0.10	0.24	1.30	0.14	4.70	0.08	0.07	The rest
5083	0.195	0.18	0.09	0.662	4.745	0.111	0.042	0.025	0.037	The rest
5059	0.037	0.09	0.01	0.76	5.41	0.003	0.57	0.024	0.11	The rest

Butt joints of 7020, 5083 and 5059 alloys sheets were made using FSW. Sheet thickness was g = 10 mm. The sheets were welded on both sides using identical 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.

Welds made by FSW method have been verified by X-ray flaw detection and showed no welding defects.

Tab. 2. FSW parameters of 7020, 5083 and 5059 aluminum alloys sheets

Tool dimensions			Angle of tool deflection α [°]	Mandrel's rotary speed V_n [rpm]	Welding speed V_z [mm/min]
D [mm]	d [mm]	h [mm]			
25	10	5.8	88.5	450	180

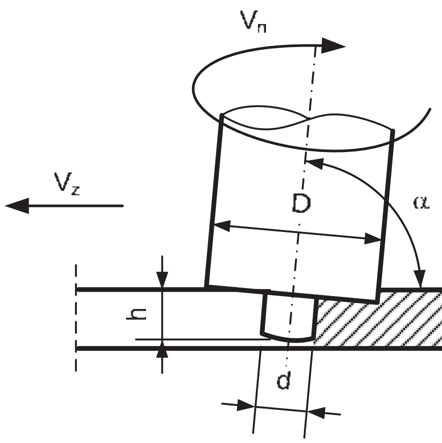

Fig. 1. The diagram of FSW [6]

In order to determine the mechanical properties was carried out static tensile test. Tensile test was carried out in accordance with PN-EN ISO 4136:2011 and PN-EN ISO 6892-1:2010 [7, 8]. Used flat samples cut perpendicular to the direction of rolling. The specimens view is presented in Fig. 2.

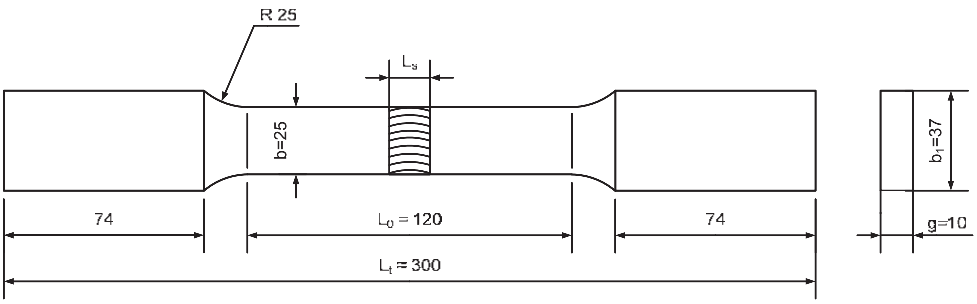

Fig. 2. The shape and dimensions of specimens used in static tensile test

The study was performed at ambient temperature, i.e. + 20 ° C ± 2. Tensile testing was carried out on samples with flat-type testing machine EU-40 on the strength of 200 kN ± 1. During the study determined parameters such as ultimate tensile strength UTS, yield stress YS, and elongation EL.

3. The research results

The mechanical properties of alloys 7020, 5083 and 5059, and their joints welded by FSW are shown in Tab. 3.

Tab. 3. Mechanical properties of alloys: 7020, 5083, 5059 and their joints welded by FSW

Alloy	Welding method	UTS [MPa]	YS [MPa]	EL [%]
7020	Native material	373	317	14.2
	FSW	367	314	13.8
5083	Native material	346	270	19.7
	FSW	322	238	10.4
5059	Native material	401	280	16.2
	FSW	367	278	12.7

The results are presented graphically in the chart (Fig. 3).

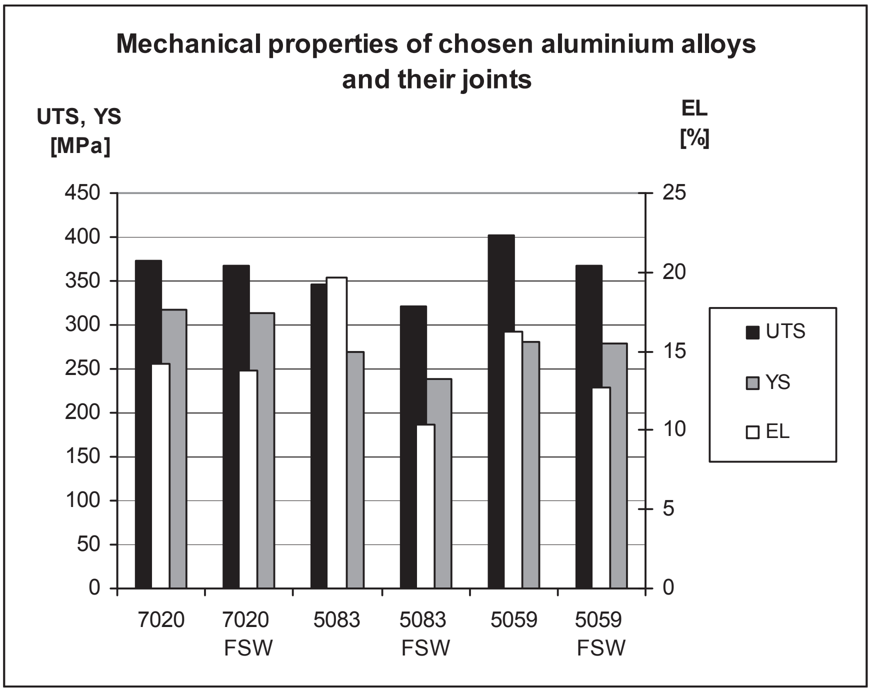

Fig. 3. Graphic interpretation of mechanical properties of compared alloys: 7020, 5083, 5059 and their joints welded by FSW

Comparing the mechanical properties of the same alloys with each other can be seen that 7020 alloy has higher strength properties of alloys 5083 and 5059. While the tensile strength of 7020 alloy is higher compared to alloy 5083 by 7.2% and less than the 5059 alloy by 7.5%, it's yield stress, a parameter which is a rams into account by the designers, is much greater .This parameter is higher respectively by 14.8% compared to 5083 alloy, and by 11.7% compared to the alloy 5059. When considering plastic properties of an alloy 7020 are the lowest, but with reserves meet the requirements of classification societies, including the PRS. The minimum value of elongation must exceed 10%.

Comparison of FSW welded joints indicates that the best properties characterized by a 7020 alloy. Tensile strength of 7020 alloy joint is the same as for alloy 5059 but about 12% greater than 5083. Definitely more pronounced difference is the yield strength. This parameter achieves the highest value for alloy 7020 and is 24.2% higher than for alloy 5083 and 11.5% for the 5059 alloy. Despite the strength properties also plastic properties are best for 7020 alloy joints.

4. **Summary**

Testing the mechanical properties conducted using a static tensile test on flat specimens of alloys 7020, 5083 and 5059 showed that the alloy 7020 is characterized by the highest strength properties. Plastic properties of the alloy are the lowest, however, sufficient for applications in the shipbuilding industry.

In the case of a FSW welded joints of aluminum alloys selected mechanical properties of the alloy are the highest for the 7020. The plasticity of this connection is the best too. Elongation reaches a value of 13.8% which is sufficient due to requirements of classification societies. Also joints 5083 and 5059 alloys are characterized by sufficient ductility due to the requirements of the shipping industry - the minimum value of elongation must exceed 10%.

In the case of joints 7020 and 5059 alloys yield strength practically does not differ from the native material. This eliminates the weakest part of the structure which so far has been weld.

Because the joining is carried out at a relatively low temperature of about 450 °C, significantly below the melting point, the heat-affected zone is minimal. Typically, the heat affected zone is characterized by the lowest strength properties of whole joint. This is especially important in the case of 7020 alloy, which is heat treated.

The research of the mechanical properties of alloys 7020, 5083 and 5059 and their joints welded by FSW allow to conclude that the application of Friction Stir Welding is possible to build the structure, of the investigated alloys, in shipbuilding industry.

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