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A Review Paper on Analysis on the Effect of Tool Profile in Friction Stir Welding of Dissimilar Materials

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Abstract – **Friction Stir Welding (FSW) is a relatively new solid state welding technique for similar and dissimilar materials, especially on current interest with aluminium alloys AA8011 and AA 8068. Methods /Analysis: The Friction Stir Welding of aluminium alloys are reviewed on this paper. The basic principles of FSW are described, followed by tool profiles which affects the weld strength. Findings: The Microstructure, Tensile strength and Hardness test by two different tool profile are reviewed. Conclusion/ Application: It is demonstrated that FSW of Aluminium alloys is becoming an emerging technology with numerous commercial applications.**

Index Terms – **Friction stir welding, Aluminium alloys, Micro structure, Tensile strength and Hardness test**

I. INTRODUCTION

A relatively new joining process, friction stir welding (FSW) produces no fumes; uses no filler material; and can join aluminium alloys, copper, magnesium, zinc, steels, and titanium. FSW sometimes produces a weld that is stronger than the base material.

II. EXPERIMENTAL PROCEDURE

It is well understood that the effect of some important parameters such as rotational speed and welding speed on the weld properties is the major topics for researchers. In all the above cases, FSW parameters are selected by trial and error to fix the major topics for researchers[3].

Lakshmi Narayanan A.K. et al[1]. conducted study on AA2219 aluminium alloy at spindle rotation of 500–1600 RPM and frictional speed of 0.37−2.25 mm per sec. They found that defect free FSW on AA2219 metals produced under a wide range of rotational speeds and welding speeds. Yang Yong et al[4]. Conducted study on dissimilar metals such as 5052 aluminium alloy and AZ 31 magnesium alloy. They found that sound weld was obtained at rotational speed of 600 RPM with welding speed of 40 mm/min. The microstructure of the stir zone is greatly refined.

Elangovan et al., conducted stud on 2219 aluminium alloy material by FSW process. They have used five different tool pin profiles - straight, cylindrical, threaded cylindrical, triangular and square with three welding speeds. Square pin profiled tool produced defect free Friction Stir Processed (FSP) irrespective of welding speeds. Of the three welding speeds used to fabricate the joints, the joints fabricated at a welding speed of 0.76 mm per seconds showed superior tensile properties, irrespective of tool pin profiles. FSW joints usually consist of four different regions, they are:

1. Unaffected Base Metal
2. Heat Affected Zone (HAZ)
3. Thermo-Mechanically Affected Zone (TMAZ)
4. Friction Stir Processed (FSP) zone

The formations of above regions are affected by the material flow behaviour under the action of rotating non- consumable tool. However, the material flow behaviour is predominantly influenced by the FSW tool profiles, FSW tool dimensions and FSW process parameters.

In the FSW process, parameter selection and tool geometry are among the key factors that determine the boundaries developed has high angle disorientations, as demonstrated by SAED pattern. That there are many second phase particles along the boundaries and in grain interiors. Thermo-mechanically affected zone is the transition zone between the base metal and the weld nugget, characterized by a highly-deformed structure. The optical microscopy does not reveal the grains properly. It shows a banded structure. There is no recrystallization in this region. TEM reveals the strengthening precipitates. There is no significant change in the size and morphology of coarser precipitates, but their orientation along rolling direction like in parent metal is absent in TMAZ. The precipitates are quite random. The finer precipitates observed in parent metal are coarsened during welding. Optical microstructure of half of the cross-section of the FS welded 7075-T6 Al, the overall view of the etched weld zone is clearly visible. The weld zone is a nearly V-shaped and widens near the top surface due to the tool geometry and the close contact between the tool shoulder and the upper surface of the weld. The SEM micrograph of the weld nugget in which the grains boundaries can be identified and the average grain size is measured to be ~4 µm. In this region, fine equiaxed grain sizes are formed due to recrystallization.

More recently, an alternative theory has been advanced that advocates considerable material movement in certain locations. This theory holds that some material does rotate around the pin, for at least one rotation and it is this material movement that produces the "onion-ring" structure in the stir zone. The researchers used a combination of thin copper strip inserts and a "frozen pin" technique, where the tool is rapidly stopped in place. T

Material on the advancing front side of a weld enters a zone that rotates and advances with the pin. This material was very highly deformed and sloughs off behind the pin to form arc-shaped features when viewed from above (i.e. down the tool axis). It was noted that the copper entered the rotational zone around the pin, where it was broken up into fragments. These fragments were only found in the arc shaped features of material behind the tool. The lighter material came from the retreating front side of the pin and was dragged around to the rear of the tool and filled in the gaps between the arcs of advancing side material. This material did not rotate around the pin and the lower level of deformation resulted in a larger grain size32.

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III. WELDING PARAMETERS

Tool Speeds:

As noted above, FSW can be a slower process than other forms of welding, such as arc or laser welding. This is because the cylindrical tool must turn to generate heat on the joint, and then traverse the length of the joint transmitting that heat. The tool is tipped with a probe, called a pin or nib, which typically rotates within the range of 200 to 2000 rotations per minute (rpm). The traverse rate of the tool along the joint line is between 10 to 500 millimetres per minute (mm/min). However, these figures are averages, and rates outside of those ranges are still used. The speed is largely determined by the application and the metal being joined, but they are not mutually exclusive a slowly rotating tool cannot move incredibly fast across the joint line, for instance.

Tool Tilt:

The tilt of the cylindrical tool can have major effects on the welding process. A general range for tool tilt is between 2 and 4 degrees, in such a way that the tool leans into the joint. While very minor, the tilt can affect how easily the tool can move across the joint line because less pressure is put in the direction of the joint line.

Plunge Depth:

The plunge depth is the depth to which the shoulder of the tool sinks into the material. While the pin extends farther (the “head,” in relation to the tool shoulder), in this distance friction creates the heat necessary to plasticize the metal. Plunge depth is determined by rotating times. Certain automated systems build up concentrated friction for a given period, then insert the tool down to its predetermined plunge depth. Others are automated to follow the plunge depth calculated beforehand based on how long the tool would need to work for that particular depth.

Tool Design:

Tool design influences heat generation, plastic flow, the power required, and the uniformity of the welded joint. Tool geometry such as probe length, probe shape and shoulder size are the key parameters because it would affect the heat generation and the plastic material flow (Gopala Krishnan S. et al[5]., 2011). The tool is an important part of this welding process. It consists of a shoulder and a pin. Pin profile plays a crucial role in material flow and in turn regulates the welding speed of the FSW process. The shoulder generates most of the heat and prevents the plasticized material from escaping from the work-piece, while both the shoulder and the tool pin affect the material flow. Friction stir welds are characterized by well-defined weld nugget and flow contours, almost spherical in shape, these contours are dependent on the tool design and welding parameters and process conditions used.

Chemical Composition of AA8011:

TABLE I. ELEMENTS AND CONTENTS

Element	Content %
Aluminum, Al	97.3 - 98.9
Iron, Fe	0.60 – 1
Silicon, Si	0.50 - 0.90
Manganese, Mn	≤ 0.20
Zinc, Zn	≤ 0.10
Copper, Cu	≤ 0.10
Titanium, Ti	≤ 0.080
Chromium, Cr	≤ 0.050
Magnesium, Mg	≤ 0.050
Remainder (each)	≤ 0.050
Remainder (total)	≤ 0.15

IV. FLOW OF MATERIALS

To better visualize the flow of material around the welding tool, two new techniques were used. First, small steel balls (0.38 mm diameter) were used as a tracer material embedded at different positions within butt joint welds of 6.4-mmthick 6061-T6 and 7075-T6 plate. A weld was run along the length of the “seeded” butt joint and stopped at a point along the tracer pattern. By stopping the forward motion of the welding tool while it is still in the seeded material, the steel shot distribution around the welding tool is preserved in the end of the weld, revealing the path that the tracer material took in traveling around the welding tool. Each weld was subsequently radiographed to reveal the distribution of the tracer material as it transitioned from its original position, around the welding tool and into the welded joint.

Many techniques for embedding the steel tracer material were evaluated in preparation for the detailed experimental work in this study. However, the most effective method of embedding the tracer material involved machining a small groove, 0.75 mm high by 0.3 mm deep, along the cutting edge of a plate of 6.4-mm aluminium and filling the groove with steel balls Prior to welding, the plates are forced together to imbed the 0.38-mm balls into the 0.3- mm groove.

This technique results in a horizontal line of steel shot arranged at any desired position within the weld by making the groove at different depths and by orienting the butt joint at different lateral positions relative to the path of the welding tool. The initial tracer line locations for 6061 and 7075. Inspection of the weld by radiography then revealed the line of tracer material in advance of the welding tool, as the material was deforming around the tool, and after passage of the welding tool. The second technique used in this study involved ending friction stir welds by suddenly stopping the forward motion of the welding tool and simultaneously retracting the tool at a rate that caused the welding tool pin to unscrew itself from the weld, leaving the material within the threads of the pin intact and still attached to the keyhole. By sectioning the keyhole at the end of a weld that was made using this “stop action” technique, one can study the flow of material in the region immediately within the threads of

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the welding tool. This technique requires the use of a numerically controlled (NC) milling machine.

V. HEAT GENERATION AND PROCESS OPERATING REGIMES

Friction stir welding differs from competing processes such as arc and laser welding, since these use an external heat source of specified power, whereas in FSW the joining process itself generates the heat. The heat input is therefore a complex function of the process variables (traverse and rotation speeds, and down force), the alloy being welded, and the tool design. Analytical estimates of heat input have assumed sliding Coulomb friction at the tool/workpiece interface with a constant coefficient of friction, or sticking friction using an estimate of the limiting shear yield stress, or have inferred contact conditions and/or heat input from measurements of machine torque.

Selected Tool Profile

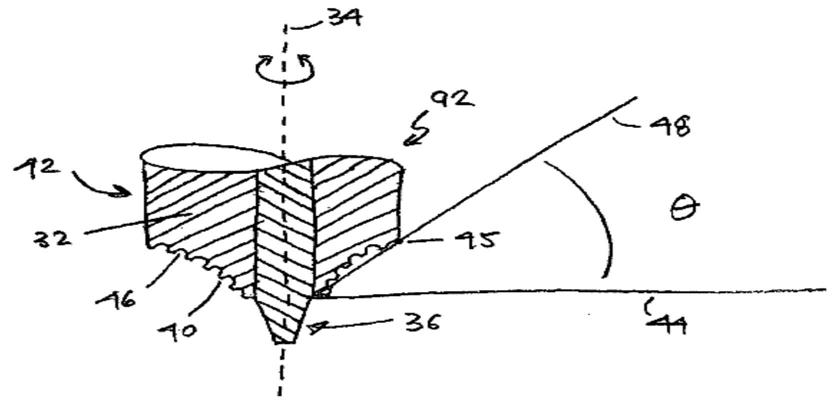

Fig 1. Taper tool profile

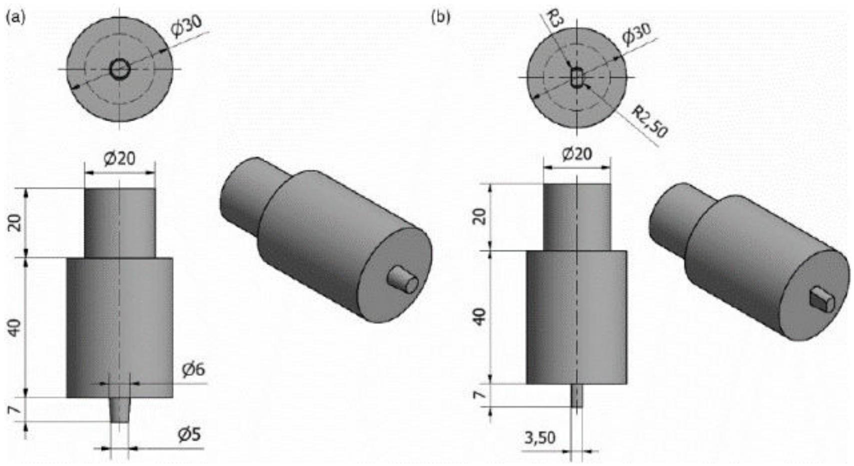

Fig 2. Cylindrical tool profile

Applications:

Application of FSW includes various industries including few of following:

- Shipping and marine industries: - Such as manufacturing of hulls, offshore accommodations.
- Aerospace industries: - for welding in Al alloy fuel tanks for space vehicles, manufacturing of wings, etc.
- Railway industries: - building of container bodies, railway tankers, etc.
- Land transport: - automotive engine chassis, body frames, wheel rims, truck bodies, etc.,

Hardness Test:

Hardness is a characteristic of a material, not a fundamental physical property. It is defined as the resistance to indentation, and it is determined by measuring the permanent depth of the indentation.

The Hardness test report generated by Rockwell hardness testing machine for the welded dissimilar workpiece of cylindrical tool profile and taper tool profile respectively.

VI. Microstructure Analysis

During microscopic examination or microstructure analysis, the structure of material is studied under magnification. The properties of materials determine how they'll perform under a given application, and these properties are dependent on the material's structure.

The microstructure of the regions of the welded dissimilar material AA8011 and AA8068 by different tool is shown in figure 4 and 5. Though the weld undergoes considerable amount of thermal cycle, there is no significant changes in the microstructure of the base metals. On the other hand, the thermal cycle, has considerably influenced the Heat affected Zone (HAZ), which is evident from the microstructure. However, there is no plastic deformation occurring in this area. In the thermo-mechanically affected zone (TMAZ), there is considerable growth in the grain boundaries which could be due to the plastic deformation and the less heat developed during the process. Also, it is evident from the microstructure that a distinct grain boundary separates the recrystallized zone (weld nugget) from the deformed zones of the TMAZ. The dynamically recrystallized zone is the stirred zone, where the material has undergone severe plastic deformation resulting in fine equiaxed grains. The term stirred zone is commonly used in friction stir processing, where sufficient volume of material is processed. Further from the microstructure of the weld nugget it is evident that the grains are highly refined, which could enhance the strength of the weldment.

Metavis Image Analysis System:

The Metavis is a complete Image Analysis System comprising of an Inverted Metallurgical Microscope, a High Resolution Digital Camera and an advanced and user friendly Image Analysis Software.

The digital camera is mounted on the inverted metallurgical microscope as shown in figure 3. The camera transfers the images to the computer. Once an image is acquired by the computer, it is processed and analysed by our Software.

Fig 3. Metavis Image Analysis Microscope

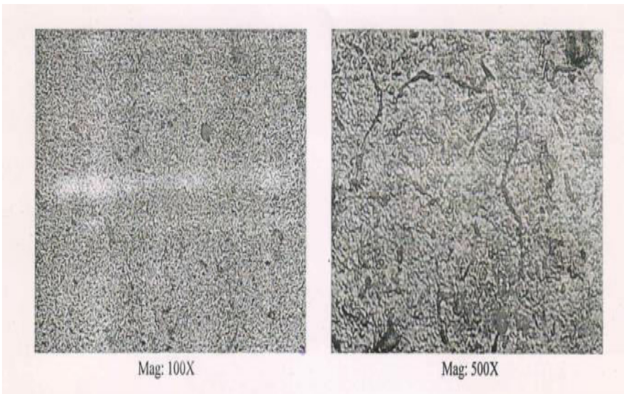

Fig 4. MS of cylindrical tool weld

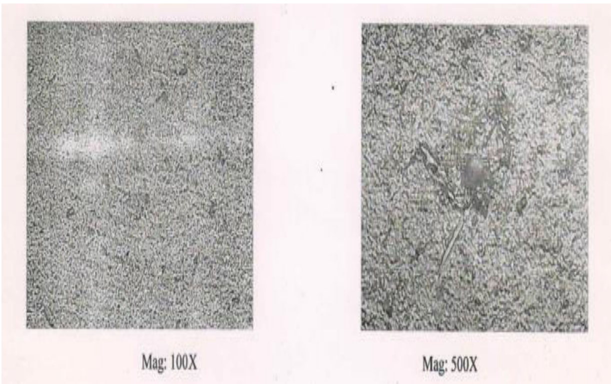

Fig 5. MS of Taper tool weld

Tensile Test:

A universal testing machine (UTM), also known as a universal tester, materials testing machine or materials test frame, is used to test the tensile strength and compressive strength of materials.

Tensile testing, is also known as tension testing is a fundamental materials science test in which a sample is subjected to a controlled tension until failure. The results from the test are commonly used to select a material for an application, for quality control, and to predict how a material will react under other types of forces. Properties that are directly measured via a tensile test are ultimate tensile strength, maximum elongation and reduction in area. From these measurements the following properties can also be determined: Young's modulus, Poisson's ratio, yield strength, and strain-hardening characteristics

The stress strain relationship for the material AA8011 and AA8011, the elasticity and the applied load was clearly marked on that graph.

VII. CONCLUSION

The present review has demonstrated the extensive research effort that continues to progress the understanding of FSW of aluminium alloys and its influence on their microstructure and properties. It identifies several areas that are worthwhile for further study. From an engineering perspective, there is a need to investigate the occurrence and significance of flaws in friction stir welds. The influence of tool design on flaw occurrence and the development of non-destructive testing techniques to identify flaws in both lap and butt welds would be beneficial. Metal flow modelling may have a role to play here, though capturing this aspect of the thermomechanical behaviour remains a significant challenge.

REFERENCES

[1] Lakshminarayanan AK, Malarvizhi S, Balasubramanian V. Developing Friction Stir Welding window for AA2219 aluminum alloy. Trans Nonferrous Met Soc. China. 2011 Nov; 21(11):2339–47.
[2] Elangovan K, Balasubramanian V. Influences of tool pin profile and welding speed on the formation of friction stir processing zone in AA2219 aluminum alloy. Journal of Materials Processing Technology. 2008 May; 200(1-3):163–75.
[3] Gould JE, Feng Z, Ditzel P. Preliminary modeling of the Friction Stir Welding process. Proceedings of ICAWT, EWI; Columbus: Ohio. 1996. p. 297–310.
[4] Yong Y, Zhang DT, Cheng Q, Zhang W. Dissimilar Friction Stir Welding between 5052 aluminum alloy and AZ31 magnesium alloy. Trans Nonferrous Met Sc. China. 2010 Jul; 20(S2): s619–23.
[5] Gopalakrishnan S., Murugan N., Prediction of tensile strength of friction stir welded aluminium matrix TiCp particulate reinforced composite, Materials and Design 32 (2011) 462–467.
[6] Chen Y, Liu, H, Feng J. Friction Stir Welding characteristics of different heat-treated-state 2219 aluminum alloy plates. Mater Sci Eng. A, MSA. 2006 Mar; 420(1-2):21–5.
[7] Kwon, Y. J., Shigematsu, I., & Saito, N. Dissimilar friction stir welding between magnesium and aluminum alloys 2008; 62:3827–3829
[8] Ramesh Babu, S., Senthilkumar, V.S., Madhusudhan Reddy, G., Karunamoorthy, L. Microstructural changes and mechanical properties of friction stir processed extruded AZ31B alloy Procedia Engineering 2012;38:2956 – 2966.
[9] El-hafez, H. A. Mechanical Properties and Welding Power of Friction Stirred AA2024-T35 Joints 2011; 839–845.
[10] Rowe C.E.D. and Thomas Wayne, __Advances in tooling materials for friction stir welding, TWI and Cedar Metals Ltd., Page 1 of
[11] FSW-Technical-Handbook, ESAB AB, Welding Automation, SE695 81 LAXÅ, Sweden. Phone: +46 584-81000 www.esab.com.
[12] Mishraa R.S., Maba Z.Y.,Friction stir welding and processing‘‘, Materials Science and Engineering R 50 (2005), page 1–78.
[13] Tozakia Y., Uematsub Y., Tokajib K., A newly developed tool without probe for friction stir spot welding and its Performance ‘‘, Journal of Materials Processing Technology 210 (2010) 844–851.

[14] Nandan R., DebRoy T., Bhadeshia H.K.D.H.,Recent advances in friction-stir welding – Process, weldment structure and properties'', Progress in Materials Science 53 (2008) page, 980-1023.
[15] Ericsson M., Sandstro R. and Brinell Centre,Influence of welding speed on the fatigue of friction stir welds, and comparison with MIG and TIG'', Journal of Materials Processing Technology 212 (2012) 1488– 1494.
[16] Pouget G., Reynolds A.P., Residual stress and microstructure effects on fatigue crack growth in AA2050 friction stir welds, International Journal of Fatigue 30 (2008) 463–472.
[17] Zimmer Sandra & Langlois Laurent & Laye Julien & Bigot Régis, Int J Adv. Manuf Technol (2010) 47: page 201–215.
[18] Sorensen Carl D. and Nelson Tracy W., Friction Stir Welding and Processing '', 2007 ASM International, page no 111-121
[19] DebRoy T. and Bhadeshia H. K. D. H., Friction stir welding of dissimilar alloys – a Perspective, Science and Technology of Welding and Joining 2010 VOL 15 NO 4 page266-270.