ANALYSIS ON THE EFFECT OF TOOL PROFILE IN FRICTION STIR WELDING ON DISSIMILAR MATERIALS

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ABSTRACT

Objective: 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 AA8068. Methods /Analysis: The Friction Stir Welding of aluminium alloys are reviewed on this paper. The basic principles of FSW followed by cylindrical and Taper tool profiles which affects the weld strength are described. Findings: The Microstructure, Tensile strength and Hardness test by two different tool profile are reviewed. Conclusion/ Application: To identify the efficient tool profile for this combination of materials in FSW. It is demonstrated that FSW of Aluminium alloys is becoming an emerging technology with numerous commercial applications.

Keywords: Friction stir welding, Aluminium alloys, Micro structure, Tensile strength and Hardness test.

INTRODUCTION

Friction stir welding was invented by The Welding Institute (TWI) in December 1991. TWI filed successfully for patents in Europe, the U.S., Japan, and Australia. 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. Because melting does not occur and joining takes place below the melting temperature of the material, a high-quality weld is created. This characteristic greatly reduces the ill effects of high heat input, including distortion, and eliminates solidification defects. Friction stir welding also is highly efficient which make this process environmentally friendly.

EXPERIMENTAL PROCEDURE

The friction stir welded joints of dissimilar aluminium alloy8011 and aluminium alloy 8068 were fabricated using a FSW machine. A total of 2 joints were fabricated by using the selected tool profiles. The mechanical properties of AA8011 are given in Table 1. The process parameters selected for the present investigation are given in figure 5. The tool used for fabricating the joints is made by high speed steel M42 of diameter 20mm with shoulder diameter as 17mm and with a cylindrical pin diameter 7mmand Taper pin of diameter 5mm.

ELEMENT	CONTENT %
Density	2.7 g/cm^3
Elastic (Young's, Tensile) Modulus	72 GPa
Elongation at Break	1.2 to 22 %
Modulus of Resilience (Unit Resilience)	8.5 to 200 kJ/m^3
Poisson's Ratio	0.33
Specific Heat Capacity	890 J/kg-K
Strength to Weight Ratio	37 to 67 kN-m/kg
Tensile Strength: Ultimate (UTS)	100to180 MPa (15 to 26 x 10^3 psi)
Tensile Strength: Yield (Proof)	35to170 MPa (5.1 to 25 x 10^3 psi)

Table 1:Mechanical properties of AA8011

Figure 1: Cylindrical tool profile

Figure 2: Taper tool profile

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) and 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 influenced by the FSW tool profiles, FSW tool dimensions and FSW process parameters Thermo-mechanically affected zone is the transition zone between the base metal and the weld nugget, characterized by a highly-deformed structure.

Figure 3: Tool fixing jaw

Figure 4: FSW setup

WELDING PARAMETERS

Tool speed: 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 at a speed of 1200 rotations per minute (rpm). The traverse rate of the tool along the joint line is between 23 to 30 millimetres per minute (mm/min).

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.

Figure 5: Input parameters

Tool Design: Tool design influences heat generation, plastic flow, the power required, and the uniformity of the welded joint. The tool used for fabricating the joints are shown in Figure 1 and Figure 2. 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. 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.

FLOW OF MATERIAL

The mode of material flow around the tool used inserts of a different alloy, which had a different contrast to the normal material when viewed through a microscope, in an effort to determine where material was moved as the tool passed .The data was interpreted as representing a form of in-situ extrusion where the tool, backing plate and cold base material form the "extrusion chamber" through which the hot, plasticised material is forced. In this model the rotation of the tool draws little or no material around the front of the probe instead the material parts in front of the pin and passes down either side. After the material, has passed the probe the side pressure exerted by the "die" forces the material back together and consolidation of the join occurs as the rear of the tool shoulder passes overhead and the large down force forges the material. The welded AA8011 and AA8068 aluminium alloy by cylindrical and taper tool profile are shown in Figure 5 and Figure 6.

Figure 6: Cylindrical profile welded plate

Figure 7**:** Taper tool profile welded plate

TENSILE TEST

A Universal testing machine (UTM), also known as a universal tester, materials testing machine is used to test the tensile strength. Tensile testing is a fundamental material 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. Tensile properties often are measured during development of new materials and processes. From these measurement, the stress strain relationship for the material AA 8011 and AA 8068 are found.

Specimen shape	Flat
Specimen Type	Aluminium
Specimen Description	Aluminium Sample
Specimen Width	5.77mm
Specimen Thickness	4.41mm
Initial G.L. For % elongation	50mm
Max. Load	30kN
Max. Elongation	1000mm
Specimen Cross Section Area	25.446mm^2

Table 2: UTM Taper Input Data

Load at Peak	1.617kN
Elongation at Peak	2.302mm
Tensile Strength	63.547N/mm^2

Table 3: UTM Taper Output Data

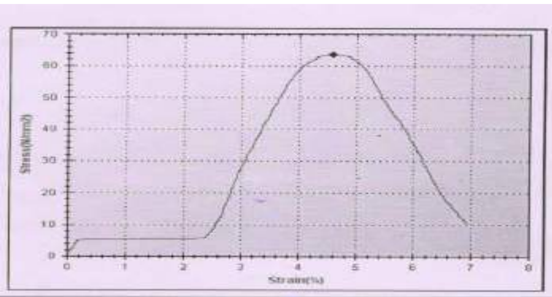

Figure 8: Taper stress strain graph

Specimen shape	Flat
Specimen Type	Aluminium
Specimen Description	Aluminium Sample
Specimen Width	5.68mm
Specimen Thickness	4.77mm
Initial G.L. For % elongation	50mm
Max. Load	30kN
Max. Elongation	1000mm
Specimen Cross Section Area	27.094mm^2

Table 4: UTM Cylindrical profile input data

Load at Peak	1.622kN
Elongation at Peak	2.083mm
Tensile Strength	59.848N/mm

Table 5: UTM Cylindrical profile output data

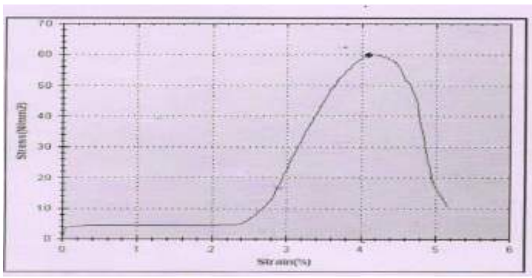

Figure 9: Cylindrical stress strain graph

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 Cylindrical and Taper tool profile are shown in Figure 13 and Figure 14 respectively.

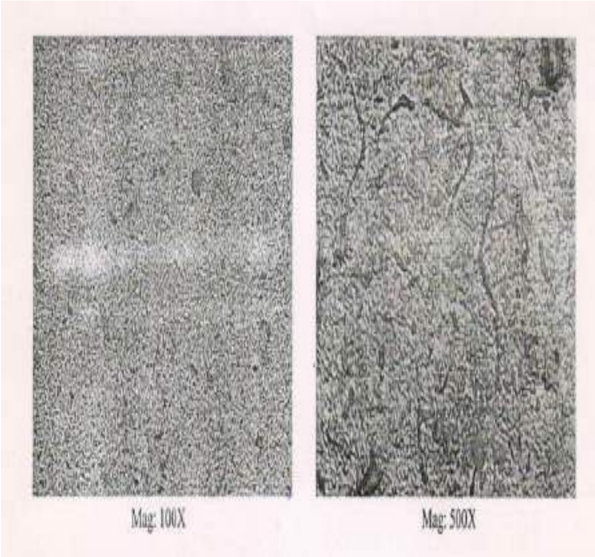

Figure 10: MS of Cylindrical tool profile weldedplate

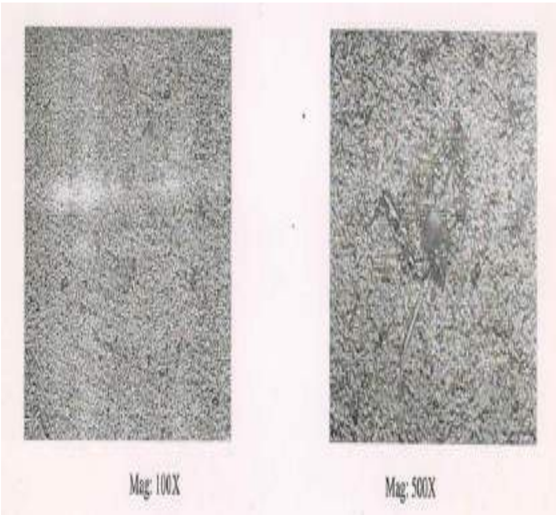

Figure 11: MS of Taper tool profile welded plate

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 are shown in Figure 14 and Figure 15 respectively.

S. No	Sample ID	Observed values, HRB			Average, HRB
		1	2	3	
1.	CY	78	76	75	76

Table 6: Cylindrical profile test results

S No	Sample ID	Observed values, HRB			Average, HRB
		1	2	3	
1.	T	92	95	93	93

Table 7: Taper profile test results

Figure 12: Tested pieces

CONCLUSION

I. From the tensile test results, the welded joint which is welded using taper tool possess high tensile strength than the cylindrical tool profile. (93>76)

II. From the hardness test results welded joint which is welded using taper tool possess greater hardness than the cylindrical tool ($63.547 N/mm^2 > 59.848 N/mm^2$)

III. From the micro structure analysis, grains form a strong bonding in the welded joint which is welded using taper tool than the cylindrical tool

IV. Hence from the results taper tool profile exhibits better values compared to cylindrical tool profile.

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