Available online at www.ijapie.org

International Journal of Advanced Production and Industrial Engineering

IJAPIE-SI-MM 514 (2017) 88–92

Special Issue on

MATERIALS & MANUFACTURING

Effect of Tool Materials and Tool Geometry on Friction Stir Welding/ Processing of Aluminium Alloy

Preety Mor, Sumit jain, Shambhavi Ratnapriya, Tanusha, R.S. Mishra

(Delhi Technological University, Delhi, India)

**Email: preetymor@gmail.com*

Abstract : The main objective of this research paper is to study the effect of various tool geometries and tool materials on the friction stir processing and welding of Aluminum and its alloy used in Automobiles industry. This study also correlates the effects of process parameters on temperature distribution in the workpiece during welding and processing. The effect of micro structural studies for finding the effect of various parameters on the grain structure of Aluminum and its alloys have been studied in detail. The effect of FSP and FSW (i.e. Tool rotation speed, Tool traversing speed, Tool pin dia,) have a significant effect on for improving mechanical properties in terms of tensile strength, micro-hardness, yield strength and strain rate of Aluminum and its alloys

Keywords: Friction stir welding/processing, microstructure improvement, Al alloys

I. INTRODUCTION

Friction stir processing is a novel surface modification technique which uses severe plastic deformation(caused by rotating tool) and frictional heat for micro-structural refinements. It is basically a thermo-mechanical process which relies on intense plastic deformation in order to refine microstructures which are mainly a result of recrystallization and represents a modification of Friction Stir Welding(FSW) Process which was invented at the Welding Institute UK as a solid state joining technique as shown in Fig-1. The major difference between FSP and FSW is that while FSW is used to join multiple work-pieces without melting of the pieces involved, FSP is employed primarily in order to modify the micro structural properties of a single work-piece. It works on following principles.FSP employs a cylindrical non consumable rotating tool comprising of a shoulder and a pin which produces friction and localized plastic deformation within processing zone.

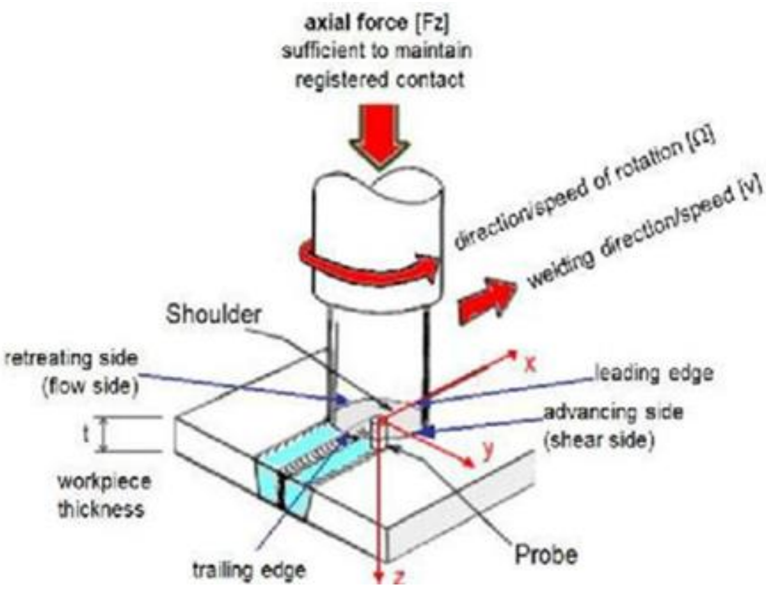

Fig-1: Friction stir processing /Welding [1]

Movement of the pin causes material to flow around the pin to the back where its extruded, forged, cooled under hydrostatic conditions to obtain desired surface characteristics. Frictional heating and mechanical mixing occurs in region covered by tool.FSP creates a 'nugget' in the region of localized heating where micro structural refinement occurs with equi-axed grains containing high angle grain boundaries.

LITERATURE REVIEW

A comprehensive review of various research data which shows the effect of different process parameters on friction stir welded / processed such as effect of tool geometries and tool materials on aluminium alloy has been discussed. The review explains the details of parameters considered by the various investigators:

Mehdi Zohoor et al. (2012), works on AA 5083 with Tool rotational speed-750/ 1900 rpm, Transverse speed25mm/min, Tilt angle-◦ Passes-4 and showed that As no. of passes and rotational speed increase, more homogenized microstructure obtained; Nugget shapes at: 750 rpm basin shape 1900 rpm-elliptical shape; CDRX responsible for formation of grains; FSP with Cu particles increases UTS, YTS; Small grain size increases hardness at higher speeds. R.S.Mishra et al. (2002) conclude that target depth-2.03 mm appropriate, Larger/ smaller depths insufficient to incorporate SiC particles; Transverse speed- 25.4 mm/min appropriate compared to 101.6 mm/min; increasing vol. of SiC particles increases hardness of sample AA5083. H.J.Liu, X.L. Feng (2012) showed that No significant effect on grain size after heat treatment as compared to that after FSP, Larger sizes of white discs of Al Cu observed, Grain boundary strengthening effects negligible after heat treatments; Microhardness decreases in SZ although homogenization of hardness in the sample obtained. F.Y. Tsai, P.W.Kao (2012) investigated that After FSP avg. size of Si particles reduced to 12 µm; Tensile elongation increased from 1-15 %; High tool rotation enhanced dissolution of ß' and Q' particles thus increasing reprecipitation as fine particles while low tool rotation speed caused precipitation coarsening .

EXPERIMENTAL SET-UP

A universal vertical milling machine used as the experimental machine in this study with a fixture used for clamping the workpiece with locking nut as shown in figure 2. The vertical milling machine has the following specifications:

Machine Name	Vertical Milling Machine
Table Size	254x1370mm
No. of Speed	8
Min	70 RPM
Max	4600 RPM
Main Motor Spindle	3 HP

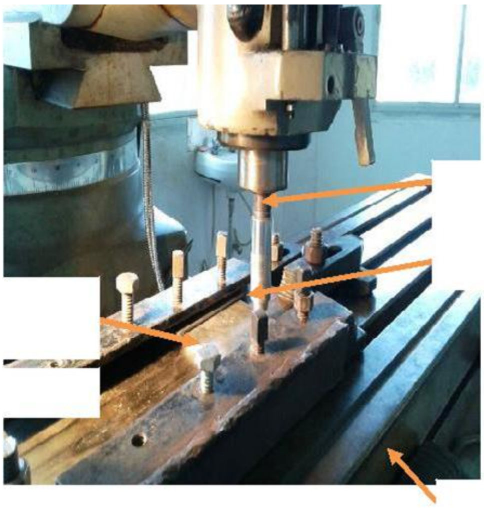

Figure 2. Pictorial front view of Fixture for friction stir welding

WORK PIECE MATERIAL

The aluminium alloy 5083 (contain magnesium and traces of manganese and chromium) plates with sub zero treatment has been used as a work piece material for the present experiments. The addition of magnesium to aluminum increases strength through solid solution strengthening and improves their strain hardening ability. These alloys are the highest strength non heat-treatable aluminum alloys and are, therefore, used extensively for structural applications. These are also used in Welded components for shipbuilding, decks, storage tanks, road and rail tanks, pressure vessels, pipes and tubes, tools and chemical apparatus. The chemical composition of aluminium alloy 5083 shown in table 1.

Table 1: Chemical Composition of AA 5083

Sr.	Elements	Observation (%)
1	Aluminium	93.70
2	Magnesium	4.83
3	Manganese	0.551
4	Iron	0.336
5	Silicon	0.290
6	Nickel	0.007
7	Zinc	0.035
8	Lead	0.030
9	Tin	0.010
10	Titanium	0.050
11	Chromium	0.100
12	Copper	0.050
13	Calcium	0.00

Preparation of specimens

Two aluminium alloy 5083 plates of size 120mm×60mm×6mm were mounted on the fixture of vertical milling machine for making butt joint by using friction stir welding process.

Tool preparation

The tools for welding AA5083 by FSW were made of high carbon steel asshown in figure 2. For holding the tool on milling machine the shank diameter was made of 17 mm, shoulder diameter was of 14mm and tool pin diameter was considered as parameters for welding of AA 5083.

Figure 3 Tools used during FSW

All the tools have same shoulder diameter of 14mm and after manufacturing the tools, the pin of the tools was annealed and oil quenched

Selection of Parameters

The parameters which selected for this investigation were: tool rotation speed, transverse/welding speed and tool pin diameter. Various experiments were conducted for optimize the various response parameters (Ultimate tensile strength). Taguchi's robust design of experiments (DOE) methodology was used to plan the experiments statistically. The contron variables with their levels are shown in table 2.

Table 2: Control variables and their levels

S. No	**Parameters**	**Levels**	**Level 1**	**Level 2**	**Level 3**
A	Tool rotation	3	1200	1950	3080
B	welding speed	3	20	25	30
C	Tool Pin diameter	3	5	6	7

All the selected parameters have equal levels. L9 and L27 orthogonal array has come out as the possible solutions for designing the experiments. Hence, L9 array was selected for the present investigation. The DOE by L9 array is consisted of nine trial runs as shown in table 3.

Table 3. Control Log for Experimentation

Experiment No.	Tool rotation speed(A)	Welding speed (B)	Tool pin dia.(D)
1	1200	20	5
2	1200	25	6
3	1200	30	7
4	1950	20	6
5	1950	25	7
6	1950	30	5
7	3080	20	7
8	3080	25	5
9	3080	30	6

The levels for each factor during each trial are more conveniently expressed in table 2. The welding of two plates of AA 5083 was done according to the entire nine trail run. The joined plates after welding are shown in figure 4.

Figure 4. Plate after friction stir welding

Table 4 Constant Parameters

Fixed Parameters	
Pressure applied	Constant
Tool pin profile	Cylindrical
Tool pin length	5.8mm
Cooling medium	Normal air
Tool material	High carbon steel
Tool angle	0°

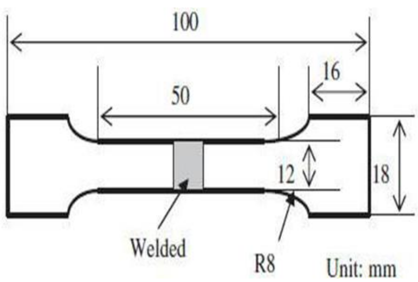

Figure 5. Specimen Size for the UTS and elongation

Table 5 Taguchi's L9 Standard Orthogonal Array for Ultimate tensile strength

EXP. NO	Tool rotation speed(A)	Welding speed(B)	Tool pin diameter(C)	Tensile strength (MPa)
1	1200	20	5	235.76
2	1200	25	6	226.44
3	1200	30	7	223.01
4	1950	20	6	249.76
5	1950	25	7	230.22
6	1950	30	5	211.41
7	3080	20	7	206.04
8	3080	25	5	161.10
9	3080	30	6	164.80

Table 6 Response Table for UTS (Means)

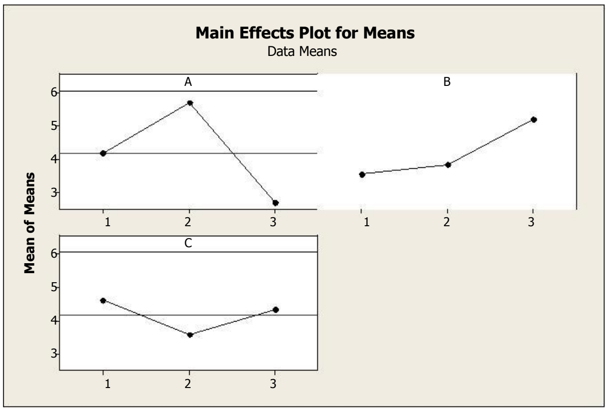

Figure 6. Effects of Process Parameters on Ultimate Tensile Strength (Means)

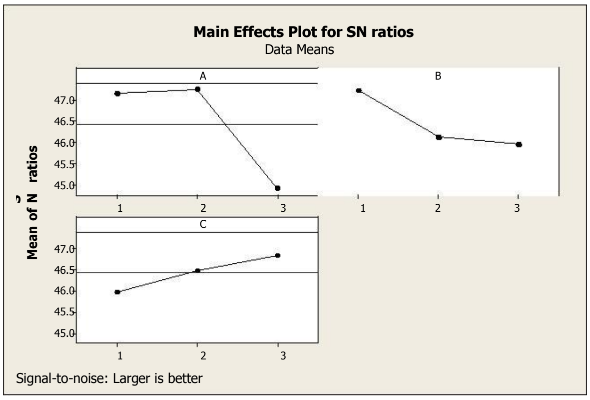

Figure 7. Effects of Parameters on UTS (S/N Ratio)

Then two tensile test specimens were extracted from each welded piece. The dimensions of the test specimens were according to American Society for Testing of Materials (ASTM) standard shown in Figure 5. Table 5 shows the values of UTS against the input parameter setting for L9 orthogonal array.

Table 6 Ranks for process parameters

Level	A	B	C
1	227.6	230.3	201.7
2	230.9	205.2	214.1
3	177.2	200.2	219.9
Delta	53.7	30.2	18.2
Rank	1	2	3

The most favorable conditions or optimal levels of process parameters have been established by analyzing response curves of mean associated with the raw data.

Analysis of Variance (ANOVA)

The ANOVA for Means data are given in tables 7.

Table 7 Analysis of Variance for UTS (Means)

Source	DF	Seq SS	Adj SS	Adj MS	F	P
A	2	5433.64	5433.64	2716.82	299.76	0.003
B	2	1569.53	1569.53	784.76	86.59	0.011
C	2	521.37	521.3	260.68	28.76	0.034
RE	2	18.13	18.13	9.06		
Total	8	7542.66				

DF - degrees of freedom, SS - sum of squares, MS - mean squares(Variance), F-ratio of variance of a source to variance of error, $P < 0.05$ - determines significance of a factor at 95% confidence level.

RESULTS AND DISCUSSIONS

Effect on Ultimate tensile strength

It can be observed from figure 6 that the Tool rotation speed, welding speed and tool pin diameter affects the Ultimate Tensile strength very significantly. Moreover, the different input parameters used in the experimentation can be ranked in the order of increasing Ultimate tensile strength as tool rotation speed, welding speed and tool pin diameter. From the figure 6, the highest Ultimate Tensile strength has been recorded with Tool rotation speed (at level 2), welding speed (at level 1) and tool pin diameter (at level 3). In Friction stir welding, the Tool rotation speed is most significant factor for increasing the ultimate tensile strength, welding speed is the second significant factor and Tool pin diameter is the third significant factor. It is also clear from the figure 6 that when the tool rotation speed is increased, the Ultimate tensile strength first increases and then on further increases in tool rotation speed, UTS decreases very sharply. But the Ultimate tensile strength first decreases and then increases as the welding speed is increased. From the figure 7, the UTS increases continuously on increasing tool pin diameter.

The ANOVA results also showed that Tool rotational speed is the most effective factor with a percent contribution of 72.10 % .The percent contribution of welding speed is 20.80 % and that of Tool pin diameter is 06.90 %.

The analysis of results showed that "A2B1C3" is the optimal parameter setting for the maximization of ultimate tensile strength. Hence, it can be concluded from this discussion that "input parameters settings of tool rotation speed at 1950 rpm, welding speed at 20 mm/min and tool pin diameter at 7mm have given the optimum results for UTS, in Friction stir welding on AA 5083.

CONCLUSIONS

In Friction stir welding, the tool rotation speed is most significant factor for increasing the ultimate tensile strength, welding speed is the second significant factor and Tool pin diameter is the third significant factor. When the tool rotation speed is increased, the Ultimate tensile strength first increases and then on further increases in tool rotation speed, UTS decreases very sharply. Ultimate tensile strength first decreases and then increases as the welding speed is increased. UTS increases continuously on increasing tool pin diameter.

REFERENCES

[1] F.Y. Tsai, P.W. Kao(2012) :Improvement of mechanical properties of a cast Al-Si base alloy by friction stir processing International journal of Materials LettersVol-80, pp.40-42.

[2] R.S.Mishra, Z.Y. Ma, I. Charit (2002). Friction stir processing : a novel technique for fabrication of surface composite International journal of Material Science andengineering, Vol-A341, pp.307-310.

[3] Mehdi Zohoor, M.K. BesharatiGivi, PSalami (2012) Effect of processing parameters on fabrication of AlMg/Cu composites via friction stir processing , International journal of Materials and design, Vol-39, pp.358365.

[4] H.J.Liu, X.L. Feng(2012): Effect of post processing heat treatment on microstructure and microhardness of water-submerged friction stir processed2219-T6Aluminium alloyInternational journal of Materials anddesign, Vol-47, pp.101-105.