THE APPLICATION OF THERMAL IMAGING METHOD FOR MONITORING THE FSW PROCESSES

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Abstract:
The article presents the authors' method for monitoring the Friction Stir Welding (FSW) processes with use of thermal imaging camera. The FSW method is a modern and still not very common method for joining materials by mixing them after plasticizing with a special tool and allows the combination of non-welding and difficult to weld materials, including combining different (dissimilar) materials. FSW method is a new method and there still are few tools to assess the quality of the process, especially on-line, that is in the making of the weld.
The authors propose a new method for on-line monitoring of the FSW processes using hybrid vision method, that is acquisition of the image of the weld with the use of a thermal imaging camera and visual band camera. The paper presents selected preliminary results of research carried out using only infrared imaging channel. Recordings were made of the welding process for different values of rotary and linear velocities of the tool. With variable parameters of velocity one can obtain weld of different quality: both normal welds and non-compliant welds. The defects included excessive burrs, discontinuities, uneven edge of the weld and others. The recorded thermal images allow identification of weld defects and non-compliances during the process. The use of a thermal imaging camera also allows detection of subsurface defects. The obtained results indicate its potential practical application.
Keywords: Thermal imaging, FSW, process monitoring, welding

1. INTRODUCTION

The article presents the authors' method for monitoring the Friction Stir Weld (FSW) process. The FSW method [1, 2, 3] is a modern and still not very popular method of joining two materials by stirring them after previous plasticization with use of proper tool. The rotary movement of the tool and its pressure against the welded surface generate friction and in consequence local heating of the materials that causes plasticization. Next the tool is moved linearly along the path of the expected weld while the tool's pin stirs the materials and the tool's shoulder compresses the material in the produced weld. The important feature of the process is that the heated materials do not transform into liquid state and remain in the solid state. The method allows joining materials that are hard to arc weld or simply unweldable, including welding of different types of materials together.

2. RESEARCH PROBLEM AND RESEARCH METHOD

There are few critical parameters to the welding process which are: spindle speed v_n, welding speed v_z, tilt angle α and the plunge force F_p. Poor choice of the parameters may result in producing faulty or just non-conformant weld. Non-conformant weld is not necessarily bad weld, but being mechanically strong it does not fulfill the requirements of the standard [4]
Typical non-conformances include excessive burrs, discontinuities, cracks or uneven edge of the weld. The below picture presents some examples of non-confomances (Fig. 1):

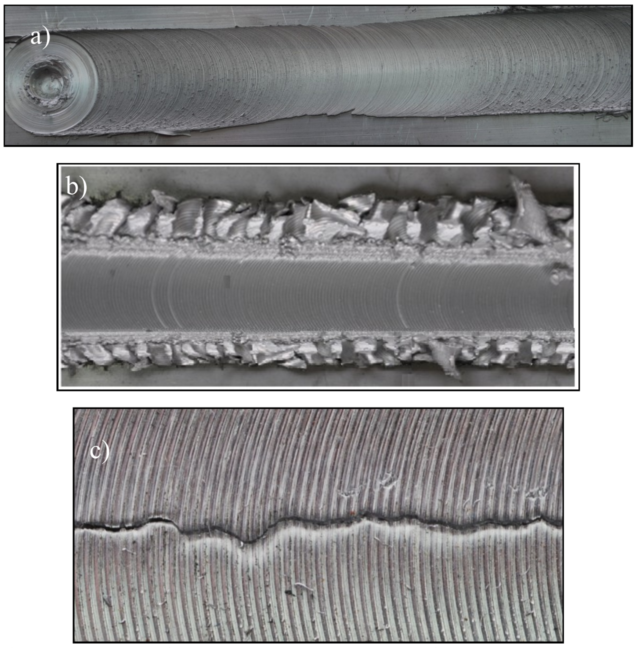

Fig. 1. Sample non-conformances in FSW process: a) uneven edge of the weld, b) excessive burr on the edges, c) crack as an effect of overheating

In case of FSW welding the on-the-fly inspection of the process should allow elimination of produced faults in an automated manner already in the welding stand and allow elimination of faulty elements. The authors of the article propose the method for monitoring the FSW process with use of hybrid vision method, that is the recording of the image of the weld with use of thermovision camera and visible light camera (Fig. 2).
The surface of the welded material is observed by a matrix infrared camera to assess the temperature field behind the

tool and with a line-scan camera that observes the surface of the material to observe the geometry of the weld.

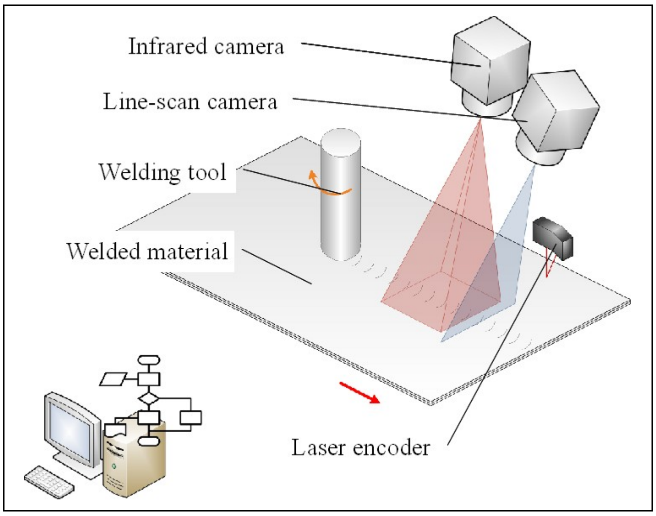

Fig. 2. The principle of the hybrid monitoring method for FSW process

The article presents selected results of introductory research performed with use of only infrared imaging.

The research on the monitoring of the FSW process of different types of materials was performed on the research stand built on the conventional vertical mill FYF32JU2. The stand was equipped with the process monitoring system based on the thermal imaging camera Flir SC5200 [5, 6], with cooled InSb sensor for short wave IR, that is for 2.5÷5.1µm. The measurement range is divided into three sub-ranges: 5 ÷ 300 °C, 25 ÷ 600 °C and 300 ÷ 1500 °C. The camera was controlled by the manufacturer's software "Altair". The view of the stand is presented in the figure 3.

Fig. 3. The view of the research stand for monitoring the FSW process with installed thermal imaging camera

3. RESULTS

Several recordings of the process were made for different rotary and linear speeds of the tool. That allowed production of both correct and faulty welds that included non-conformances such as excessive burrs, discontinuities or uneven edge of the weld. The recorded thermal sequences allow identification of the faults and non-conformances of the weld during the welding process. The application of thermal imaging camera allows also detection of sub-surface faults.

The view of sample image from the camera recorded during correct process of FSW welding is presented on the figure 4 and the figure 5 presents sample profile of the temperature during along the measurement line.

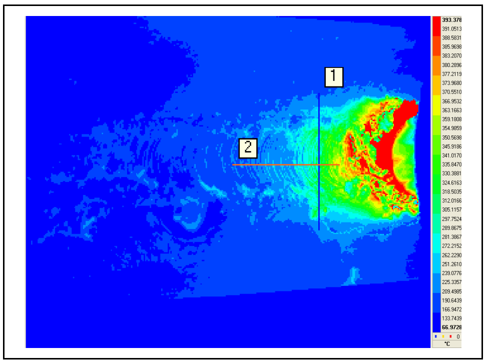

Fig. 4. The results of the measurement of the temperature with use of the camera: the thermogram from the FSW welding process

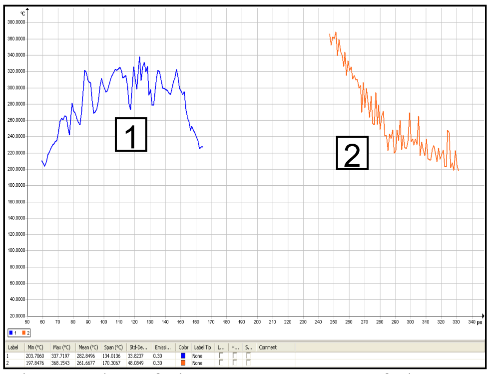

Fig. 5. The results of the measurement of the temperature with use of the camera: the profiles of the measured temperature along the measurement lines (see fig. 4.)

One of the characteristic phenomena in case of FSW welding is appearance of excessive burr on both sides of the weld. The are also situations when part of the burr (a shaving) is pushed out behind the tool and stays on the surface of the weld causing disturbances during the measurement with the camera. Such disturbances are clearly visible on the thermograms and on the temperature profiles as local momentary decrease or increase of the temperature. The view from the camera and profile with disturbance are presented in figures 6 and 7.

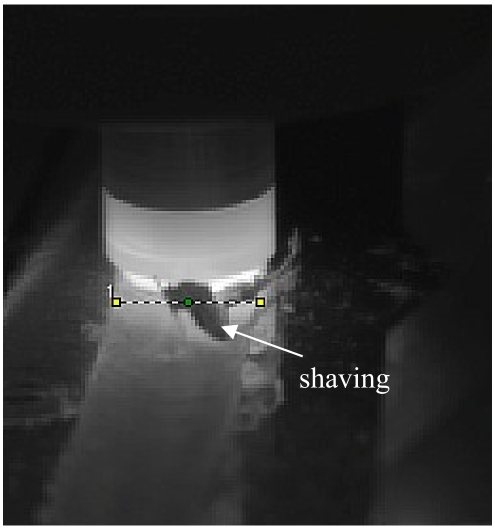

Fig. 6. Thermogram with recorded disturbance in form of a shaving

The recorded temperature profile (fig. 7) has a clear “pit” that shows the presence of foreign material in the range of observation of the surface of the weld.

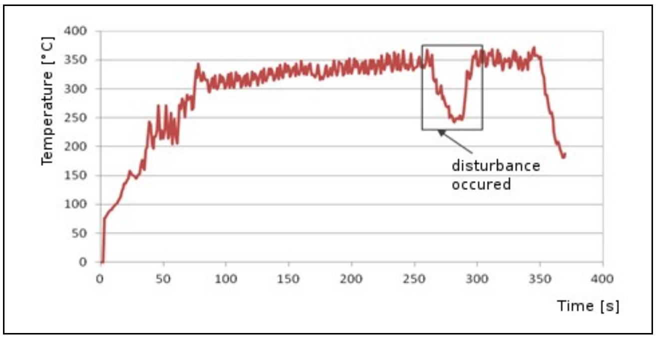

Fig. 7. The profile of the temperature with marked result of the disturbance in form of a shaving

The applied system intended for monitoring the FSW processes, built based on the thermal imaging camera allows also detection of the sub-surface faults such as empty spaces under the layer of the metal, cracks or the thermal results of tool’s pin fracture, which are visible on the infrared camera but are not visible by eye.

The view of the weld after the process, the thermogram of the surface of the weld recorded during process and the temperature profiles along the lines 1 and 2 are presented in figure 5 and 6.

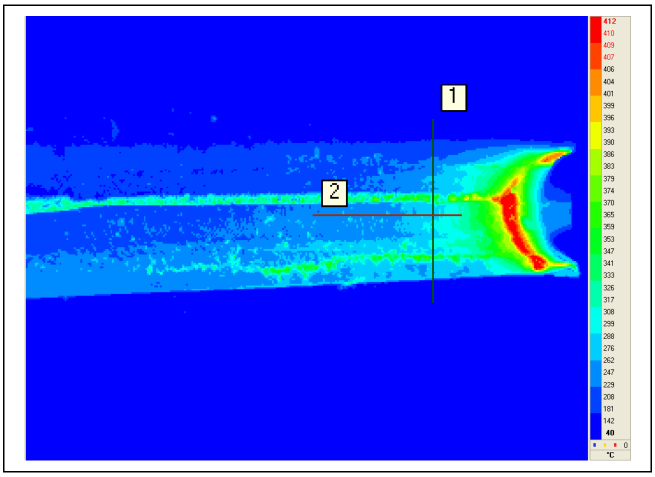

Fig. 8. Detection of sub-surface faults: thermal image of the surface during the process (see fig. 9)

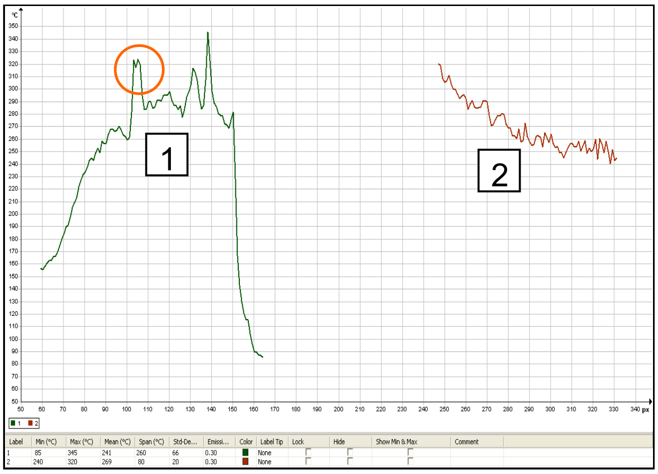

Fig. 9. Detection of sub-surface faults: temperature profiles along the lines 1 and 2 (see fig. 8); marked is a temperature peak that shows the sub-surface cavity

4. FUTURE DEVELOPMENT OF THE METHOD

As it was said before the article presents only the preliminary results of the research. The presented system will become a part of a hybrid system for monitoring the process of Friction Stir Welding. Future development of the method includes building the visual light optical system (Fig. 10) based on Basler runner 2k [7] line-scan camera, LED lighting system and a laser encoder system for triggering the line-scan camera synchronously to the movement of the welded material.

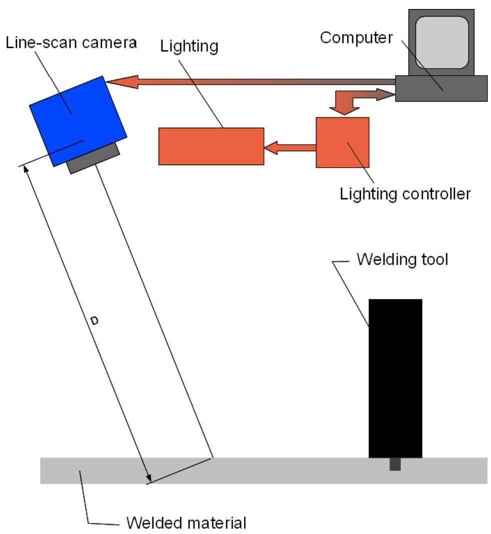

Fig. 10 The concept of visual light part for the monitoring system

The laser encoder is based on the interferometers and consists of several optical elements out of which only one need to move (Fig. 11). So that only the reflector is fixed to the working table of the FSW stand and the rest of the encoder (source, detector and interferometer) are fixed on the separate stand.

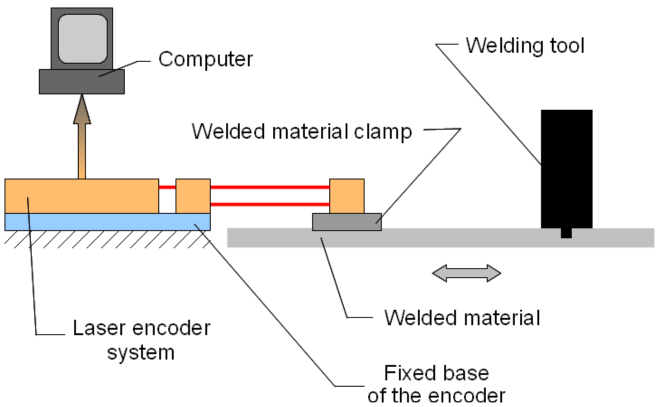

Fig. 11. The principle system of laser encoder for triggering the line-scan camera

5. CONCLUSION

The presented results contain only a qualitative analysis of possibility of application of the thermal imaging camera for monitoring the Friction Stir Welding processes. The presented method is a new method for monitoring the friction stir welding processes using thermal imaging. The obtained results indicate its potential practical application and the method is to be further developed to become a part of a hybrid system for monitoring the FSW processes.

The use of the infrared radiation allows contactless measurement and, what is particularly valuable, allows detection of sub-surface faults otherwise detected only by destructive testing.

The method is mainly intended for monitoring the Friction Stir Welding processes. The general concept of using both infrared and visual light analysis allows also other applications such as monitoring the arc welding processes, monitoring the processes of hot assembly of products and in testing the construction elements in high temperatures.

REFERENCES

[1] Lohwasser D., Chan Z.: Friction Stir Welding. From basics to applications. Woodhead Publishing Series in Welding and Other Joining Technologies No. 66, USA 2010

[2] Birsan D., Visan D., Mircea O.: Temperature monitoring in friction stir welding using thermovision method. The Annals of "Dunarea de Jos" University of Galati, Fascicle XII, Welding Equipment and Technology, 2009, s. 45-49

[3] Dawes, C. J.: An introduction to friction stir welding and its development. Welding & Metal Fabrication, UK, 1995

[4] ISO 25239-5:2011 Friction stir welding -- Aluminium -- Part 5: Quality and inspection requirements

[5] Minkina W., Dudzik S.: Infrared Thermography: Errors and Uncertainties. John Wiley & Sons, UK, 2009

[6] www.flir.com

[7] www.basler.com