ISSN: 1231-4005
e-ISSN: 2354-0133
DOI: 10.5604/01.3001.0010.2804

THE POSSIBILITY OF APPLICATION THERMOGRAPHY METHOD FOR CONTROLLING FRICTION STIR WELDING OF AW-5083 ALUMINIUM ALLOY SHEETS

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Abstract

The article presents the research results of thermography method used for monitoring process of friction stir welding of sheets made of AW-5083 aluminium alloy. Nowadays monitoring the temperature is used in many fields of science, including in the diagnosis of machining and joining processes such as turning, grinding, milling, welding, etc.

Friction Stir Welding (FSW) – a new technology can be successfully used for butt-welding of different types of aluminium alloy sheets. FSW method can be an alternative to traditional arc welding methods i.e. MIG or TIG. The joining process was carried out on laboratory stand built on the basis of universal milling machine FWA-31. The parameters of joining AW-5083 alloy sheets chosen after optimization of the FSW process were presented.

For determining temperature and its distribution in tool-workpieces contact area, noncontact infrared method was chosen. Infrared camera ThermoGear G100 produced by NEC Avio Infrared Technologies Co., Ltd. was used. The camera has two measuring ranges defined: -40-+120°C and 0-500°C.

Average value of the temperature between the tool and joined metal sheets was about 380°C in case when correct parameters of welding were chosen. Controlling the temperature allow catch the moment when the material of joined sheets is plasticized (370°C) which is best to start the linear moving of the tool and the same start of welding.

The study can be the basis for the use of thermography method to monitor the process and determine the parameters of the friction stir welding for obtaining a high quality joint.

Keywords: *Friction Stir Welding − FSW, thermography, monitoring, 5xxx aluminium alloy, shipbuilding*

1. Introduction

Aluminium alloys are materials, which are 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 weld able 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 [5, 7, 9]. The advantage of these alloys is their relative insensitivity to layer corrosion and stress corrosion, the disadvantage – relatively low strength of welded joints, below 300 MPa.

Continuous development of welding technology (welding method, type of fillers, type of connector) resulted in significant improvements in the properties of welds but their strength is still less than the base material [1-3, 5].

An alternative to traditional methods such as MIG or 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. 1a). 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 simplicity of obtaining joints with high, reproducible properties [1, 3, 5, 6, 9]. Compared to traditional arc welding methods used in the shipbuilding industry, this method does not require such time-consuming preparation of joined plates and the use of additional materials, such as filler material and shielding gases. 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. Supply of large amounts of heat causes structural changes in the material causing the heterogeneity of construction and thus differentiation of the mechanical properties of cross-section of the joint.

The industrial applicability of the most popular in shipbuilding industry 5xxx series alloy 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. Constant development of FSW method and methods of monitoring the joining process results obtaining joints with the best possible quality.

Measuring the temperature of joining and machining processes is considered as a basic method used for controlling that processes [8]. One of the methods for monitoring friction stir welding of metal sheets is the thermography method.

The aim of this study was to determine the possibility of monitoring the friction stir welding process using thermography method. AW-5083 alloy sheets were joined by FSW method using different welding parameters. During optimization of welding process, the temperature was monitor in real time and recorded for further analysing.

2. The research methodology

The study used EN AW-5083 H321 aluminium alloy. The chemical composition of the alloy is given in Tab. 1.

Tab. 1. Chemical composition of researched aluminium alloy

Chemical composition (%)									
Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Zr	Al
0.195	0.18	0.09	0.662	4.745	0.111	0.042	0.025	0.037	balance

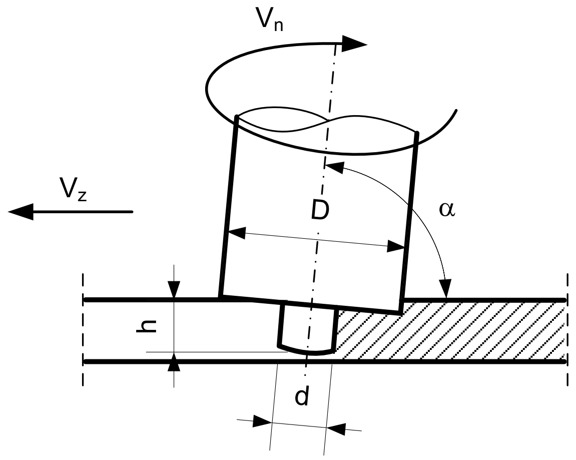
Butt joints of AW-5083 alloy sheets were made using FSW. Sheet thickness was g = 12 mm. With exception of provided general cleanliness of the sheets there was not used any degreasing agent interfaces connected elements.

For joining sheets made of 5083 alloy was used tool with conical pin. For optimizing quality of joints were used different parameters: angle of tool deflection, tool's rotary speed and welding speed. The welding parameters are shown in Tab. 2. The sheets were welded on both sides using identical parameters.

Tab. 2. FSW parameters of 5083 aluminium alloy sheets

Kind of tool	Tool dimensions			Angle of tool deflection α [°]	Tool's rotary speed V_n [rpm]	Welding speed V_z [mm/min]
	D [mm]	d [mm]	h [mm]			
With conical pin	20	10 – in the top 6 – in the bottom	7.5	88-89.5	150-750	52-180

The diagram of friction stir welding and view of the tool are shown in Fig. 1.



a) b)

Fig. 1. The diagram of FSW (a) and view of tool used in research (b)

The stand was built on the basis of universal milling machine FWA-31. The view of laboratory stand used in research is shown in Fig. 2 as well as thermography camera used for monitoring joining process.

a) b)

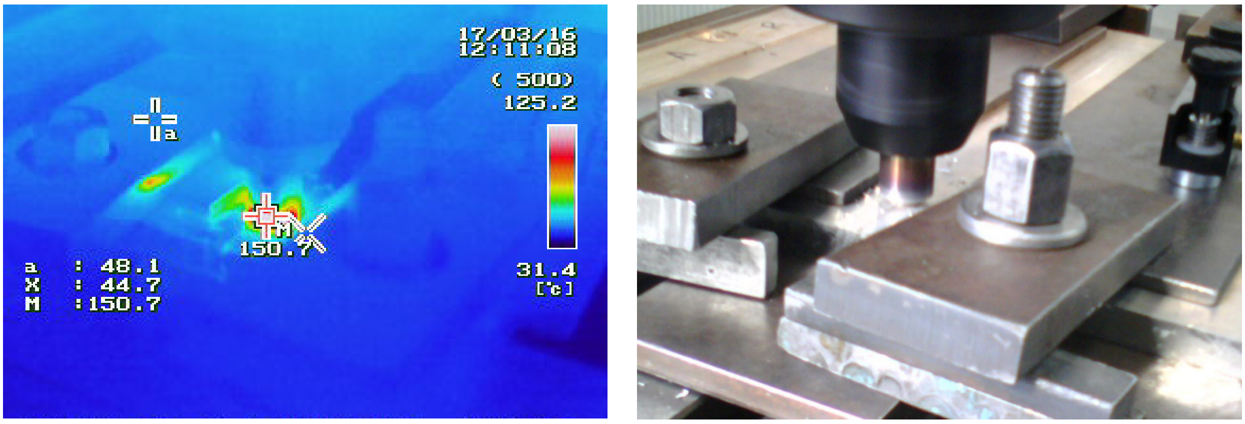
Fig. 2. View of: a) laboratory stand, b) thermography camera, used in research

For determining temperature and its distribution in tool-workpieces contact area, noncontact infrared method was chosen. This was mainly due to thermography ability to measure temperatures over some area, not only in point, in real time. As a result of measurement, it is obtained a data set that is presented in a form of a colourful map: a thermogram [10].

For measuring the temperature, infrared camera ThermoGear G100 produced by NEC Avio Infrared Technologies Co., Ltd. was used. The camera has two measuring ranges defined: -40-120 and 0-500°C. The measurement accuracy is ±2°C or 2% of reading, whichever is greater. The thermogram consists of 76800 measuring points (320 points in 240 lines) [11]. The image capture support functions of a 2-megapixel visible camera. To analyse the results, computer software InfReC Analyzer NS9500 Lite generate Excel file report with temperature value for each point.

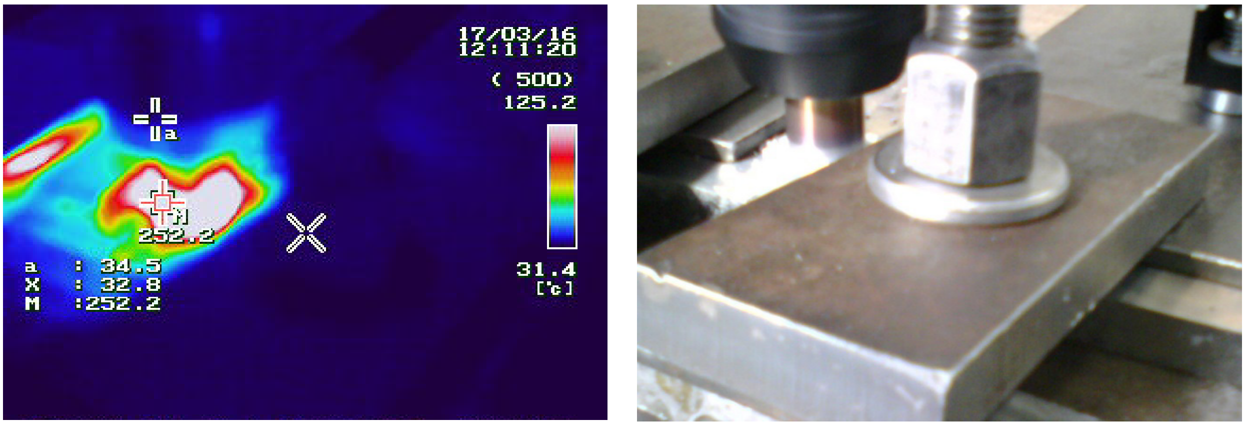
3. The research results

The data recorded during research can be shown as pictures obtained from two cameras: infrared and visual. In Fig. 3-5 are shown thermograms and visual pictures, done at the same time, during monitoring friction stir welding, in first stage of that process – plasticizing.



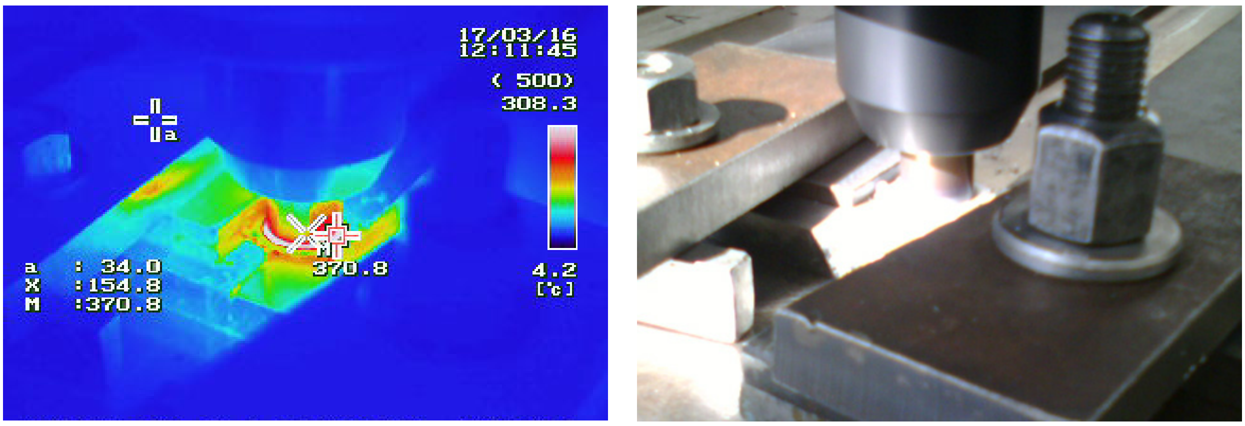
a) *b)*

Fig. 3. Thermogram (a) and visual picture (b) of FSW process during plasticizing – relatively low temperature in contact point (150.7°C)



a) *b)*

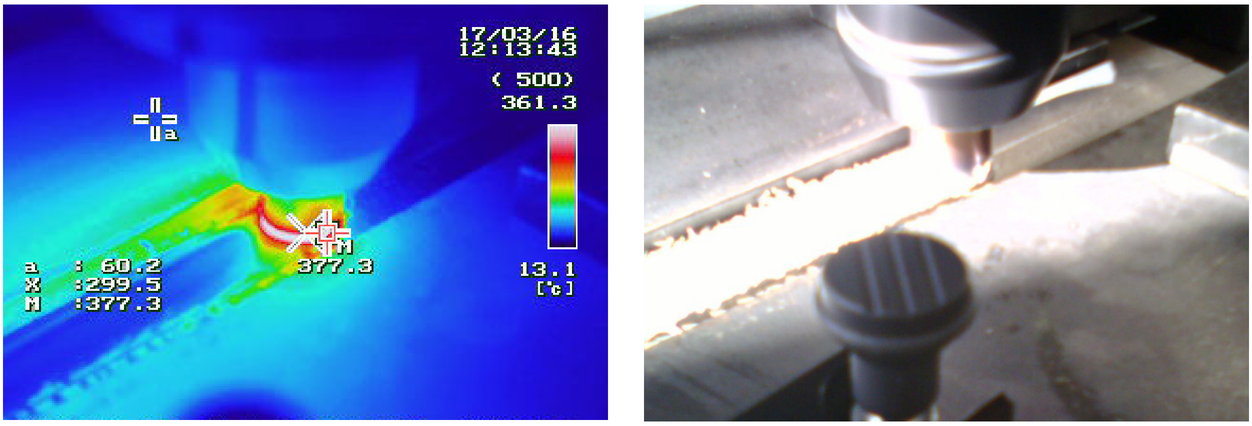
Fig. 4. Thermogram (a) and visual picture (b) of FSW process during plasticizing – medium temperature in contact point (252.2°C)



a) *b)*

Fig. 5. Thermogram (a) and visual picture (b) of FSW process during plasticizing – sufficient temperature to start welding (370.8°C)

Monitoring of temperature of FSW process allows find good moment for starting welding. In Fig. 6 are shown thermogram and photo of friction stir welding during joining process with correct temperature.



a) *b)*

Fig. 6. Thermogram (a) and visual picture (b) of FSW process during welding – correct temperature allowing obtain high quality of joint (377.3 °C)

During plasticizing temperature rise up to correct level ensuring obtain high quality of joint. Starting welding with too low temperature causes occurrence big forces in the tool. In the extremely case that forces can be so big that may cause breakage of the tool. View of broken tool, caused by welding with too low temperature, is shown in Fig. 7.

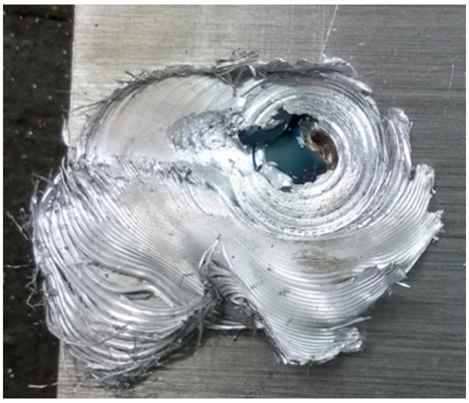


Fig. 7. View of broken FSW tool into 5083 alloy sheet – result of joining with too low temperature

On the other hand, too high temperature of welding may cause occurrence of welding defects in joints, e.g. discontinuities or pores. An example of the welded joint with too high temperature is shown in Fig. 8.

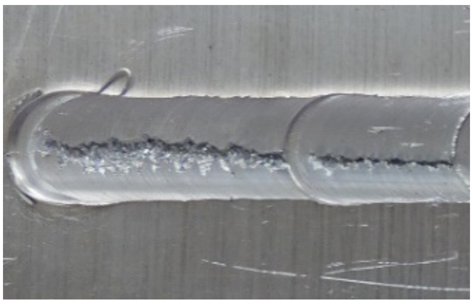


Fig. 8. An example of friction stir welded joint with too high temperature – visible welding defects

The optimizing process of welding parameters using thermography method enables obtaining proper joint without flaws. View of an exemplary joint without visible welding defects is shown in Fig. 9.

Fig. 9. An example of friction stir welded joint with correct temperature – lack of welding defects

4. Summary and conclusions

Friction Stir Welding is an alternative to traditional methods of arc welding for joining aluminum alloys. Bonding occurs by mixing of the plasticized material of joined sheets at a temperature of about 400°C, which is in the solid state. This makes it possible to obtain joints having a higher strength compared to welds obtained by traditional MIG or TIG methods. In the research were used joints of 5083 aluminum alloy − the most commonly used in shipbuilding.

The 5083 alloy is susceptible to the strengthening of plastic processing. This alloy sheets were− brought in H321 that is hardened after cold working.

One of the ways of monitoring the welding process is a thermovision method. This is a non-contact method for controlling the temperature of contact area between the tool and the joined metal sheets. Welding temperature control allows selecting the right moment to start welding after plasticizing the material in the first phase of the process. During the study, the process temperature was determined to provide a high quality joint. The optimum temperature of starting the welding, when the material is plasticized, is approximately 370°C, while the temperature range of the welding process should be approximately 370 – 400°C. Too low welding temperature causes high forces on the tool, which in extreme cases can cause the breakage of the tool pin. Too high temperature may result in occurrence of welding defects in the joint – discontinuities and pores.

References

[1] Anderson, T., *New developments within the Aluminium Shipbuilding Industry*, Svetsaren, Vol. 58, No. 1, pp. 3-5, 2003.

[2] Czechowski, M., *Effect of anodic polarization on stress corrosion cracking of some aluminium alloys*, Advances in Materials Science, Vol. 7, No. 1/11, pp. 13-20, 2007.

[3] Czechowski, M., Pietras, A., Zadroga, L., *The properties of aluminium alloys 5xxx series welded by new technology Friction Stir Welding*, Inżynieria Materiałowa, Nr 6/137, pp. 264-266, 2003.

[4] Dudzik, K., *Influence of joining method for hardness distribution in joints of AlZn5Mg1 alloy,* Journal of KONES Powertrain and Transport, Vol. 17, No. 4, pp. 137-141, Warsaw 2010.

[5] Dudzik, K., Charchalis, A., *Mechanical properties of 5083, 5059 and 7020 aluminium alloys and their joints welded by FSW*, Journal of KONES Powertrain and Transport, Vol. 20, No. 2, pp. 69-73; Warsaw 2013.

[6] Dudzik, K., Czechowski, M., *Analysis of possible shipbuilding application of Friction Stir Welding (FSW) method to joining elements made of AlZn5Mg1 alloy*, Polish Maritime Research No.4, 2009, pp. 37-40, 2009.

[7] Hirata, T., Oguri, T., Hagino, H., Tsutomu, T.T, Chung, S.W., Takigawa, Y., Kenji, H.K., *Influence of friction stir welding parameters on grain size and formability in 5083 aluminum alloy*, Materials Science and Engineering, A 456, 2007.

[8] Labuda, W., Khudoley, A., *The influence of burnishing process on surface roughness of stainless steel researched by optical profiler*, In METAL 2016, 25th Anniversary International Conference on Metallurgy and Materials, Ostrava: TANGER, pp. 765-770, 2016.
[9] Lahti, K., *FSW – possibilities in shipbuilding*, Svetsaren, Vol. 58, No.1, pp. 6-8, 2003.
[10] Molenda, J., Charchalis, A., *Determining the emissivity at the tool-chip interface during S235JR steel turning,* Journal of KONES Powertrain and Transport, Vol. 22, No. 2, pp. 149-154, Warsaw 2015.
[11] www.nec-avio.co.jp.