15th International Research/Expert Conference
"Trends in the Development of Machinery and Associated Technology"
TMT 2011, Prague, Czech Republic, 12-18 September 2011

MEASUREMENT IN FRICTION STIR WELDING PROCESS

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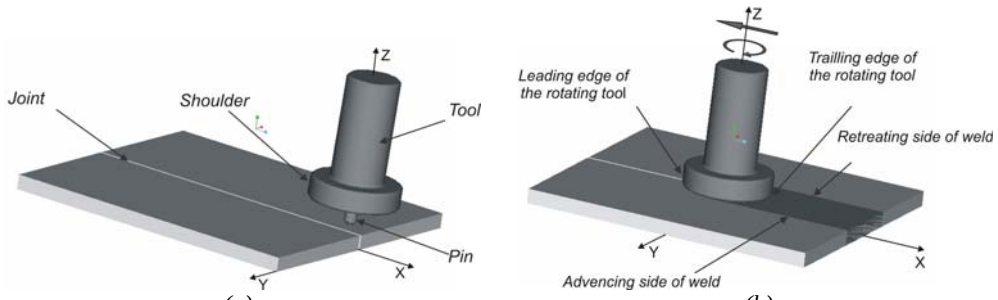
ABSTRACT
Method of Friction Stir Welding - FSW has a wide application for join similar and dissimilar materials, without melting of material, using rotating cylindrical tools. The material is plastically deformed and joined in the solid state. This papers refers the equipment for measurement components of welding force: Main Welding Force - Fz (Down Force), Side Force - Fx and longitudinal force Fy. In this paper the equipment measurement temperature across of section of welding parts is given. Reliable results are obtained because the precise analog-to-digital measurement equipment, related to information measuring system is use.
Keywords: Friction Stir Welding - FSW, Shoulder, Pin, Temperature Measurement, Welding Force (Down Force), Traverse Force, Side Force.

1. INTRODUCTION
During the nineties of the last century a new method of joining similar and dissimilar materials in the solid state without melting of material, known as friction stir welding - FSW is developed. The process is patented by The Welding Institute - TWI in England in 1991, and invented by Wayne M. Thomas who has successfully joined plates of aluminum alloys [1, 4]. Method of friction stir welding has very quickly found its application in shipbuilding, aviation and space industry, railroad and other industries. It is primarily used to join plates of larger thickness. Tools that are used in the process of welding are cylindrical and consisted of two concentric parts (Figure 1.a), which are rotating at the great speed. A larger diameter part of the tool is called the shoulder, while the smaller diameter part is called the pin. Rotating tool slowly approaches the joint line and plunges into material (Al alloys - sheet metal with of thickness 7.8 mm), which creates heat. Due to that the temperature increases to the heat metal forming where mechanical mixing and joining of materials is performed, enabling the tool to move in the longitudinal direction or along the joint lines (Figure 1.b). After passing of the tool along the joint lines the solid phase of weld (joint) remains, where the upper plane remains smooth and flat thanks to the tool shoulder, while the lower plane of the work piece is formed from the basis on which the work piece is standing and it is also smooth and flat [2, 3, 4].



(a) *(b)*

Figure 1. Tool and work piece; (a) Presentation of tools and sheet metal prior to friction stir welding process, (b) Presentation of tools and sheet metal during the friction stir welding process [2]

2. MEASURING OF FORCES

Measuring of forces is performed by using precise analogue digital measuring equipment, related to information measuring system. An analog signal from the sensor units (strain gauge) through the digital six-channel intensifier - the bridge and transferable units is transferred to the AD/DA card, where it is converted to digital and saved to the PC with the installed software package for data acquisition GLOBAL-LAB. Diagrams obtained in this way in the current voltage (V) and time (s), based on the known relationships and values of the calibration of measurement equipment providing diagrams of forces (N) in function of time (s). The Figure 2 presents an overview of the research sites.

Figure 2. Research site: 1- The base plate, 2 - Support plate, 3 - Work piece clamp, 4 - Work piece of Al alloys, 5 - Tool for FSW, 6 - Clamp part of the milling machines, 7 - Special carrier with glued measuring tapes, 8 - Measuring bridge, 9 - BAS, *10 - PC with A/D card and software GLOBAL LAB, 11 - Work table of milling machine*

Down force *Fz* is the largest value when the rotating tool with its pin is embedded into the material. According to that, the work piece increases its temperature due to the friction of the tool pin to the work piece. Then, force *Fz* declines up to the moment of contact of the larger part of tool shoulder with the work piece, at that point the force Fz reaches its maximum value, because a large area of tool shoulder starts embedding in the work piece. Work piece increases its temperature even more because of friction coming from shoulder and pin simultaneously. When the milling machine is provided with crosswise movement of the work table or with selected welding speed, forces *Fx*, *Fy* and *Fz* are retaining constant values, to the moment when the tool is out of the work piece. Diagram of down force *Fz*, and diagram of forces *Fx* and *Fy* are given in the Figure 3.

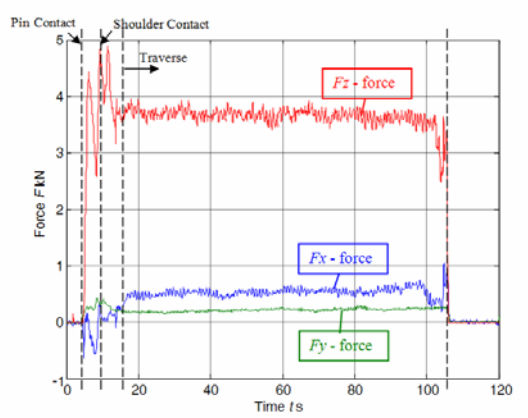


Figure 3. Diagram of forces obtained using the sensor (strain gauge)

3. TEMPERATURE MEASUREMENT

Temperature measurement in the process of friction stir welding of the similar and dissimilar materials is performed with precise analog-to-digital measuring equipment connected with information measurement system.

Information measurement system is consisted of: sensors - thermal couple, measuring module and the PC with software *Measurement & Automation Explorer* and LabVIEW where the processing of measuring signals is performed, and data are obtained in graphical and data form [9].

Thermal couples are made of Al-Cr wire, which is welded at the top with the device for welding of thermal pairs and fine wires. The other end of thermal couple is set in the aperture 1.5 mm of diameter, which was created in work piece to the position of a defined measurement point and it is glued with special adhesive. Scheme of the thermal pairs placing is described in Figure 4, and Figure 5. presents thermal pairs that are placed in work piece.

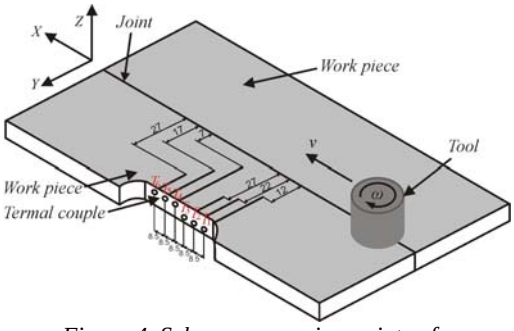


Figure 4. Scheme measuring points of temperature in welding work piece

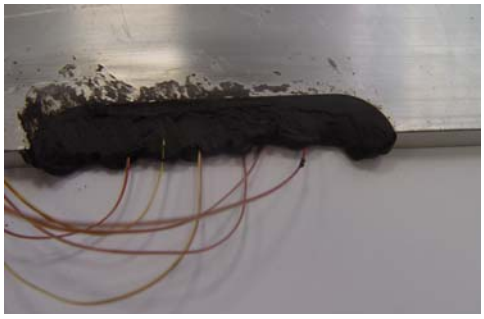
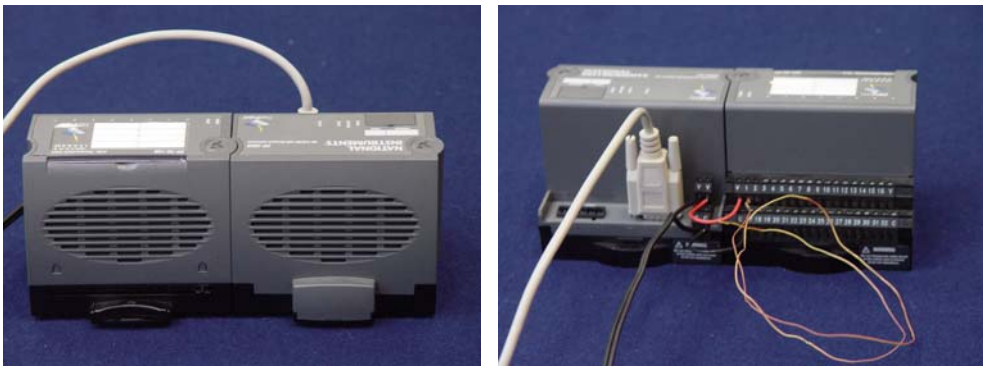


Figure 5. Thermal couples that are placed in work piece dimensions of 200x50x7.8 mm

Measuring module is consisted of a network module type "National Instruments" FP-1000, and eight channel input module for thermal couples type" National Instruments" FP-TC-120. Network module is connected to the eight channel input module with a parallel 40-pin port (Figure 6.a) and has the possibility of adding a sequence of input modules type FP-TC-120, for as many channels as there are thermal couples. Network module is connected to the unidirectional current source of 24 V, and over 9-pin standard port to the PC (Figure 6.b). Figure 7. presents a work piece with thermal couples, which are connected over the input module to the network module that is connected to the PC.

For data acquisition, the program created with LabVIEW software is used whose manufacturer is National Instruments. Measured values of temperature in certain points of the sample are given in the Figure 8.



a) *b)*

Figure 6. Measuring module

Figure 7. Connected information measurement system for temperature measurement

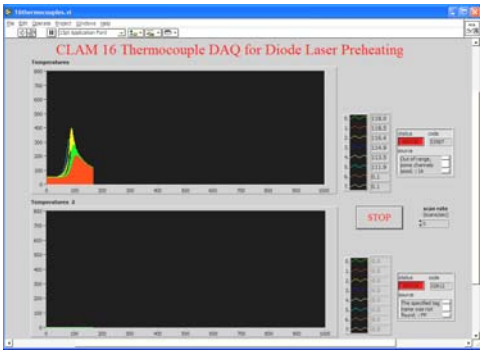


Figure 8. Experimentally obtained temperature changes in the function of distance from the line of contact.

4. CONCLUSION

Regarding to the pointed complexity of friction stir welding process in the introductory part of the work, it is necessary to make precise measuring of the experimental researches in this field. To achieve this goal a reliable and practical information measurement system for temperature measurement is needed as described in this paper. Information measurement system and other applied equipment can be used for other types of measuring in the above process, but also for other similar technologies, in which the temperature has an important role in the proceeding of the process. Measuring of forces was performed using accurate analog-to-digital measuring equipment connected with information measuring system. Digital data obtained by applying information measurement system, are suitable for further application and processing using modern software such as MATLAB. Data processing can be automated in that way.

5. REFERENCES

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