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Study On the Effect of FSW Process Parameters of Dissimilar Aluminium Alloy

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***Abstract*—This Aluminium alloy has gathered wide acceptance in the fabrication of light weight structures requiring a high strength to weight ratio. Friction stir welding (FSW) is widely used for the welding of aluminium. Welding input parameters play a very significant role in determining the quality of a weld joint. The welding parameters such as tool shoulder diameter, tool rotational speed, welding speed, axial force play a major role in deciding the joint strength. In present study an attempt has been made to join the AA8011 and AA 3003 aluminium alloy. A serious problem with fusion welding, even when a sound weld can be made, is the complete alteration of microstructure and the attendant loss of mechanical Properties. Being a solid-state process, friction stir welding has the potential to avoid significant changes in microstructure and mechanical properties. The Objective of the study is to evaluate the microstructural changes effected by Friction Stir Welding of aluminium alloys.**

Keywords— AA8011 & AA3003 Aluminium alloy; Friction stir welding; Welding speed; Axial force; Mechanical properties; Microstructure.

I. INTRODUCTION

Welding is a fabrication or sculptural process that joins materials, usually metals or thermoplastics, by causing fusion, which is distinct from lower temperature metal-joining techniques such as brazing and soldering, which do not melt the base metal. In addition to melting the base metal, a filler material is typically added to the joint to form a pool of molten material (the weld pool) that cools to form a joint that is usually stronger than the base material. Pressure may also be used in conjunction with heat, or by itself, to produce a weld. Compared with many of the fusion welding processes, such as metal inert gas welding MIG), Tungsten inert gas welding (TIG), electron beam welding (EBW) and laser beam welding (LBW) that are routinely used for joining aluminium alloys, Friction Stir Welding (FSW) is an emerging solid state joining process in which the material that is being welded does not melt and recast. Friction stir welds will not encounter problems like porosity, alloy segregation and hot cracking, and welds are produced with good surface finish and thus no post weld cleaning is required [1].

FSW was invented at The Welding Institute (TWI), UK in 1991

A. *Friction Stir welding*

Dissimilar materials joints are widely used in power generation, chemical, petrochemical, nuclear, aerospace, transportation and electronics industries due to their technical and beneficial advantages. Due to different chemical, mechanical and thermal properties of materials, dissimilar materials joining present more challenging problems than similar materials joining by friction stir welding (FSW).

Therefore, the solid-state joining methods, such as friction stir welding, roll welding, and explosive welding have received much attention. The relative motion between the tool and the substrate generates frictional heat that creates a plasticized region around the immersed portion of the tool. The tool shoulder prevents the plasticized material from being expelled from the weld. The tool is traversed along the joint line, forcing the plasticized material to coalesce behind the tool to form a solid-phase joint. The micro structural evolutions after the FSW process are characterized by three zones: the Stir Zone (SZ), the Thermo-Mechanically Affected Zone (TMAZ), and the Heat-Affected Zone (HAZ).

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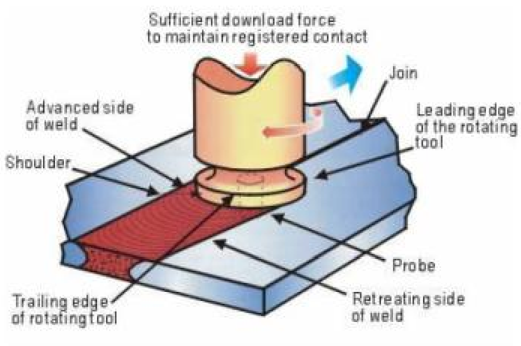

Fig.1. Schematic of Friction Stir Welding

It was reported that sound dissimilar FSW joints were difficult to achieve, and the joints usually failed at the nugget zone or along the interface between the two materials during the mechanical tests. The poor weld formed is due to the ability of the various brittle IMCs formed in the nugget zone. A sound FSW could be obtained by offsetting the tool to the Al side under a lower heat input condition .It is well documented that many parameters, such as tool offsetting, rotation rate and traverse speed, influenced the weld properties of the dissimilar FSW. Christo Ananth et al.[7] discussed about E-plane and H-plane patterns which forms the basis of Microwave Engineering principles.

Limited studies have been performed on the FSW dissimilar Al-Fe joints till now, and systematic research on the FSW parameters is still lacking. Therefore, it is worthwhile to study the effect of FSW process parameters on the microstructure and mechanical properties of the dissimilar FSW Al–Fe joints. In this paper, various FSW butt Al–Fe joints were produced under different weld parameters and the microstructure and mechanical properties were studied in detail. The purpose of this study is to find out the feasible combination of FSW process parameters to perform defect free welding of dissimilar materials and to investigate the effect of the tool offset as a strategy to weld dissimilar materials.

II. LITERATURE RIVIEW

The effect of FSW parameters on temperature was examined by Arunkumar et al .They concluded that the rotation RPM, welding speed and axial force are the significant parameters in deciding the impact strength of the joint.

Patel A.K.M et al studied the friction stir welding to join the AA8011 aluminium alloy by using the conventional milling machine. The Tensile strength of the joint increases with increase in welding speed and travel speed. It reaches maximum and then start decreases, same effect is also observed by varying the axial force. Maximum joint tensile strength is achieved by using 18 mm shoulder diameter. The maximum tensile strength achieved in the FSW joint is 75% of the parent metal tensile strength.

Apart from this, there have been lot of efforts to understand the effect of process parameters on material flow behavior, Microstructure formation and mechanical properties of FSW welded joints. Finding the most effective parameters on properties of FSW as well as realizing the influence on the weld properties have been major properties for researchers.

Extensive literature of Friction Stir Welding of Al alloy does indicate that there are few areas particularly on the relationship between welding parameters and change in the mechanical properties of weldment. This paper focuses on finding the optimal speed (rpm) and feed rate mm/s with respect to mechanical properties such as microstructure study.

III. EXPERIMENTAL PROCEDURE

Al 8011Aluminum and Al 3003 aluminium plates of 5mm in thickness, 100mm in length, and 50mm in width were butt-welded using a Friction stir welding.

TABLE 1

CHEMICAL COMPOSITION IN % WT

Name of the Alloy	Aluminium %	Copper %	Iron %	Manganese %	Silicon %	Zinc %	Residuals %
3003	96.8 ~ 98	0.2	0.70	1.0 ~ 1.5	0.6	0.1	0.15

Alloy	Al %	Fe %	Si %	Mn %	Zinc %	Cu %	Tit %	Cr %	Mg %	Reminders %
8011	98.9	1	0.90	0.2	0.1	0.1	0.08	0.05	0.05	0.20

Fig 2. FSW Machine

Fig 3.Threaded tool

The plates of Al 8011 and Al 3003 were machined to the required dimensions (100 mm X 50 mm X 5 mm).FSW was carried out on a FSW machine manufactured by RV machine tools, India. Specification of FSW as follows: SPM 4 machine with min tool rotational speed of 600 RPM and a weld speed of 5mm/min as shown in the fig. 2. Threaded cylindrical tool made up of Super high speed steel used in this study and had a

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shoulder 15 mm in diameter and a pin 4.5 mm in diameter and 5.7mm in length as shown in the fig. 3. The process parameters of the FSW taken up for the experiment and their levels are given in the table.

TABLE -2

PROCESS PARAMETERS

Sl.No	Rotational speed (rpm)	Weld Speed (mm/min)	Axial Force (KN)
JB 1	1000	30	4
JB 2	1000	45	5
JB 3	1000	60	6
JB 4	1100	30	4
JB 5	1100	45	5
JB 6	1100	60	6
JB 7	1200	30	2
JB 8	1200	45	3
JB 9	1200	60	4

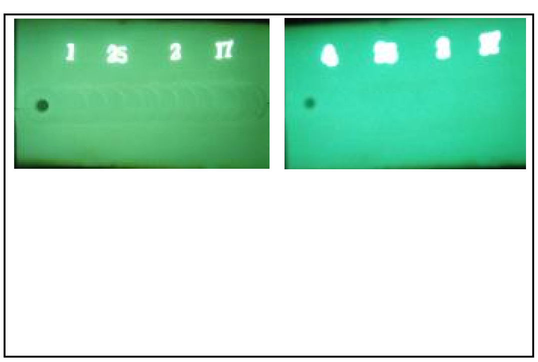
Welds were made with a clock-wisely rotating threaded pin at different parameters. Position of the job is decided as AL3003 on retracting side and AL8011 on the advance side against the tool feed.

To perform Friction stir welding and testing of dissimilar material welded samples, the following machines/equipment's were used; Shaper machine for dimensioning the work piece ,A Frictional stir welding machine with FSW fixture , Radiography: X-ray 130KV and 5MA as per the ASTM-12. The specification is ASME sec V, IX. The type of the film used is Kodak AA-400, Microstructure: Metallurgical Microscope –METSCOPE-1A

Whenever the stronger material and the soft material were friction stir welded together, previous studies indicate that the weld quality was clearly influenced by the fixed location. For a sound weld to occur the stronger material should be fixed at the advancing side and the softer material should be placed at the retreating side.

IV. RESULT AND DISCUSSION

A. Radiography test



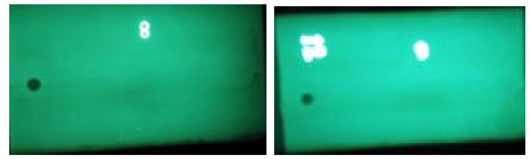


Fig 4. Defect free samples

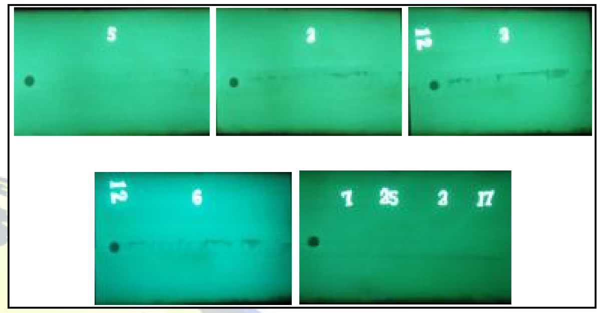


Fig 5. Surface defect samples

TABLE -3 SUMMARY ON RADIOGRAPHIC TEST

S.NO	SIZE	INTERPRETATION	REMARKS
JB 1	3'x6'	No defect	Acceptable
JB 2	3'x6'	Lack of penetration	Not Acceptable
JB 3	3'x6'	Lack of penetration	Not Acceptable
JB 4	3'x6'	Porosity	Acceptable
JB 5	3'x6'	Lack of fusion	Not Acceptable
JB 6	3'x6'	Lack of penetration	Not Acceptable
JB 7	3'x6'	Lack of fusion	Not Acceptable
JB 8	3'x6'	Porosity	Acceptable
JB 9	3'x6'	No defect	Acceptable

- The acceptable pieces in radiography test are 1,4,8,9. Others are not acceptable by interpretation of the lack of fusion and lack of penetration.

B. Microstructure analysis

The various zones on the metals such as Base1 metal, HAZ, Weld Zone, Base 2,HAZ 2,Weld 2 of FSW joints were studied. Since the intensities of heat and mechanical actions are more in both advancing side (AS) and retreating side (RS) of the FSW joint, the micro structural fruition in these zones is considered. The SEM micrograph of weld metal region the high magnification SEM image clearly shows that FSW joint consists of upper bainite and acicular ferrite throughout the stir zone.

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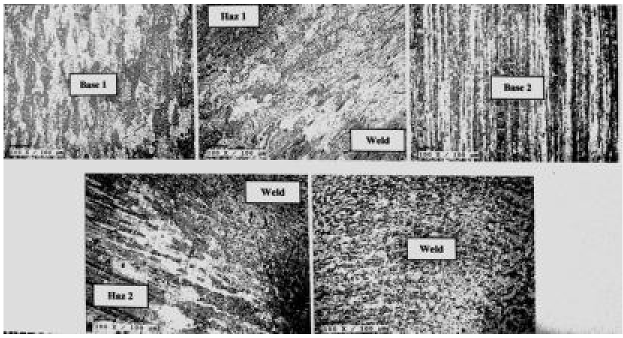

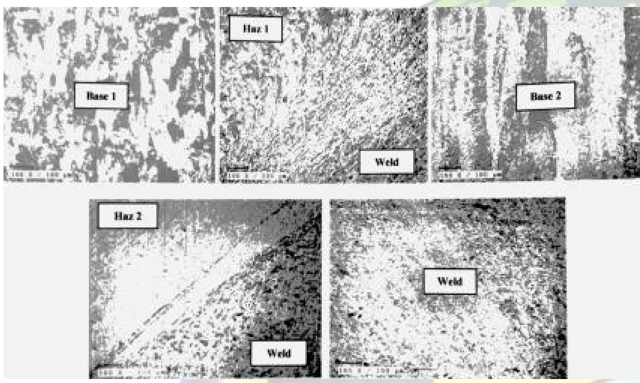

Fig 6. Microstructure of welded samples

BASE 1(3003): The microstructure shows the elongated Al-Mn eutectic particles in a matrix of AL solid solution.

HAZ 1(3003): The microstructure shows the eutectic particles of Al-Mn in a matrix of AL solid solution.

BASE 2(8011): The microstructure shows the elongated Al-Si eutectic particles in a matrix of AL solid solution.

HAZ 2(8011): The microstructure shows the eutectic particles of Al-Si in a matrix of AL solid solution

WELD: The microstructure shows the eutectic particles of Al-Mn and Al-Si eutectic particles in a matrix of AL solid solution.

V. CONCLUSION

In this paper an attempt was made to investigate of FSW process parameter for dissimilar aluminium alloys AL8011 and AL3003 in the structural properties. From the investigation the following conclusions were arrived. 1) The Optimum parameters recommended for threaded pin profile friction stir welding is with Tool rotational speed 1200 rpm,Weld speed -45 mm/min and axial force 4 KN. 2) The weld quality and microstructure is much stable irrespective of the other two parameters implying that the TRS 1200 is the most optimum parameter and in any other tool Rotational speed with the other two parameters namely weld speed & axial force, when changed, significantly changes the mechanical properties for this combination. 3) Lack of penetration observed in welded samples 2, 3 & 6 when we increase the weld force and axial force. Lack of fusion observed in welded samples 5, 7 due to decrease in axial force. 4) Poor properties and micro structures were obtained due to insufficient reaction between Al-Fe matrix components .

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