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Optimization of Process Parameters of Friction Stir Welding of Dissimilar Aluminum Alloys (AA6061-T6 and AA6082-T6)

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Abstract

Objective: Friction Stir Welding (FSW) is a process in which the tool is given the desired rotation and feed to produce the heat required to weld the joints. The recrystallization temperature is achieved thereby leading to formation of strong weld without the melting of joining materials. In this examination, the Friction Stir Welding of different 6 series Alloy flat pieces (AA6061 and AA6082) of 6 mm thickness was explored. **Methods/Analysis**: Experimental conditions were finalized and this welding method was performed on plates at various tool rotational velocities of 800, 1100 and 1400 rpm by shifting the welding speeds i.e. 120, 150 and 180 mm/min and tool pin profiles (cylindrical strung and decrease threaded). Tensile tests were done on the acquired welded joints and the outcomes had been investigated utilizing Taguchi L9 strategy. **Findings**: It was concluded from the present study that the tensile strength is mostly affected by tool rotational speed. Confirmation experiment shows that error (%) associate with tensile strength is 4.03. Optimal setting of process parameters for tensile strength is 1400 rpm, 120 mm/min with cylindrical threaded tool (TPI-22). **Application/Improvement:** Friction Stir Welding method can emerge as an efficient process used in welding of aluminum alloys with different compositions.

Keywords: Friction Stir Welding (FSW), Tensile Strength (TS)

1. Introduction

FSW is a unique welding method which utilizes the warmth delivered by the turning instrument to weld the joints[1]. It dispenses with the liquefying related deformities amid traditional welding. This process is in particular has find many applications in welding of similar and dissimilar aluminum alloys. Aluminum alloys are broadly utilized as designing materials as a part of industry as a result of their better corrosion resistance, high electrical and thermal conductivity[2]. Since Friction Stir Welding (FSW) was imagined for the joining of Cu amalgams which are not effectively joined with customary combination welding technique, Friction Stir Welding has been connected to the joining of Ti composites Cu composites, Al compounds, Mg amalgams, and Fe compounds in the earlier years[3]. These materials indicated enhanced mechanical properties unless the procedure parameters are advanced. The welding process done conventionally introduces many defects into the weld like entrapment of gases in the weld zone[4–6]. These types of defects are removed in Friction Stir Welding process as the processing is done in solid state[7]. Large amount of work has been done in the welding of aluminum alloys but the feasibility of process for joining aluminum alloys with different compositions with the optimization of process parameters to achieve excellent mechanical and metallurgical properties still needs more research.

2. Experimentation

The AA6061 and AA6082 plates with dimensions (100

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mm x 50 mm x 6 mm) were used for experiment. The weld joints were formed using VMC machine. The fixture as shown in Figure 1 was used for carrying out experimental work.

Figure 1. Fixture.

The HSS Tools[8] was utilized for completing the welding process with three diverse tool pin profiles as shown in Figure 2. The distinctive tool pin profiles utilized as a part of this study are displayed in Figure.

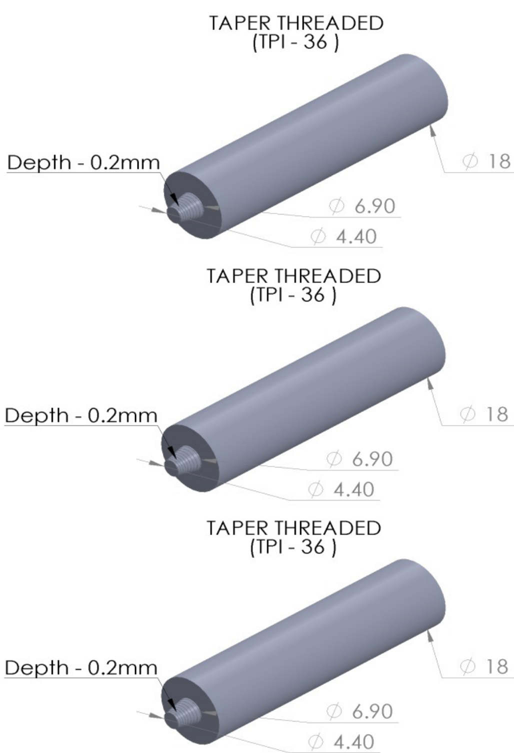

Figure 2. Tools.

The procedure parameters are tool feed rate, tool rotational speed and tool pin profile[9]. For the advancement of procedure, configuration of definite trial was made by L9 orthogonal. The working parameters as shown in Table 1 implemented in this study were resulted from the trial runs. The levels taken for each process parameter are three which are displayed in the Table 1.

Table 1. Working parameters

	process parameters	level 1	level 2	level 3
A	Rotational velocity of tool (rpm)	800	1100	1400
B	Feed rate of tool (mm/min)	120	150	180
C	Pin profile of tool	Taper-threaded	Cylindrical threaded(tpi-22)	Cylindrical threaded(tpi-14)

The samples with gauge length of 25 mm, aggregate length of 100 mm and width 6 mm were set up from weld samples for tensile test according to ASTM-E8. Three tensile test samples were set up at every level.

3. Analysis for Tensile Strength

Tensile strength is the property of a material to withstand elongation i.e. when pulling force is applied in both directions[10].

Table 2. Tensile strength

EXP NO.	ABC	TS1	TS2	TS3	S/N RATIO	MEAN
1	111	109.50	112.00	111.50	40.9052	111.00
2	122	125.20	121.28	123.36	41.8284	123.45
3	133	127.40	126.20	127.10	42.0690	126.90
4	212	167.10	165.17	164.20	44.3747	165.49
5	223	127.91	126.54	128.74	42.1252	127.73
6	231	118.00	117.20	120.27	41.4721	118.49
7	313	163.00	164.93	164.13	44.2976	164.02
8	321	141.90	143.01	142.02	43.0645	142.31
9	332	128.92	131.76	130.20	42.2974	130.29

The three tensile test samples corresponding to each set of input parameters were formed. The Table 2 represents the values of tensile strength at different sets of parameters. Table 3 and Table 4 represent the response table for S/N ratio and mean. Table 5 to Table 7 represents the analysis of variance for tensile strength, S/N ratio and mean. With surge in RPM, frictional powers expands which creates more warmth at the interface because of which bond arrangement happens proficiently and quality of weld improves. Likewise at less RPM heat produced is insufficient and the refinement of grains turns out to be exceptionally poor which diminishes the tensile strength. Region of lower hardness on AA6082 side is area of tensile failure. Crack happened in the transition zone amongst TMAZ and HAZ. The failure of samples took place at lower hardness region on alloy AA6082-T6 side. The tensile strength is mostly influenced by tool rotational velocity. Confirmation test as shown in Table 8 demonstrates that error (%) related with tensile strength is 4.03. From Figure 3 and Figure 4, it can be concluded that the optimal setting of procedure parameters for tensile strength is 1400 rpm, 120 mm/min with cylindrical threaded tool (TPI-22).

Table 3. Response table for signal to noise ratio

LEVEL NO.	ROTATIONAL VELOCITY OF FSW TOOL (RPM)	FEED RATE OF FSW TOOL (MM/MIN)	PIN PROFILE OF FSW TOOL
1	41.60	43.19	41.81
2	42.66	42.34	42.83
3	43.22	41.95	42.83
DELTA	1.62	1.25	1.02
RANK	1	2	3

Table 4. Response table for mean

LEVEL NO.	ROTATIONAL SPEED OF FSW TOOL (RPM)	FEED RATE OF FSW TOOL (MM/MIN)	PIN PROFILE OF FSW TOOL
1	120.5	146.8	123.9
2	137.2	131.2	139.7
3	145.5	125.2	139.6
DELTA	25.1	21.6	15.8
RANK	1	2	3

Table 5. Analysis of variance for TS (confidence level-95%)

SOURCE	Degrees of freedom	Sequential sum of squares	Adjusted sum of squares	Adjusted mean square	F	P
A	2	2940.68	2940.68	1470.34	13.39	0.000
B	2	2243.42	2243.42	1121.71	10.21	0.001
C	2	1481.83	1481.83	740.92	6.75	0.006
ERROR	20	2196.57	2196.57	109.83		
TOTAL	**26**	**8862.50**		**1.59**		

Table 6. Analysis of variance for signal to noise ratio (confidence level-95%)

SOURCE	Degrees of freedom	Sequential sum of squares	Adjusted sum of squares	Adjusted mean square	F	P
A	2	4.054	4.054	2.027	1.39	0.419
B	2	2.436	2.436	1.218	0.83	0.545
C	2	2.073	2.073	1.037	0.71	0.585
ERROR	2	2.920	2.920	1.460		
TOTAL	**8**	**11.483**				

. P<0.05(1-0.95). Therefore data is considered to be significant

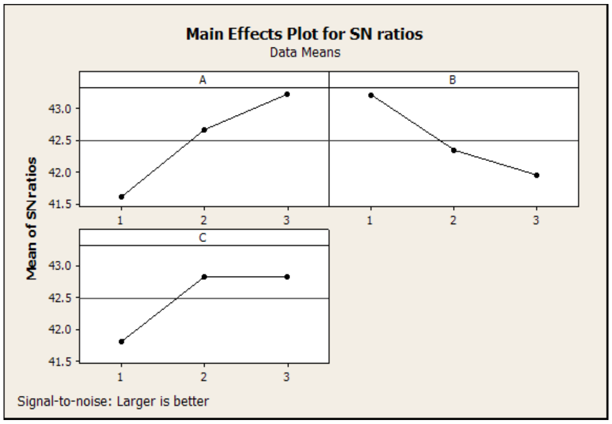

Figure 3. Main effects plot for signal to noise ratio.

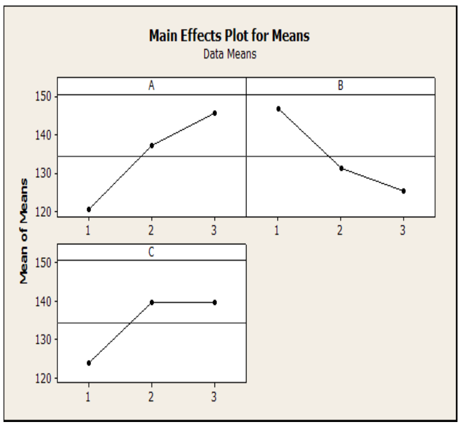

Figure 4. Main effects plot for means.

Table 7. Analysis of variance for MEAN (95% confidence level)

SOURCE	DOF	Seq SS	Adj SS	Adj MS	F	P
A	2	980.2	980.2	490.1	1.36	0.424
B	2	747.8	747.8	373.9	1.03	0.491
C	2	493.9	493.9	247	0.68	0.594
ERROR	2	722.6	722.6	361.3		
TOTAL	**8**	**2944.6**				

Optimal value of tensile strength=A3+B1+C2-2(Tavg)

=145.50+146.80+139.70-2(134.32)

=163.36MPa

4. Conclusion

On the basis of experimental observations made on castings components following conclusions can be drawn.

- The tensile test is for the most part influenced by tool rotational velocity.
- The percentage of error associated with tensile strength is 4.03.
- Tensile test tests generally failed in the area of least hardness on AA6082-T6 side.
- Optimal setting of process parameters for tensile strength is 1400 rpm 120 mm/min with cylindrical threaded tool (TPI-22).

5. Scope For Future Work

In the present work only few process variables are taken so still there are areas where research can be done:

- The processing of surface by friction stir process can help improve the surface properties.
- Also research can be done to find other types of friction stir processes e.g. friction stir surfacing etc.

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Table 8. Confirmation experiment

Quality Characteristic	Optimal setting of process parameters	Significant process parameters (at 95% confidence level)	Predicted optimal value of quality characteristic	Confirmation experimental value
TENSILE STRENGTH	A3B1C2	A B C	163.6MPa	157 MPa

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