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Experimental Investigation of Friction Stir Welding Of T6061 and T6082 Aluminium Alloys by Using En19 Circular and Taper Tool

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Abstract: *Friction Stir Welding (FSW) is solid state Joining Process. Heat is generated between tool and work piece and there is no need of filler material for joining similar and dissimilar materials. An experimental investigation has been conducted on a Milling machine for joining aluminum of grade 6061 with 6061, 6082 with 6082, 6061 with 6082 by using EN19 Tool material with Round and Taper Profiles with a Rotational speed of 1120 RPM, Feed 25 mm/min and depth of cut 3.5 mm, inclinational angle of the tool 0.5. The mechanical properties of the joints, Ultimate Strength, Yield strength, Vickers Hardness and Microstructure of the joints are evaluated. The results found that 6061-6061 with Taper profile has given has good Hardness (57HV), Tensile Strength(142 N/mm2) and Yield Strength(112 N/mm2) and Grain Structure number is 6 (ASTM E112)*

I. Introduction

Friction Stir Welding (FSW), is a Solid State Welding Process invented and patented by The Welding Institute UK (TWI) in 1991 [1]. The idea behind the FSW welding technique is based on the principles of thermo-mechanical joining of the materials by means of a special tool, without the use of filler materials and gas shield [2]. Aluminum is one of the typical metal which is very difficult to weld by normal fusion welding process because of its low melting point and high thermal conductivity. The most commonly used welding methods are GTAW and GMAW and SMAW but these welds are not suitable because of its inferior welds, blow holes and porosity and under cut.. FSW is a most successful welding process to overcome this difficulty[3]

Magdy M. El-Rayes, Ehab A. El-Danaf et al (2012), investigated the influence of multiple passes on the microstructural and mechanical properties of 6082 aluminum alloy. Ehab A.El-Danaf et al studied FSW of 6082 AA using different feed rates and rotational speeds, Post weld heat treatment (PWHT) is influential in recovering the joint's strength, grain size for all welding conditions ranged from 2.3 to 2.8 μm and post weld heat treatment resulted in changing the main texture components. T. Minton & D.J. Mynors (2006), investigated whether a conventional milling machine is capable of performing the task of friction stir welding, by producing same thickness welds of 6.3mm and 4.6mm 6082-T6 aluminum sheets using a Parkson Vertical Mill Type A machine. The process mechanism of friction stir welding, the evolution of the microstructure 6061 Al plates as a result of these processes and also determines the mechanical properties of the welded joints.

Several studies have been carried out on the effects of similar and dissimilar aluminum alloys and parameters on the microstructure and mechanical properties in the weld zone with various configurations. In particular, the effect of the tool shape on the material and the resultant properties have not yet been revealed in detail. In this study, Al 6061-Al 6061, Al 6061-Al 6082 and Al 6082- Al 6082 with a thickness of a 4 mm thick plates are friction stir welded on Milling machine by varying different tool materials and profiles kept constant the parameters depth of cut, inclination angle, feed and rotation speed. In this study The tool is made of EN19 is selected because of high strength and withstand at high temperatures with a circular and taper threaded profiles were selected for different combinations of selected specimens of size 100*55mm. The samples tested on a Vickers Hardness test, Universal testing machine and Optical micro scope and get the results Hardness, Tensile Strength, Yield Strength and Micro structure. Finally, the mechanical and microstructural properties of the joints are evaluated and compared.

II. Experimental Setup

In this process the aluminum plate of 4 mm thickness with grades T6061 and T6082 are selected.

EN19 Too was selected with a circular and taper with helical grooves are selected with a dimensions as shown in Table 3. The mechanical properties of the T6061 and T6082 are depicted in the Table1 and Table 2. The experiment was conducted on a conventional Milling machine as shown in the fig.1

2.1 Process Variables

A), Tool Design: The Design of the tool is a critical factor. It determines the quality of weld and its maximum welding speed, The tool materials should be sufficiently strong, tough, hard and wear resistance at the welding temperature. EN 19 material was selected as Tool materials. It is high quality alloy steel with tensile strength, good ductility and shock resistance. It is widely used in automotive gears and parts, shafts, towing pins, load bearing tie rods, Oil and Gas Industry application.

Table 1: Chemical composition of EN 19 Alloy Steel

C	Mn	Cr	Mo	Si	S	P
0,35-0.45	0.5-0.8	0.9-1.5	0.2-0.4	0.1-0.35	0.05	0.035

Table 2: Mechanical Properties of EN19 Alloy Steel

Tensile N/mm2	Yield N/mm2	Elongation %	IZOD KCV J	Hardness Brinell
850-1000	680	13	50	248-382

Source : Smiths Metal Centres, Data Sheet 2017

The rod of 40 mm dia has procured and machined as per the following dimensions.
The following parameters are taken in to consideration

Table 3: Process Variables

Fig 1. Experimental set up

B) Rotational Speed of the Tool: The Rotational speed of the tool is also known as machine spindle RPM affects the quality of the Joint. With increase in rotational speed, the heat generated by friction also increses which directly affects the temperature at welding position. For this experiment 1120 RPM is selected.

C) Welding Feed Speed : The welding feed speed is also know as tool advancing speed is also affects the welding joint quality. With decrees in tool rotational speed the time for which the tool in contact with work increses, so that the heat generated due to friction is also increases which directly affect the temperature at the welding position. The feed is selected 25 mm/min

D) Depth of Cut(Axial Force): The depth of cut is also termed as Axial Force required to weld the joint. Based on the thickness of the material this force is selected. There is a limitation of this force based on the machine specifications and thickness of the materials selected, In our case the depth of cut is fixed 3.5 mm.

Parameters	1	2
Tool Profile	Circular	Taper Threaded
Rotational Speed(RPM)	1120	1120
Feed(mm/min)	25	25
Depth of cut(mm)	3.5	3.5
Inclination angle	0.5 deg	0.5 deg
Tool		
Tool Dimensions	Outer Dia 18 mm Pin Dia 4.8 mm Length of Pin 3.3 mm	Outer Dia 18 mm Pin Dia (D) 4.8 mm Pin Dia (d) 3.8 mm Length of Pin 3.3mm Taper angle 8.5 deg

FIG 2 Sample 1 Circular Tip 6082-6082

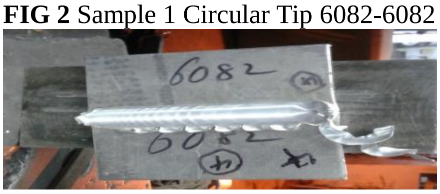
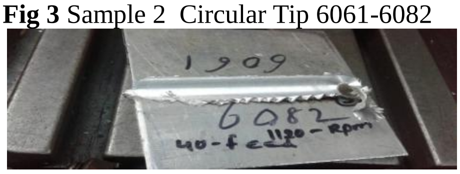


Fig 3 Sample 2 Circular Tip 6061-6082



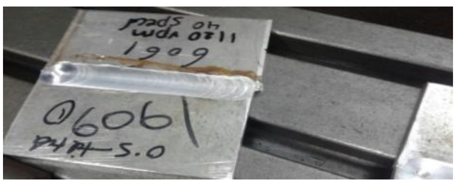


Fig 4 Sample 3 6061-6061 With Taper Tool

Fig 5 Sample 4 6061-6082 with taper tool

III. Test Results and Discussions:

After friction stir welding of the samples, mechanical properties of the results are evaluated. The mechanical properties of the welded joint are Tensile and Yield strength, Vickers Hardness and Microstructure of the materials are analized.

a)Tensile and Yield Strength

This test is conducted by using Universal Testing machine This test is used to measure the strength of a welded joint. A portion of the welded plate is locate the weld midway between the jaws of the testing machine. The width thickness is of the test specimen are measured before testing and the area in square inches is calculated by multiplying these before testing and the area in square inches is calculated by multiplying these two figures. The tensile test specimen is then mounted in a machine that will exert a stationary or a portable type. A machine of the portable type, operating on the hydraulic principle and capable of pulling as well as bending test specimens. As the specimen is being tested in this machine, the load in pounds is registered on the gauge. In the stationary types, the load applied may be registered on a balancing beam. In either case, the load at the point of breaking is recorded

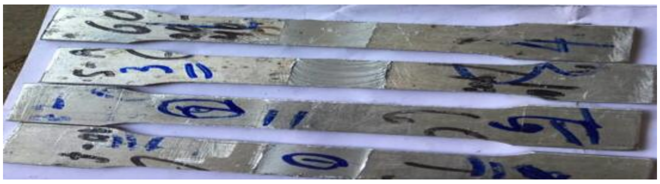


Fig:6 Test samples for Conducting Tensile Strength and Yield Strength

1.6061-6082 by using circular tip of EN19 tool
2. 6061-6082 by using taper thread tip of EN19 tool
3. 6082-6082 by using circular tip of EN19 tool
4. 6061-6061 by using taper thread tip of EN19 tool
The following table gives the final results obtained from Universal Testing machine

Table 4. Test Results Tensile and Yield strength

Sl.NO	Material Combination	Ultimate Tensile Strength N/mm2	Yield Strength N/mm2
1.	6061-6082 – Circular Tip	131.58	82.3
2.	6061-6082 - Taper Threaded	110.96	93.2
3.	6061-6061 Taper Tip	142.0	112.45
4.	6082-6082 Circular	213.4	143.05

B) Vickers Hardness Test:

The Vickers hardness test method consists of indenting the test material with a diamond indenter as shown in Fig., in the form of a right pyramid with a square base and an angle of 136 degrees between opposite faces subjected to a load of 1 to 100 kgf. The full load is normally applied for 10 to 15 seconds. The two diagonals of the indentation left in the surface of the material after removal of the load are measured using a microscope and their average calculated. The area of the sloping surface of the indentation is calculated

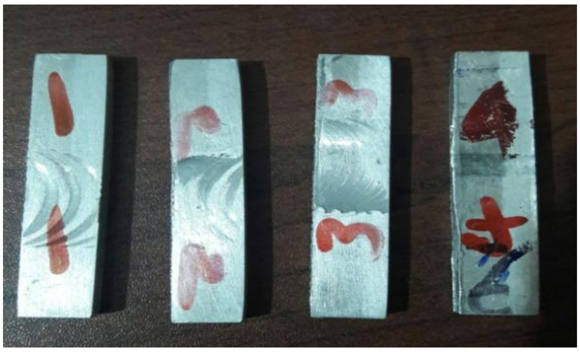


Table 5 Vickers Hardness Test Results

Sl.NO	Material Combination	Vickers Hardness HV
1.	6061-6082 – Circular Tip	40.00
2.	6061-6082 - Taper Threaded	40.33
3.	6061-6061 Circular Tip	57.00
4.	6082-6082 Taper Threaded	51.67

C) Microstructure:

The test samples are analyzed Microstructure as per ASTM E 112 and the following table indicates the Microstructure values

Table 6 Microstructure Values as per ASTM E 112

Sl.NO	Material Combination	Microstructure Value
1.	6061-6082 – Circular Tip	6.0
2.	6061-6082 - Taper Threaded	6.5
3.	6061-6061 - Circular Tip	6.0
4.	6082-6082 - Circular Tip	6.5

IV. Conclusions

The experiments have been conducted On a Milling machine by using EN19 Tool with Various tool profiles for Friction Stir Welding of T6061-6082 with Circular Profile T6061-6082 With Taper Profile,6061-6061 With Taper Profile, 6082-6082 With Circular profile. The samples are tested on a Universal Testing machine for Ultimate Tensile Strength, Yield Strength, Vickers Hardness, Microstructure. 6082-6082 with circular tool (EN19)has got the values of Tensile strength 97.668N/mm², Yield strength 53.772N/mm², Hardness 51.67HV, Grain size 6.5) 6061-6082 with circular tool(EN19) has got the values of Tensile strength 131.579N/mm², Yield strength 82.307N/mm², Hardness 40HV, Grain size 6) 6061-6061 with taper thread profile(EN19 has got the values of Tensile strength 142.074N/mm², Yield strength 112.452N/mm², Hardness57HV, Grain size 66061-6082 with taper thread profile(EN19 has got the values of Tensile strength 110.957N/mm², Yield strength 93.204N/mm², Hardness 49.33HV, Grain size 6.5. The results found that 6061-6061 with Taper profile has given has good Hardness(57HV), Tensile Strength(142 N/mm2) and Yield Strength(112 N/mm2) ,Vickers Hardness 57HV and Grain Structure number is 6 (ASTM E112).

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