# INFLUENCE OF JOINING METHOD FOR MECHANICAL PROPERTIES OF 7020 ALUMINIUM ALLOY JOINTS

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**Abstract**

*The article presents the research results on the mechanical properties of aluminum alloy 7020 and its FSW and MIG welded joints. Welding parameters used for the connection of the sheets made of 7020 alloy 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, especially MIG, which is the most common method of joining aluminum alloys used in shipbuilding. 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.*

*Friction stir welded joints of 7020 alloy have higher strength properties compared to MIG welded joints. The yield stress of FSW joint is higher by 14.2% compared to MIG welded joint, and at the same level as the native material. Plastic properties of FSW joint are much higher than MIG joint (over 40%). Confirmation of high strength properties of FSW joint is the place of crack - beyond the weld in the native material.*

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

## 1. Introduction

Aluminium alloys are getting more and more interest in the shipbuilding industry as these alloys allow a significant reduction in ship structure weight compared with the weight of steel structures. The use of aluminium reduces the weight by about 50%, thereby increasing the displacement of the vessel and maintaining the displacement for load or speed increase and stability improvement. 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. 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. An alternative to these alloys could be the Al-Zn-Mg (7xxx series) alloys. 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 [1-3, 5]. 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 [4, 6, 7]. 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 and MIG method.

## 2. The research methodology

The testing used EN AW-7020 T6 aluminium alloy (supersaturated and artificially aged). The chemical composition of 7020 alloy is given in Tab. 1.

*Tab. 1. Chemical composition of investigated aluminium 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 | The rest |

Butt joints of 7020 alloy 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.

*Tab. 2. FSW parameters of 7020 aluminum alloy sheets*

| Tool dimensions | | | Angle of tool deflection $\alpha$ [°] | 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 |

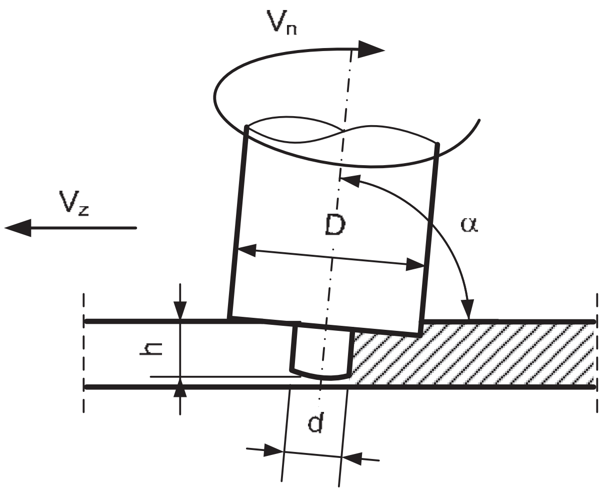


*Fig. 1. The diagram of FSW [7]*

Sheet alloy 7020 with a thickness g = 12 mm were welded by the MIG method. Preparation of welds was made in accordance with the procedures required by the shipbuilding industry. Cutting and beveling the edges (at the Y by an angle of 60º) was performed by mechanical processing. The surfaces of the groove and lying in its immediate vicinity, before welding were cleaned of oxides by means of rotating stainless steel brushes and then skimmed petroleum ether. Preparation for welding and weld joints were made in a closed position to protect against weather. To avoid distortion welding joints was performed in an arrangement, and the relief was only after the terminal connector has cooled down. Installation of the joints was carried out using the bonding joints. During the welding of cracked tack welds were cut, because of the possibility of cracks even after careful melting cracked welds. Welds after the stitches were cut finishes bottom of the weld face, and then put a layer root pass.

For the 7020 alloy welding wire used alloy AlMg5 (5356) - Nertalic AG5 SAF. The chemical composition of welding wire is shown in Tab. 3 and welding parameters are presented in Tab. 4.

As the shielding gas argon was used with a purity of 99.99%.

*Tab. 3. Chemical composition of welding wire - 5356 alloy*

| Chemical composition [%] | | | | | | | |
|---|---|---|---|---|---|---|---|
| Mg | Zn | Cu | Si | Fe | Mn | Ti | Al |
| 5.0 | max. 0.10 | 0.10 | max. 0.25 | 0.40 | 0.15 | 0.10 | The rest |

*Tab. 4. MIG welding parameters of 7020 aluminum alloy sheets*

| Diameter of welding wire [mm] | Welding current [A] | Voltage [V] | Number of layers | Argon consumption [$m^3/h$] |
|---|---|---|---|---|
| 1.6 | 190 - 230 | 28 | 4 + prewelding | 16 - 18 |

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. Used flat samples cut perpendicular to the direction of rolling. The specimens view is presented in Fig. 2.

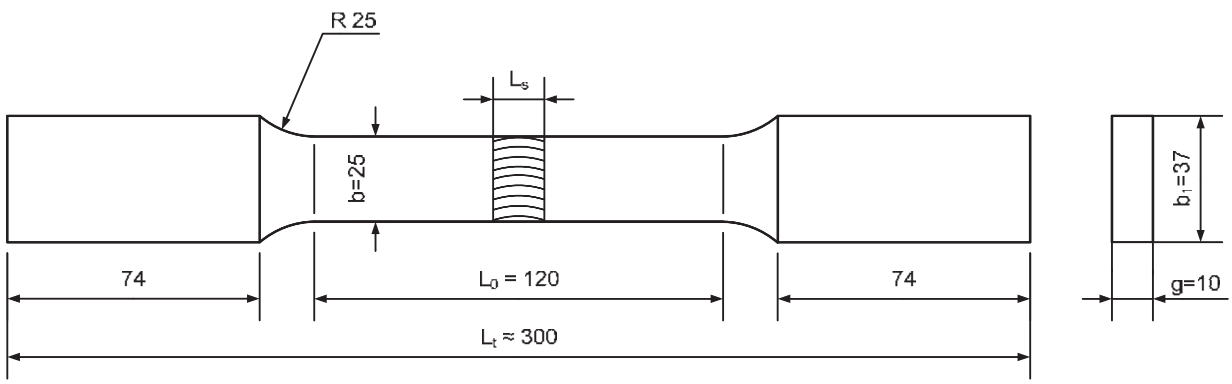


*Fig. 2. The shape and dimensions of specimens used in static tensile test (g=10 mm for FSW, g=12 mm for native material 7020 and MIG)*

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 7020 alloy and its joints welded by FSW and MIG are shown in Tab. 5 and they are presented graphically in the chart (Fig. 3).*

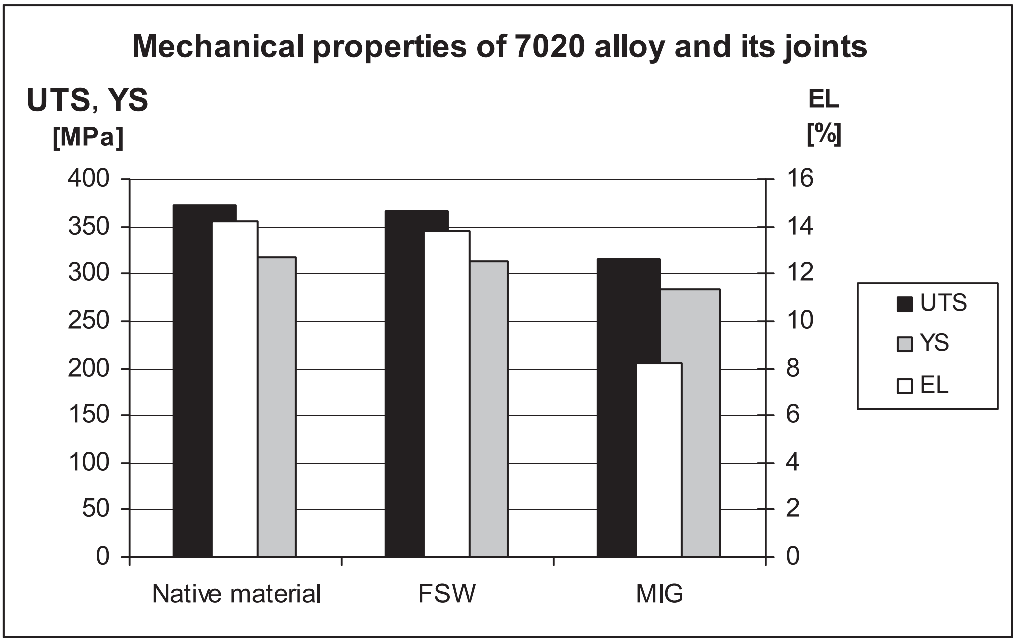


*Fig. 3. Graphic interpretation of mechanical properties of 7020 alloy and its FSW and MIG welded joints*

*Tab. 5. Mechanical properties of 7020 alloy and its joints welded by FSW and MIG*

| Welding method | UTS [MPa] | YS [MPa] | EL [%] |
|---|---|---|---|
| Native material | 373 | 317 | 14.2 |
| FSW | 367 | 314 | 13.8 |
| MIG | 315 | 283 | 8.2 |

The mechanical properties of joints welded by FSW are practically the same as the native material. This is confirmed by the crack place, that in all the FSW welded specimens was found in the native material at a distance of about 20 mm from the weld. Heat affected zone (HAZ) in the case of Friction Stir Welding, is minimal, concluded that the cracks was in the native material – unchanged by the heat of welding. An exemplary view of FSW welded specimen subjected to the static tensile test is shown in Fig. 4.

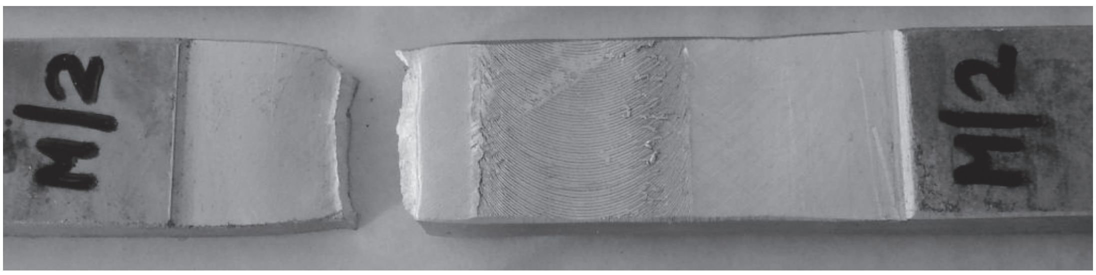


*Fig. 4. Sample view of 7020 alloy welded by FSW subjected to the static tensile test - a crack in the native material*

In the case of joints bonded using traditional arc welding method – MIG, both strength and plastic properties decreased compared to the native material. This decrease was for the Ultimate Tensile Strength (UTS) approximately 15% and in the case of the yield strength (YS) approximately 10%. The most noticeable change was in the plastic properties - elongation (EL) of MIG welded joint has fallen by as much as 42% comparing to the native material. All MIG welded samples were cracking at the weld. An exemplary view of the MIG welded sample subjected to the static tensile test is shown in Fig. 5.

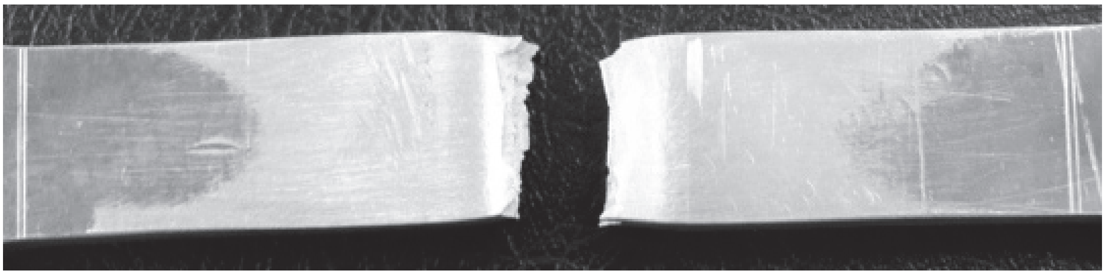

*Fig. 5. Sample view of 7020 alloy welded by MIG subjected to the static tensile test - a crack in the weld*

## 4. Summary

Testing the mechanical properties conducted using a static tensile test on flat specimens of 7020 aluminium alloy and its joints welded by FSW and MIG showed that the FSW welded joints are characterized by the highest strength properties. All specimens cracked in the native material, not in the joint and even in the heat affected zone (HAZ), what confirm that the joint has higher strength properties than aluminium alloy 7020. This is the reason why all researched parameters practically not differ between FSW joints and the native material. High strength of FSW joint eliminates the weakest part of the structure which so far has been weld (that situation is in the case of MIG joints).

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.

In the case of native material 7020 aluminium alloy and its joints welded by FSW elongation reaches a value of 13.8% – 14.2% which is sufficient due to requirements of classification societies - the minimum value of elongation should exceed 10%. In the case of joints welded by traditional MIG method plastic parameter (EL) reaches 8.2% what is over 40% lower than the FSW joint. That could be a problem in some more responsible ship constructions.

The research of the mechanical properties of 7020 aluminium alloy and its joints welded by FSW and MIG allow to conclude that the application of Friction Stir Welding is possible to build some constructions in shipbuilding industry.

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