Feasibilty Study of Adopting Acoustic Emission Testing in Friction Stir Welding Process for Effective Control of Defects

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Abstract— This Paper investigates the use of Acoustic Emission Testing as an effective Non destructive Testing Method to control defects in Friction Stir Welding. Friction Stir Welding (FSW) is most advanced, rapid and reliable type of Welding process which produces quality welded joints of similar and dissimilar materials with the help of frictional heat and pressure. This process is best suited for Aerospace industry and other commercial applications due to its capability of welding low melting point materials with low energy consumption and versatility. The process uses non-consumable cylindrical tool to join sheet and plate materials, without melting them. The defects in welding joints play a major role in determining the product quality, weld strength, cost, etc. A cost effective and accurate Non Destructive Testing method is required to monitor process and avoid defects. Acoustic Emission (AE) testing is a powerful method of examining the behavior of materials deforming under stress.

I. Introduction

FSW is emerging as a key technology in many industrial applications, especially those involving the joining of light alloys, such as aluminium. The increased application of these materials, primarily by large companies and by very demanding industrial sectors, e.g., aerospace, naval, and automotive, has generated significant research and development in FSW. But, due to the solid state nature of FSW, many of the resulting weld imperfections are different than those found in fusion welds, e.g., inclusions, volumetric imperfections, and undercut. Instead, many imperfections are of a metallurgical nature and cannot be identified with typical NDT techniques. Since the quality of FS welds impacts manufacturing cost and product quality, appropriate quality control should be implemented to detect imperfections in friction stir welds. Among the NDT methods. AE refers to the generation of transient elastic waves produced by a sudden redistribution of stress in a material[1].

A. FSW Process

The working principle of Friction Stir Welding process is shown in Fig. 1. A welding tool comprised of a shank,

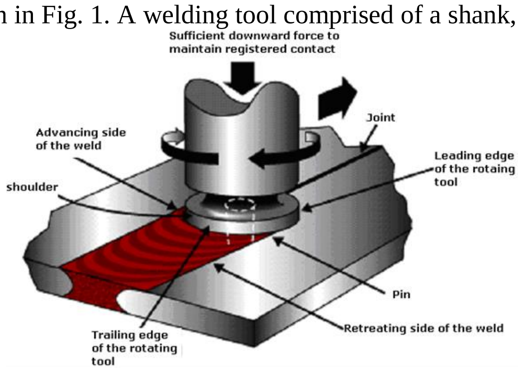


Fig. 1: FSW Process

shoulder, and pin is fixed in a milling machine chuck and is rotated about its longitudinal axis. The work piece, with square mating edges, is fixed to a rigid backing plate, and a clamp or anvil prevents the work piece from spreading or lifting during welding[2].By keeping the tool rotating and moving it along the seam to be joined, the softened material is literally stirred together forming a weld without melting[3]

B. Defects in FSW

The main aim is to prevent the air flow until the FS welds are usually free of imperfections. However, some imperfections may arise due to improper stirring of the parent material, inadequate surface preparation, lack of penetration of the pin, or inadequate axial forging forces. Some typical FS **Figure:**

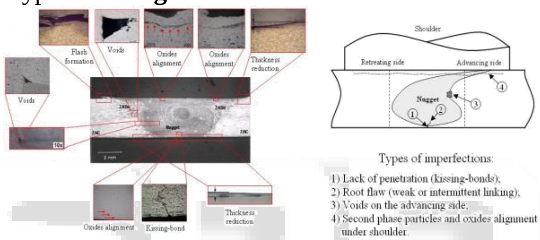


Fig. 2: Typical imperfections in FS welded butt joints

weld imperfections include lack of penetration (incorrectly called "kissing-bond"),root imperfections (weak or intermittent welding), cavities on the advancing side of the weld, and second phase particles and oxides aligned under the shoulder [4]

C. NDT Development for FSW

In general, the data available on the application of NDT to FS welds is scarce. The typical NDT techniques, such as, visual inspection, magnetic particle inspection, dye penetrant inspection, and radiographic inspection, do not enable the detection or quantification of typical FSW imperfections. Ultrasound and eddy-current NDT processes, even in their most evolved form, although allowing the detection of most of the imperfections in the weld, are very sensitive to coupling and lift-off conditions,

materials and methods between the probes and the surfaces under inspection. None of these NDT techniques, in a standalone condition, allow the assessment of the morphological diversity and localization of all FSW imperfections. It has been found that there are a great possibilities for AE application in Friction stir welding since AE monitoring is one of the most sensitive techniques used for real-time detection of defects[4]

D. Acoustic Emission in FSW

Acoustic Emission (AE) is a relatively new technique that appears well suited to detect the defect occurring during the welding process. AE monitoring enables necessary diagnosis to be made during each welding pass, so that remedial action can be taken at minimum cost. Real-time discontinuity detection and characterization of welds is the major advantage of AE it was confirmed, through initial energy effects, that AE techniques can be reliably applied to in-process strength monitoring in any type of friction welding, as the cumulative AE counts occurring during welding and cooling periods were quantitatively correlated with reliability at 95 % confidence level to the joint strength of welds, bar-to-bar (AISI 4140 to 1117 & 12L14) and tube to-tube (AISI 1020 to 304 stainless steels)[5]. The real time quality evaluation of welded joints can be done experimentally by Acoustic Emission technique[6]

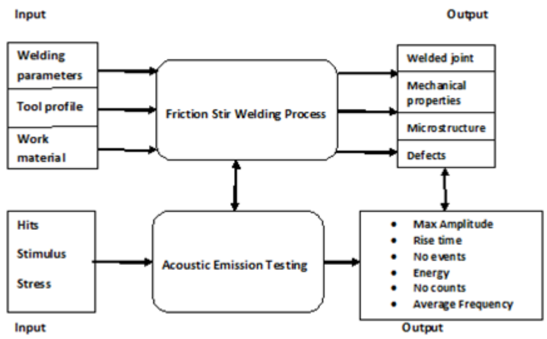


Fig. 3: Use of Acoustic Emission in FSW Process{8}

tool wear during FSW can be noticed by AE technique[7] A study of the possibility of the use of the acoustic signals of the electric arc for the monitoring on-line process of GMAW-S. showed behavior of the parameters in normal conditions is characterized for be continues and with small variations. This continuity is interrupted when the presence of instabilities exists[9]

II. Materials & Experiments

A. *Materials*

In this study Aluminum plates of grade 7020-T6 with size 150 mm X 300 mm and thickness of 5mm are used to prepare welds using FSW machine. The tool was made of OHNS die steel with fixed probes with hardness in the range of 50-55HRC with conical and cylindrical grooves. FSW machine with 10tons capacity and tool rotation speed of 1-300rpm is used to prepare weld joints[6]

B. *Acoustic Emission Testing Equipment*

The standard PCI-2 based System with Frequency Response of 3 kHz - 3 MHz (at -3 dB points) and Max. Signal Amplitude of 100 dB AE.The Sensor mad of Piezo electric transducer with 100 kHz – 2 MHz is used along with suitable filter and amplifier[10].

C. *Process Parameters*

In the present investigation, three level process parameters, i.e. Rotational speed, Traverse speed and

Rotation Speed (rpm)	Traverse Speed (mm/min)	Plunge depth (mm/min)	Weld Distance (mm)
1000	50	4.75	120

axial force were considered. A sample parameters combination shown in table1.The FSW joint shown in following figure is with respect to specimen 2.

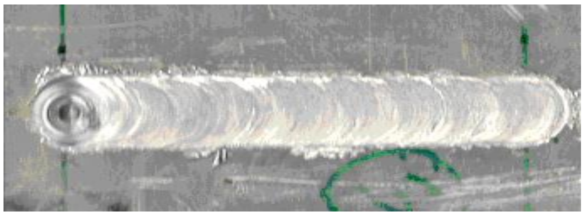


Fig. 4: Weld joint prepared with FSW

D. *Radiography &Tensile Test*

Radiography tests are conducted to confirm the results obtained from acoustic emission testing. A tensile test carried out with specimens based on ASME standards to find out weld quality and found satisfactory results with Strenght of 292.7N/mm2 and Joint efficiency of 78.05% at tool speed of 1000rpm.

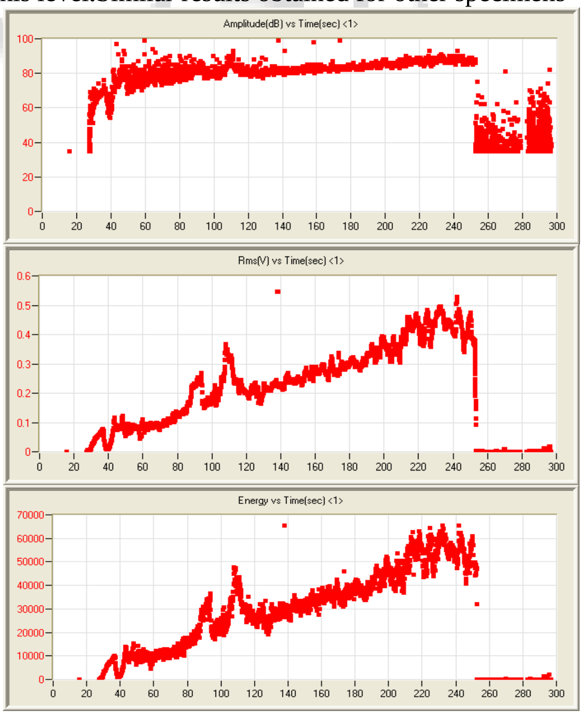
III. Results And Discussion

During welding process continuous high amplitude signals of 80 – 100 dB were observed. The initial increase in signals is due to friction generation when tool pin forges and extrudes the material in its path. As welding continues, there will be continuous stirring and forging takes place along with high friction resulting in continuous signal emissions. The graphs shown are for Specimen 6. Important AE signals like Amplitude,Energy,RMS with respect to Time were monitored during FSW process. AE signals patterns as shown in Figure.It can be observed

that there is an increase in Amplitude, RMS and Energy at 110 sec.

Amplitude	Duration	RMS	Energy
90dB	110 sec	0.38 V	$50X10^3$dB

Radiography tests also proved that there is a defect at this level**.**Similar results obtained for other specimens



with varied combination of welding parametes which showed that a confirmed relationship exists between AE signals and welds defects in FSW.

IV. Conclusion

It can be observed from the above results that Acoustic Emission Testing can beeffectively used for monitoring of

FSW of 7020-T6 alloy material for defects. Among the AE parameters RMS Voltage, Energy, Amplitude and counts are more sensitive to the condition of welding.AET provides a unique, effective performance for monitoring of defects.So it can be concluded that AET provides a effective platform to monitor real time defects and take suitable measure in terms of controlling weld parameters.

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