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Experimental Investigation of Mechanical Properties on Friction Stir Welded Aluminium Alloy

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***Abstract:*-- Friction Stir welding (FSW) is used as an alternative technique from recent years for joining metals. A solid-state process consisting non-consumable tool becomes more attractive and feasible method for applications in the industries. In this research study, change in Mechanical properties of friction stir welded aluminum alloy of 6000 series is observed concerning the change in their input parameters i.e. tool RPM, feed rate and tool tip cross section (conical, square, triangular). Analysis done from these investigations will be presented and described.**

Index Terms:- FSW, A6000 Series, Tool pin profile, Microstructure, Impact Strength (Charpy and Izod Tests), Taguchi Analysis.

I. INTRODUCTION

In today's epoch FSW is a fully developed solid state joining technique which has many notable benefits than the traditional joining methods. Nowadays, FSW has attracted much attention from researchers and people due to its huge advantages, where the use of the non-consumable tool is one of them. This method is greatly used for stainless steel and aluminium alloys. The intense of research is increasing day by day on Friction Stir Welding process. In FSW, joining of work pieces is done without the use of filler materials, although no external heat is provided instead it generates heat by the action of pressure and movement of tool i.e. rotational speed and transverse feed. The heat due to friction while processing increases the temperature of work pieces and softens them slightly less than their melting points while pressure force acting perpendicularly helps to extrude the metal into the interface, thus enables joining of work pieces. Most researches have endeavored to optimize and analyze the subject of FSW. Y.J.Chao et al. (2001) experimented by fusion of AA2024-T3 and AA7075-T7351 Aluminum alloy by FSW. In the process, vibrant compressive flow was observed by split Hopkinson pressure bar system. Compressive strain-stress curves were created by the process. The conclusion shows that yield shows the reduction in yield stress. Sutton et al. (2002) inspected this method and arranged the welding of 7mm thick 2024-T351 aliminium sheet. Dispersive X-ray measurement and hardness test were processed and analyzed . These test verified a segregated, banded microstructure which consists of hard particles. Study exemplify that the band spacing is directly related with welding tool advance per revolution. Pasquale Cavalierea and Squillace (2005) reported the outcome by use of 7mm thick sheet of 7075 aluminum alloy to examine the mechanical and Microstructural properties. The sheets were processed perpendicularly to the rolling direction and evaluation of mechanical properties was done at the room temperature in the transverse and longitudinal direction. Sarang Shah and Sabri Tosunoglu (2012) investigational study used FSW as a process to join the material series of the AA6082 Aluminum alloy. It is concluded from the study that heat generated during the process is generally about 80-90% of melting temperature. Material's welding speed is between 250mm/min to 400 mm/min.

II. EXPERIMENTAION AND RESULTS

FSW joint fabrication of 6000 series similar aluminium plates was done by FSW machine i.e. Vertical Milling machine. Total of 9 joint were fabricated as per Taguchi Technique design plan.Chemical Composition of the material of 6000 series aluminium is given in Table 2.1 followed by process parameters taken for technique.

Table 2.1 Chemical Composition

Aluminium	95.8 - 98.6 %
Chromium	0.04 - 0.34 %
Copper	0.15 - 0.4 %
Ferrous	Max 0.7 %
Manganese	Max 0.15 %
Magnesium	0.8 - 1.2 %
Silicon	0.4 - 0.8 %
Tin	Max 0.15 %
Zinc	Max 0.25 %

Table 2.2 Process Parameters

Tool Shape	Conical	Square	Triangular
RPM	1000	1200	1400
Feed Rate	16	20	25

A tool used for the operation was made of Mild Steel. In order of variant, 6 tool specimen of 2 each of different cross section (Triangular, Conical, Square) tip were made in Lathe machine with its respective operation. Tool description is given in Table 2.3 followed by Fig 2.2, which consist of operation.

As shown in Fig 2.1 below, Tools used in the process of different Cross section i.e. Conical, Triangular & Square are arranged respectively, followed by tool description as in Table 2.3.

Fig 2.1 Conical, Square and Triangular tools

Table 2.3 Tool Description

Description	Conical	Square	Triangular
Tip /pin dimension	Depth- 4mm Inner Dia- 4mm Outer Dia – 9mm	Sides – 6mm Depth – 4mm	Sides – 7mm Depth – 5mm
Tool shoulder dimension	Length – 25 mm Dia- 20 mm	Length –25 mm Dia- 20 mm	Length –25 mm Dia- 20 mm
Tool holder dimension	Length– 44 mm Dia- 16 mm	Length–44 mm Dia- 16 mm	Length– 44 mm Dia- 16 mm

Fig 2.2 FSW Operation

Impact Strength i.e. Charpy and Izod test and Microstructure have been carried out. For each fabricated plate, part of the welded section was cut to perform respective tests.Fig 2.2 is the sample picture of the operation we have done in our operation area on vertical milling machine where a tool is clamped and placed perpendicularly against the axis of tool rotation.Following result of the test was obtained while performing the test as shown in table 2.4

Table 2.4 Charpy and Izod test for Impact Strength

Shape	RPM	Feed rate (mm/min)	Charpy (J)	Izod (J)
T	1000	16	266	142
T	1200	20	288	84
T	1400	25	190	116
S	1000	16	30	126
S	1200	20	122	136
S	1400	25	175	146
C	1000	16	68	108
C	1200	20	150	62
C	1400	25	216	85

NOTE: T, S & C represents the Triangular, Square and Conical shape.

These tests were performed in Impact Strength Testing Machine.Similarly, Microstructure was taken from Tool Maker's Microscope at 50x resolution. Sample process is shown in Fig 2.3.

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Fig 2.3 Tool Maker's Microscope with sampled specimen

III. RESULT AND DISCUSSION

Optimization of Process Parameter is done by using Taguchi analysis via Minitab Software.Data means is calculated, response table is shown in Table 2.4 for Impact (Charpy and Izod test). Where shape ranked 1 over rpm and feed rate as per Taguchi Analysis.

Table 2.5 Response Table

LEVEL	SHAPE	RPM & FEED RATE
1	114.8	123.3
2	122.5	140.3
3	181.0	154.7
DELTA	66.2	31.3
RANK	1	2

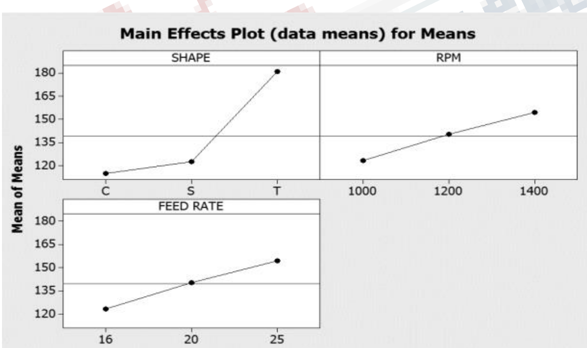
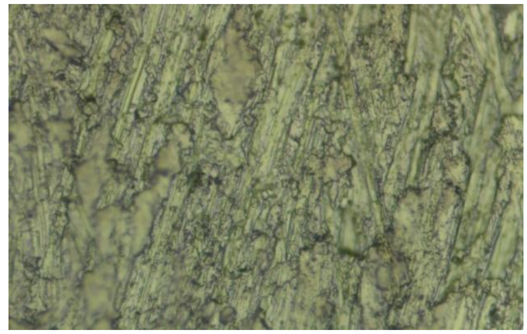
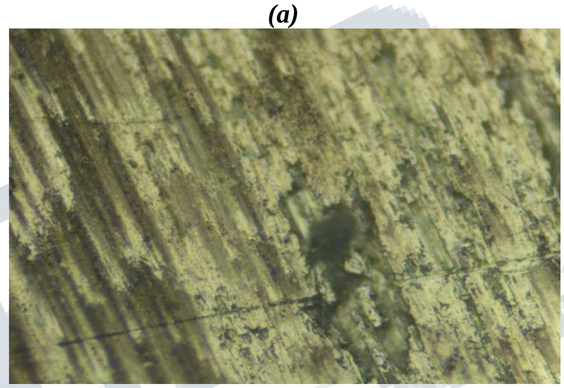


Fig 2.4 Main effect plot for Means

Mean result of Impact strength as per Taguchi Approach is observed with Nominal is best as per result, shown In Fig 2.5. The main objective is to maximize the Strength in all aspects.



(a)



(b)

Fig 2.5 MicroGraph of respective factors

The micrograph as shown in Fig 2.4 (a) taken for trial no. 4 whereas Fig 2.4 (b) is for trial no. 1. It indicates an increase in heat generation along with complete mixing of weld metals.Theoretically microstructure should be onion ring type but practically the results do differ as 100% efficiency is not possible because of many factors that include vibration, metal diffusion, heat generation etc , thus output obtained is good as it holds good impact strength in respective experiment.

CONCLUSION

There are numerous techniques to solve the optimization problems ,various traditional methods are also presently used but not much accurate and lacks in better result, though it is concluded that Taguchi analysis is more realistic and do posses very less possibility of errors. The present study is to analyze the effect of process parameters on Impact Strength. The maximum value of Strength is observed at 1400 rpm with 25 feed rate as processed with triangular tool tip shape. It is observed that more the rpm means more diffusion of metal along dependence of tool tip structure. Microstructure do give us the overview of the welding bead settlement and indicates us quite good output although not accurate but acceptable as per the strength is of concern.

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