IJREAT International Journal of Research in Engineering & Advanced Technology, Volume 1, Issue 4, Aug-Sept, 2013
ISSN: 2320 - 8791
www.ijreat.org

Experimental and theoretical study on effect of welding speed and tool pin profiles on aluminum friction stir welded butt joints

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Abstract

Friction stir welding process is an emerging solid state joining process in which the material that is being welded does not melt and recast. This process uses non-consumable tool to generate frictional heat in the butting surfaces. The welding parameters tool pin profile plays a major role in deciding welding quality. In this paper finite element analysis was made to understand the effect of welding speed and tool pin profile on FSP zone formation in Aluminum alloy 6061 and 6082. Five different tool pin profiles are used to fabric the welding joints. we are also studied the coupled field analysis for both cutting tools and welding plates . By observing the results, thermal flux is more for Round Taper tool. Temperature is also produced for required melting point of plates. So for using Friction Stir Welding, Round Taper cutting tool is more effective than other cutting tools from FEA results.

Keywords: *FSW, Aluminum, Tool Profile, FEA, Welding speed.*

1. Introduction

Friction stir welding (FSW) is a significant manufacturing process for producing welded structures in solid state. This process offers several advantages compared to the conventional welding methods including higher mechanical properties and lower residual stresses as well as reduced occurrence of defects. In FSW process, a rotating tool having a shoulder moves along the welding line. Rotational motion of the shoulder generates frictional heat leading to a softened region around the pin while the shoulder prevents deforming material from being expelled. In fact, a weld joint is produced by the extrusion of material from the leading side to the trailing side of the tool.

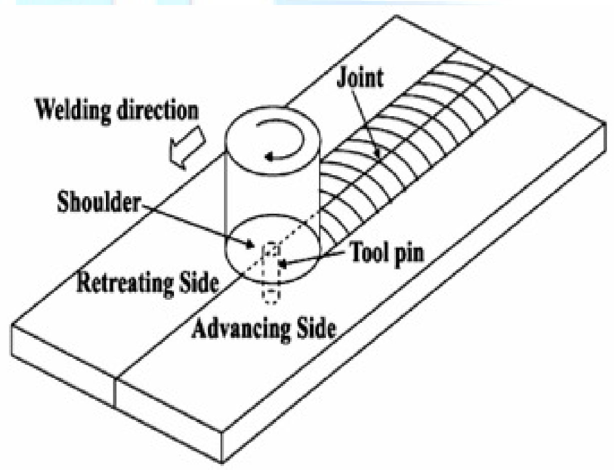

Fig 1: Schematic diagram shows friction stir welding process

Regardless of the material in which a friction stir weld is performed, the resulting microstructure has four distinct zones that result from the welding process. The area of all four of these zones comprises what is commonly referred to as the Weld Affected Zone (WAZ).The first constituent of the WAZ is the Dynamically Recrystallized Zone (DXZ), also known as the weld nugget, which lies at the centre of the weld along the weld seam. This zone is bordered on either side by the remaining two constituent zones, the Thermo Mechanically Affected Zone (TMAZ) immediately surrounding the DXZ, and the Heat Affected Zone (HAZ) surrounding the outside edges of the TMAZ.

The microstructure can be broken up into the following zones: 1.Stir Zone 2.Flow Arm Zone 3.Thermo Mechanically Affected Zone 4.Heat Affected Zone.
The design of the tool is a critical factor as a good tool can improve both the quality of the weld and the maximum possible welding speed. It is desirable that the tool material is sufficiently strong, tough, and hard wearing at the welding temperature.
Further it should have a good oxidation resistance and a low thermal conductivity to minimise heat loss and thermal damage to the machinery further up the drive train. Improvements in tool design have been shown to cause substantial improvements in productivity and quality. In this paper an attempt is made to understand the effect of welding speed and tool pin profile on FSP zone formation in Aluminium alloy 6061 and 6082. Five different tool pin profiles are used to fabric the welding joints. Those profiles are 1.Stright cylindrical, 2.Tapered cylindrical, 3.Threaded cylindrical, 4.Triangular, 5.Squre. In this project we studied the coupled field analysis for both cutting tools and welding plates. We also conducted experimental work by using CNC milling machine. In that we prepared the fixture, cutting tools and plates Main parameters taken for this paper are cut feed, spindle RPM.

2 Experiments

The friction stir welds have been carried out by using a properly designed clamping fixture that allows the user to fix the two sheets (100mm × 50mm) with the rolled plate of 3mm thickness to be butt welded on a CNC vertical milling machine. Figure-3 shows the vertical CNC milling machine used for experimental work

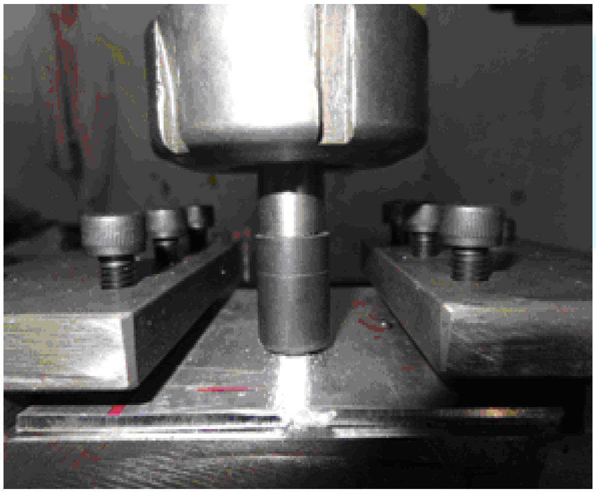

Fig2: Experimental Setup describing clamping and welding of FSW plates
The result of the FSW procedures was six sets of welds on each alloy. The welding parameters that are paired with each sample are presented in table1

Table1 : FSW operating parameters

TYPE OF ALLOY	SPEED (RPM)	FEED (MM/MIN)
6061	1400	8
	1200	8
	1000	8
6082	1400	8
	1200	8
	1000	8

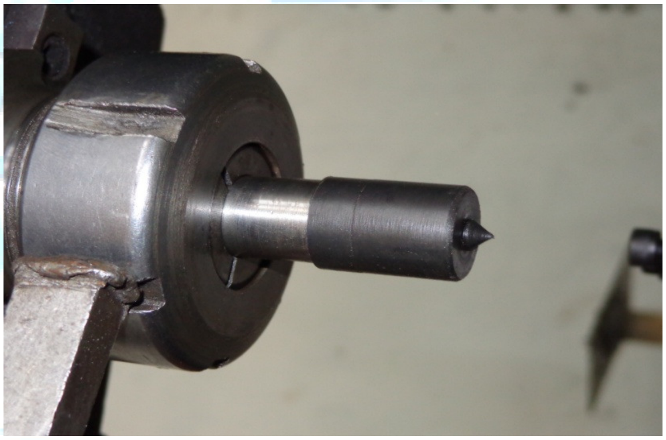

Fig 3: Tool used for FSW process

3 Design of FSW Tool Profiles

Pro/ENGINEER design software was used for designing the i) Round ii) Taper iii) square iv) Triangular and v) threaded tool profiles by taking the stranded dimensions of the tools. The designed models were used in the ANSYS to do the coupled analysis

4 Finite Element Analysis

Couple field analysis was conducted on the FSW joints with different tool profiles using ANSYS software , Element type as a Solid brick 20 node 90 and Meshing type as Triangular Meshing ,Loads applied on top area of the cutting tool

Table 2 FEA Structural analysis results

Tool Profiles	**RPM**	**AA - 6061**		**AA – 6082**	
		Displacement	**Stress**	**Displacement**	**Stress**
Round Tool	1000	0.001019	298.821	0.001019	298.213
	1200	0.001158	340.81	0.001261	339.896
	1400	0.001737	390.205	0.001716	202.15
Round Taper Tool	1000	$0.881e^{-03}$	359.675	$0.870\ e^{-03}$	359.422
	1200	0.001272	316.49	0.001256	315.811
	1400	0.001727	396.647	0.00171	365.213
Square Tool	1000	$0.997\ e^{-03}$	215.966	$0.0997\ e^{-03}$	215.616
	1200	0.001269	246.555	0.001254	246.124
	1400	0.001727	382.981	0.001706	282.341
Thread Tool	1000	0.00113	1710	0.00113	1692
	1200	0.001287	1937	0.001271	1930
	1400	0.001753	2839	0.00173	2204
Triangular Tool	1000	$0.885\ e^{-03}$	153.276	$0.001123\ e^{-03}$	154.822
	1200	0.001275	190.233	$0.976\ e^{-03}$	151.386
	1400	0.001735	232.643	0.002202	232.223

Table 3 Thermal Analysis Results

Tool Profile	**RPM**	**AA-6061**			**AA-6082**		
		Temperature	**T.G**	**T F**	**Temperature**	**T.G**	**T F**
Round Tool	1000	673^0C	5398	971.667	673^0C	5432	934.365
	1200	703^0C	6232	1122	703^0C	5879	1011
	1400	723^0C	6138	1105	723^0C	6177	1062
Round Taper Tool	1000	673^0C	5460	982.811	673^0C	5498	945.616
	1200	703^0C	5909	1064	703^0C	5950	1023
	1400	723^0C	6208	1117	723^0C	6251	1075
Square Tool	1000	673^0C	5919	1065	673^0C	6041	1039
	1200	703^0C	6406	1153	703^0C	6449	1109
	1400	723^0C	6730	1211	723^0C	6775	1165
Thread Tool	1000	673^0C	5082	914.677	673^0C	1910	314.146
	1200	703^0C	1327	86.098	703^0C	9505	1635
	1400	723^0C	7015	1263	723^0C	10134	1743
Triangular Tool	1000	673^0C	4916	884.829	673^0C	4329	744.516
	1200	703^0C	5457	982.322	703^0C	4684	805.708
	1400	723^0C	5903	1063	723^0C	4922	846.504

Table 4 Tensile Properties

Alloy	**Speed (rpm)**	**Feed (mm/min)**	**Load (N)**	**Elongation (mm)**	**Tensile strength (N/mm²))**
AA-6082	1000	8	6300	12	106.66
AA-6082	1200	8	8800	15	146.66
AA-6082	1400	8	9600	17	160

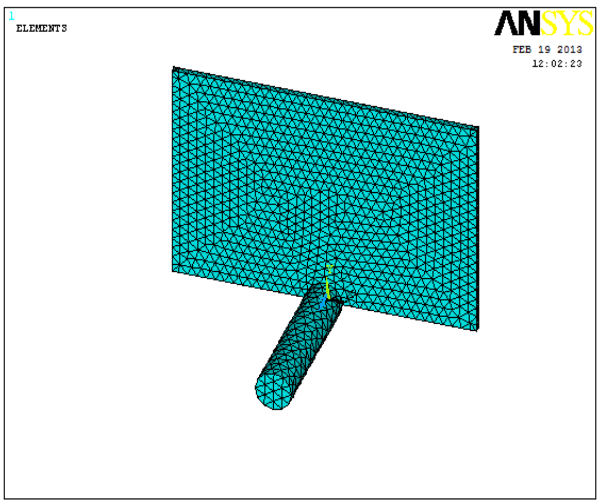

Fig 4 Mesh model

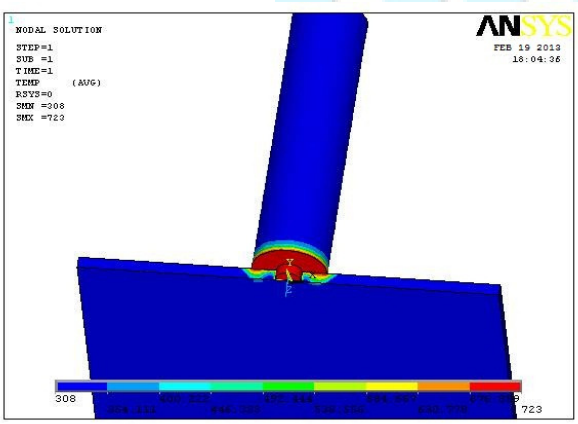

Fig 5 Temperature distribution

5 Results and Discussions

The coupled analysis results are shown in Tables 2 and 3 and the tensile test results of the FSW joints are shown in Table4. The Tables can be effectively used to understand the effect of FSW process parameters such as welding speed; tool profiles friction stir welded AA6061and 6082 aluminum alloy joints

6 Conclusions

In this paper we studied the five types of cutting tools Round, Round taper, Square, Triangle and Thread for doing Friction Stir Welding. We have conducted FEA process coupled field analysis on tools Round, Round taper, square and triangle to verify the temperature distribution, thermal flux, gradient and stresses. By observing the results, thermal flux is more for Round Taper tool. Temperature is also produced for required melting point of plates. So for using Friction Stir Welding, Round Taper cutting tool is more effective than other cutting tools from FEA results

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