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COMPARING NUMERICAL AND EXPERIMENTAL SOLUTIONS OF FRICTION STIR WELDING OF AN ALUMINIUM PLATE

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Abstract: *Friction Stir Welding (FSW) is one of the most effective solid state joining processes and has numerous potential applications in many industries. The aim of this paper is to describe an experimental method of measuring the thermal field during the FSW and compare it to the thermal-fluid simulation of FSW using the finite element method in program SYSWELD. The thermal results from the numerical simulation using SYSWELD are presented for aluminum alloy.*

Keywords: Friction Stir Welding (FSW), Aluminum alloy, Finite element method, Thermo-fluid model.

1. Introduction

Friction stir welding (FSW) is a relatively new joining technology which was developed and patented in 1991 by The Welding Institute (TWI) in the United Kingdom (Chen and Kovacevic, 2003). The description of the principle of friction stir welding is described in previous papers of the authors (Jančo et al., 2016, Jančo et al., 2019). This welding technique can be applied in the automobile, aerospace industries as well as other places of engineering (Frigaard et al., 2001, Feulvarch et al., 2007, Jančo et al., 2016).

2. Measuring the thermal field during Friction Stir Welding

Experimental measurements by a thermo-camera and thermocouples were made on the apparatus of the Welding Research Institute in Bratislava and Faculty of Mechanical Engineering STU in Bratislava. Thermography was chosen as the first measurement method (Fig. 1). Thermography enables non-contact measurements of the surface temperature of bodies. In principle, it is the sensing of an object emitting infrared radiation, which is directly dependent on the surface temperature of the monitored object during the experiment a FLIR® SC660 thermal imaging camera was used to measure the temperature field.

Fig. 1: Experimental measurement by FLIR® SC660.

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The result from this method are presented in the Fig. 2.

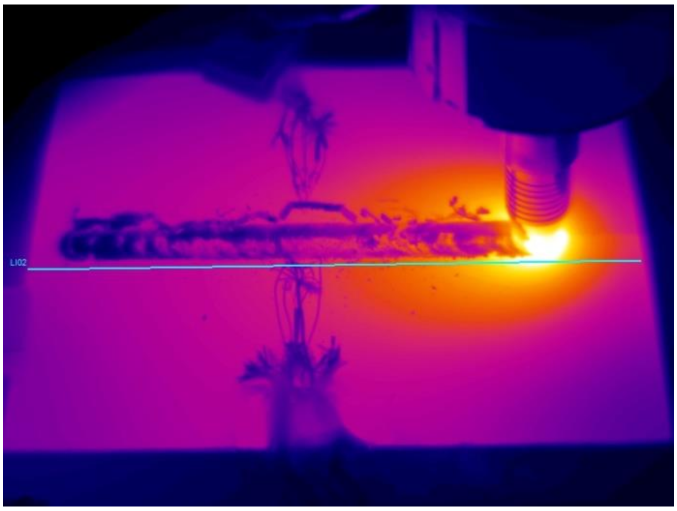

Fig. 2: Thermal imaging of a non-stationary temperature field on an aluminum plate.

The second way to verify the temperature field was by thermocouples. The position of thermocouples on experimentally welded plates is shown in Fig. 3.

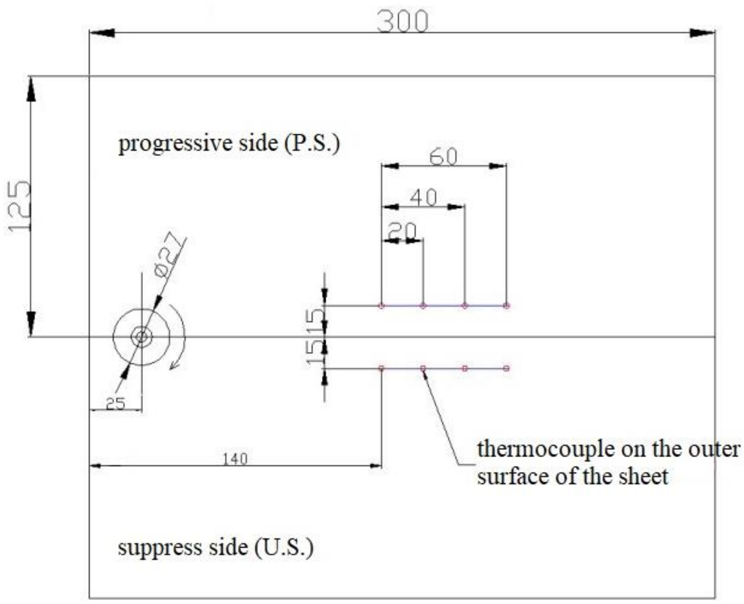

Fig. 3: Sensor location (Scheme).

The 4 points on the progressive side (P.S.) as well as the 4 points on the suppress side (U.S.) were evaluated using thermocouples, as per Fig. 3. The whole process of the experiment was also scanned by the thermo-camera in Fig. 1. Fig. 4 shows the result measured by the thermocouples at the point according to the diagram in Fig. 3.

3. Numerical solution of the thermal field during the Friction Stir Welding

For the numerical solution of the thermal field we used SYSWeld, a software, with the FSW (Friction Stir Welding) module. The steps of the solution are described in Jančo et al., 2016, Jančo et al., 2019. For the simulation aluminium alloy AlMg4.5Mn0.7 was used with material properties presented in Jančo et al., 2016, which is the function of temperature. The blacking plate was made of steel, again, the material properties are described in in Jančo et al., 2016. For the welding process we used the following properties: the friction coefficient was 0.238, the linear welding velocity was 1.67 mm/s, the tool rotation velocity was 41.89 rad.s^{-1}, the room temperature was 15°C and the heat exchange coefficient for convection was 19 W/(m^2.K). The theoretical background and equations of FSW module is described in Jančo et al., 2016.

The finite element model consists of 63261 elements and 70340 nodes as shown in Fig. 6. The boundary conditions are described in detail in Jančo et al., 2019. Results of the thermo-fluid analysis is presented in Fig. 7.

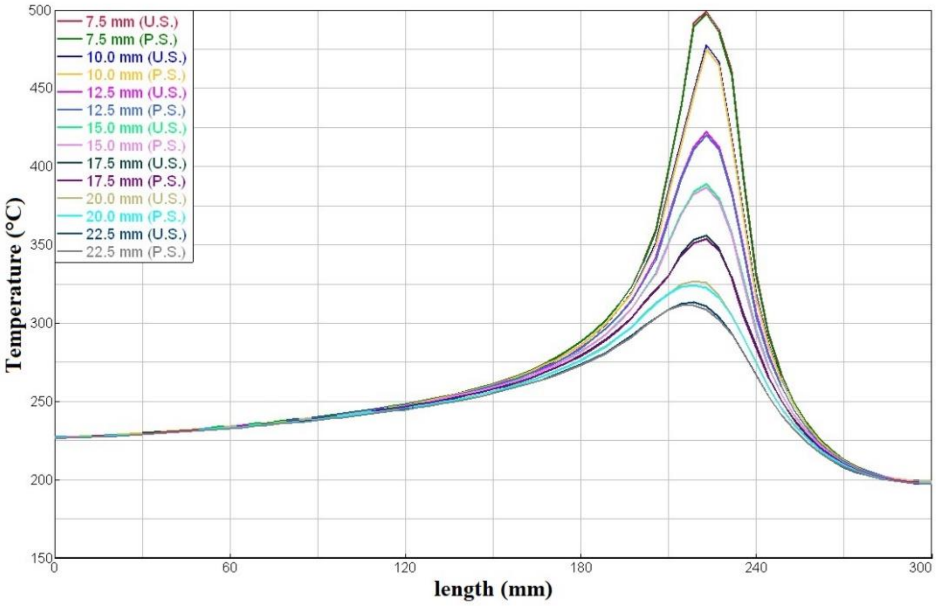

Fig. 4: Temperatures in selected points.

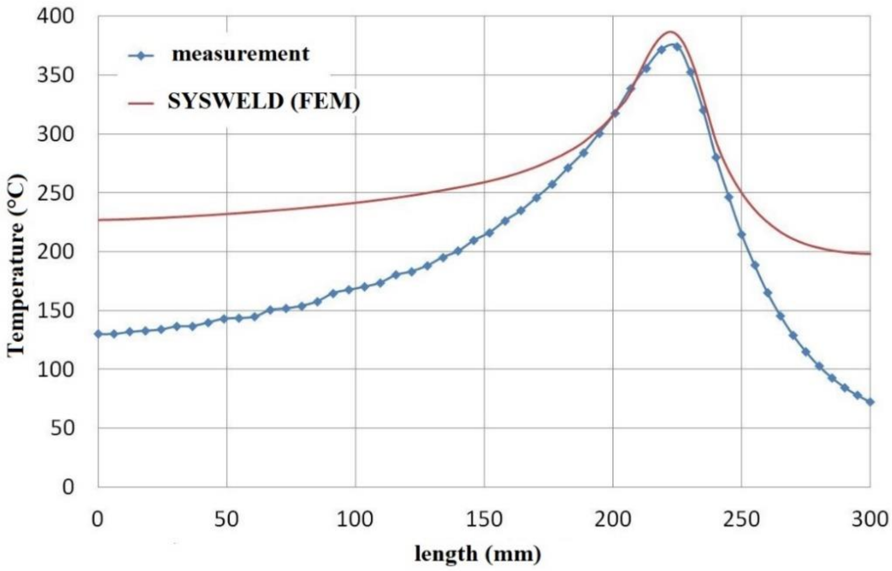

Fig. 5: Comparison of experiment results with numerical solution.

4. Conclusions

In this paper the experimental measurement of a thermal field taken with a FLIR® SC660 camera (see Fig. 1) and thermocouples (see Fig. 3) are presented. The result from the thermo camera is presented in Fig. 2. In section 3, the numerical solution of the thermal field is presented with the thermo-fluid analysis using the SYSWeld software and the FSW module. The result of the numerical solution of the thermal field calculated with SYSWeld and measured with the camera are in a good agreement. Maximum temperature is 525.2 °C at time 225 s in Fig. 7.

In Fig. 4 the graph of temperatures at a selected point from the weld line in the progress side (sign. P.S.) and suppressed side (sign. U.S.) are presented.

Modeling and measurement of the temperature evolution in the FSW of AlMg4.5Mn0.7 Al alloy is conducted, and the experimental values validate the efficiency of the proposed model.

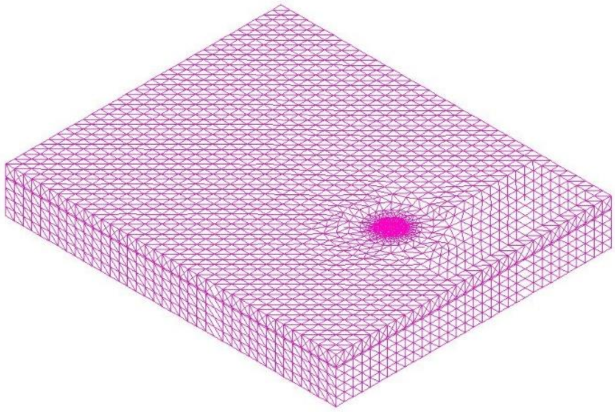

Fig. 6: FEM model for thermo-fluid analysis (sheet and backing plate).

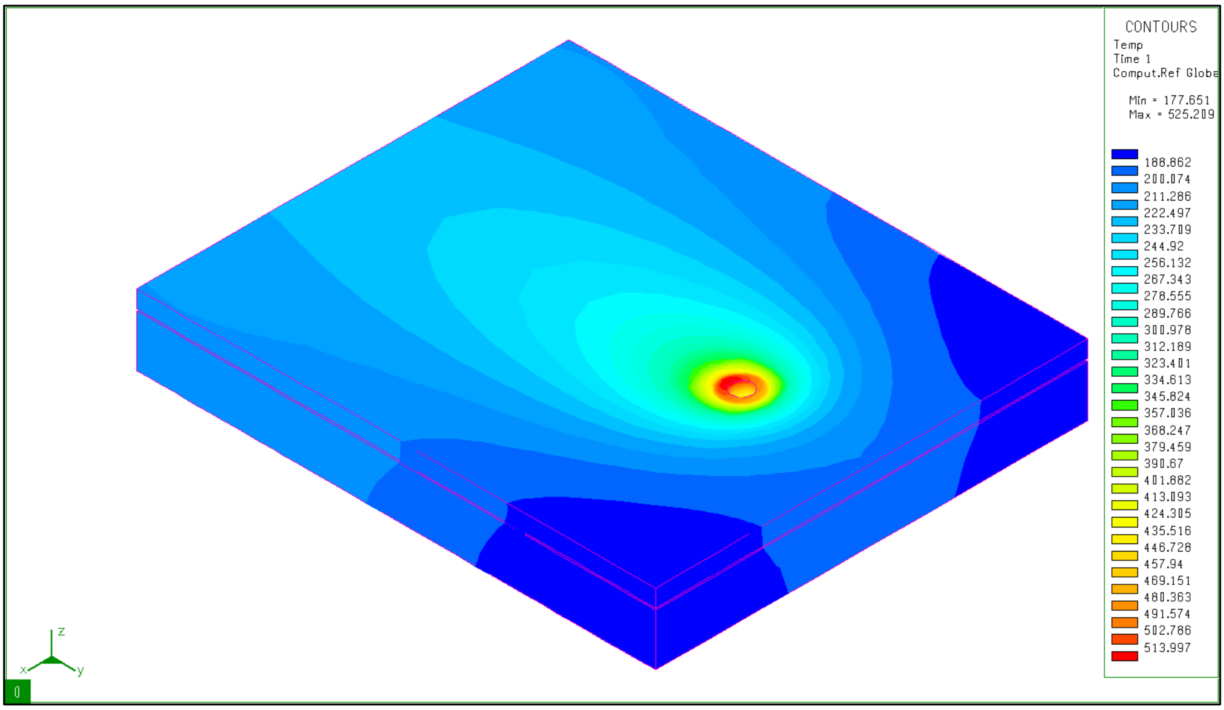

Fig. 7: Temperature field at time 225 s.

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