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Friction Stir Welding Parameter Optimization for Aluminum

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Abstract: Friction stir welding (FSW) is a modern, innovative and efficient welding method for welding materials that are difficult to weld by traditional methods of fusion welding. Welding parameter plays an important part in determining weld performance. The correct choice of welding parameters will result in sound welds, which will enhance the material's mechanical properties. Radiography and ultrasonic analysis are very effective ways of detecting and measuring faults or harmful defects without altering materials functionality or serviceability. Aluminum alloy is a material of light weight and has many industrial applications. However, traditional fusion welding methods do not allow them to be easily welded because the consistency of the welded joint is compromised due to porosity, hot cracking and distortion. In this paper FSW technique welds AluminumAA-5083 with variation of the tool's rotational and transverse speed. Ultrasonic radiography and immersion testing was conducted to identify various defects on the welded materials. It is found that as transverse velocity increases, the heat input generation decreases which cause the cavity or groove like defects.

Keywords: Friction Stir Welding,Immersion Ultrasonic Scanning, Welding Parameter.

INTRODUCTION

Aluminum (Al) alloy is a material of light weight, and has several industrial applications. Yet modern fusion welding techniques do not allow them to easily weld because the consistency of the welded joint is compromised due to the presence of porosity, hot cracking and distortion. The Friction stir welding (FSW) is a modern and promising welding method that welds the material below its melting temperature and it has exhibited superior features such as excellent joint strength, mechanical properties and low energy.This method is successful for joining materials that are hard to weld via traditional fusion welding. The FSW process may also be followed by dissimilar alloy material. This technique was discovered as a solid-state joining technique at the Welding Institute (TWI), United Kingdom in December 1991, and was first applied to aluminum alloys. A non-consumable tool with either a specially designed pin or shoulder is used in the FSW process which is both rotated and interpreted throughout the welding process. It allows the heat generation to plasticize the material and the air movement to reach the material. During the process, the sum of heat input is very critical in determining the weld quality and depends on the various welding parameters such as axial force, rotational speed, transverse speed, configuration of the tool, plunge depth and tilt angle between the tool and welding materials.This defect decreases weld quality and therefore it is very important to analyze these defects to improve the welding parameter for which effective non-destructive assessment and inspection is required. With that FSW application in aerospace and aviation, characterization and non-destructive assessment of defects become one of the focal issues, because both design and welding require information as feedback for optimization. This work contrasts two planar NDE methods: Radiography and C-Scan ultrasonic[1][2].

X-ray radiography is used to picture the welds that help to identify and locate the defects. For welds X-ray image variance for intensity is induced by weld homogeneity. Ultrasonic evaluation method is a possible solution for FSW because FSW defects can influence the uniformity of the weld zone resulting in variance of the propagation of the ultrasonic probe. Weld consistency was checked using a pulse echo, a technique in ultrasonic imaging called C-scanning. This paper introduces a high resolution ultrasonic c

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scan technique for weld imaging and its contrast with the radiography process was studied in order to find optimum welding parameter[3], [4].

METHODOLOGY

Experimental technique:

- *Sample preparation*

The base material used in this analysis is the 6.5 mm thick aluminum alloy AA 5083 whose chemical composition is specified in Table 1. The samples were welded to the butt along the rolling path using FSW tool. The FSW method is schematically illustrated in the fig.1, 2 A FSW device with a taper threaded pin with a diameter of 6 mm to 4 mm, a pin length of 5.95 mm, a left hand thread with a pitch length of 1.5 mm and a shoulder diameter of 20 mm was selected for welding[5][6].

Table.1: Chemical Composition of Sample

Si	Fe	Cu	Mn	Mg
0.08	0.16	0.04	0.8	4.5

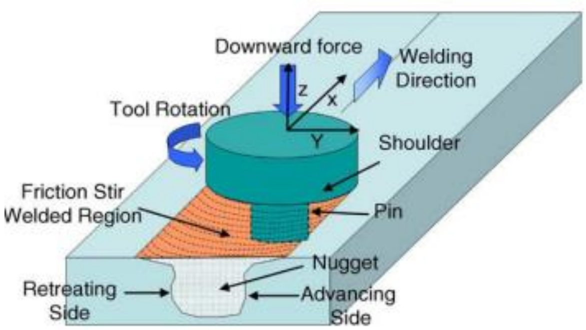

Figure 1: Schematic of FSW

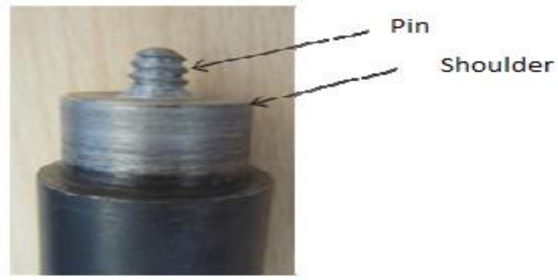

Figure 2: Tools for FSW

Apart from the welding parameter such as rotational and transverse speed, the important parameters during the welding cycle is such as plunge depth, tool tilt, initial heating period and tool down velocity. The plunge depth during the welding process is 6.05 mm, and the inclination of the tool used is 20 towards the forward weld side. The initial heating time and the down feed for the machine are 10 sec and 10 mm / min.Table 2 lists welding parameters used in this study. The welding is performed at different transverse velocities as shown in Table 2. The tool's rotational speed in each weld varies slowly from 1000 rpm to 200 rpm, as shown in Fig. 3. Thus the weld gap and the rotational velocity are interrelated[7][8].

Table.2: Welding Parameter

Sr.No	Job counter	Welding Speed (mm/min)	Rotational speed (rpm)	Weld distance (mm)
1	JC 1337	54	1000 to 250	155
2	JC 1338	61	1000 to 250	155
3	JC 1339	64	1000 to 250	155
4	JC 1340	70	1000 to 250	155
5	JC 1341	74	1000 to 250	155

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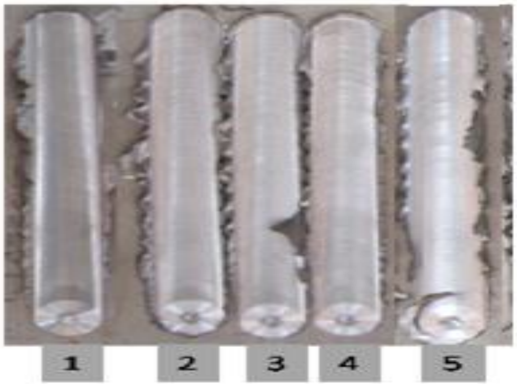

Figure 3: Sample Images

- *Digital radiography :*

Radiography was conducted using the optical X-ray method. The X-ray was created with 90 KV voltages, 1.2 mA voltages from source and the exposure time used to get the image for 4 s.

- *Immersion Ultrasonic Testing:*

Immersion Ultrasonic C scanning tastings were conducted using a 10MHz frequency detector, 2 "focal length and coupling spray. The sample was scanned both along the joining as well as across the joining using a resolution of 0.1 mm. the experimental setup is showing in the fig.4 and Fig.4, 5 displays the view of the immersion tank where the test sample is being scanned by the microscope.The first amplitude of the ultrasonic test method reveals echo of the front wall whereas the second amplitude shows echo of the back wall and use electronic locks. Selected echoes are collected from the entire return signal. The A, B and C scan detects and locates the flaw[9][10].

Figure 4: Ultrasonic Test- Experimental Set-up

Figure 5: Ultrasonic Immersion Tank

RESULTS AND DISCUSSION

The Fig 6 displays the radiographic representation of all the samples so it is obvious that they are all free of defects. A scan and B scan of weld no 2 shows the respective in Fig 7 and Fig 8. Signal disruption in a scan shows the discontinuity of the material. B scan results also reveal material discontinuity in the wall between front and back. C scan image of all samples is shown in Fig 9 which is showing the difference in

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the amplitude of the signal, while the rotational velocity on each weld ranges from 1000 rpm to 200 rpm. It is evident from the analysis of A, B and C that there is a presence of defect.

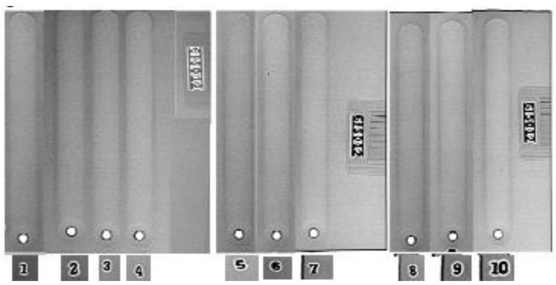

Figure 6: Radiography Image

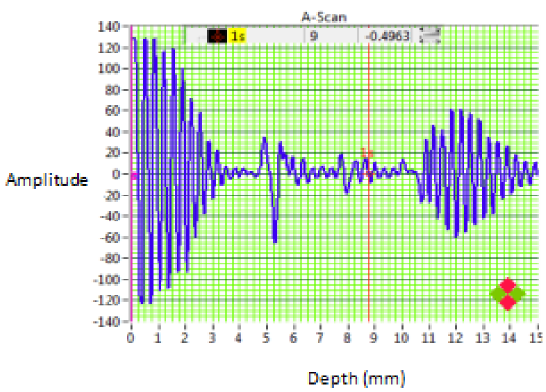

Figure 7: A Scan of Weld 2

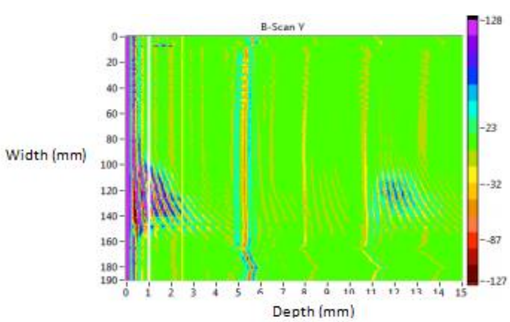

Figure 8: B Scan of Weld 2

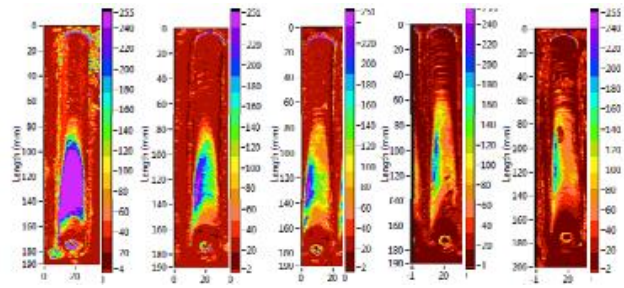

Figure 9: C Scan of Weld 2

From the results of the C scan, while variability in rotational speed is the same for all samples, the size of the defect increases with increasing transverse welding speeds. It means that as the transverse speed increases the generation of heat inputs decreases which causes the defect to happen. Under optical microscopes cavity or grooves such as defects are observed. During the cycle this defect indicates inadequate heat input or excessive stirring.

CONCLUSION

The following conclusions have been made on the basis of the study:

- The ultrasonic immersion technique for determining weld consistency is better than optical X-ray.
- The welding parameter such as tool rotational and transverse velocity plays a very important role in the interpretation of the welding.
- The amount of the heat input for the process depends upon the transverse speed of the tool and it is proportional of the tool speed.

- Optimum welding parameter is the deciding factor for obtaining the sound weld.

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