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A Study on Fracture Sem Analysis by Optimization of FSW When a Composite Material Al 6061 Mixed with Fly Ash is Done with Cooper Using Anova Method

V. Mouni Sashi Tej*

Abstract

The current study aims to examine how different parameters in friction stir spot welding influence hardness and tensile strength, while identifying the most suitable parameter combinations to enhance the overall quality of the fabricated components. The experimental work involves joining dissimilar materials, where one specimen consists of Aluminum alloy 6061 reinforced with 10% fly ash, and the other is a copper alloy. Various process conditions are altered during testing to evaluate their impact on the mechanical behavior of the welded joints. The process parameters varied and their respective values are speed of the tool 1120 rpm, 1400 rpm and 1800 rpm & Dwell Time on – 20 sec, 23 sec, and 26 sec. here the process is done using tool pin depth as 2.5mm and 2.8mm. The parameter optimization was carried out through the Taguchi approach by adopting an L18 orthogonal array. Minitab software was utilized to perform the analysis and determine the most effective combination of process settings. The better work piece is investigated by using SEM analysis to verify the metallographic structures.

Keywords: FSW, Composite material, Fly ash, al6061, cooper, metallographic

INTRODUCTION

Friction stir welding (FSW) was developed by TWI in 1991. It offers various advantages such as small thermal deformation, sound mechanical properties, fine and uniform weld microstructure, high welding efficiency, and green welding process, which has received considerable attention in welding aluminum alloys. As FSW is developed, studies on FSW of other advanced materials, such as magnesium alloys, copper alloys, titanium alloys, steels, and super alloys, have been reported.

LIERATURE REVIEW

Presented a study focused on friction stir spot welding applied to dissimilar materials, specifically AA6061-T6 aluminum alloy and commercial copper alloy. The investigation considered key process variables including dwell time, tool rotational speed, plunge rate, and tool diameter ratio. Experimental trials were designed using a structured approach to analyze parameter influence. The results indicated that a maximum shear fracture load of 4.79 kN was achieved at a rotational speed of 2000 rpm, plunge rate of 7 mm/min, dwell time of 25 seconds, and a diameter ratio of 3.5. Under these conditions, uniform material movement around the tool pin was observed, which contributed to improved joint quality. Enhanced strength was also associated with favorable hook geometry, such as optimized height, width, and

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initiation distance. Additionally, the formation of intermetallic phases like Cu9Al4 in the copper region and CuAl in the aluminum region played a role in strengthening the joint.

Examined how tool pin shape and rotational speed affect microstructural changes as well as mechanical behavior in AA5052-H112 friction stir spot welds. Their findings revealed that both hook formation and the width of the bonded region were strongly influenced by these parameters. The weld strength varied depending on the pin configuration and speed. At rotational speeds of 900 and 1400 rpm, cylindrical pins produced stronger joints compared to step pins. However, in the case of step pins, weld strength improved as rotational speed increased. The highest tensile/shear and cross-tension loads, measured as 3589 N and 3419 N respectively, were obtained using a cylindrical pin at 1400 rpm. Different fracture patterns were also reported, including shear-type and mixed failures under tensile loading, while nugget pull-out and debonding were observed during cross-tension tests.

Provided a comprehensive review on friction stir spot welding of aluminum and copper combinations. Due to their favorable thermal and electrical characteristics, these materials are widely used in industrial sectors, making their effective joining highly valuable. The authors discussed the advantages of FSSW as a solid-state joining technique suitable for such dissimilar materials. Their review covered various aspects including tool design, joint morphology, microstructural evolution, defect formation, and mechanical performance. Furthermore, they highlighted areas that require additional research, such as understanding material flow behavior, analyzing temperature distribution during welding, exploring interlayer additions, and incorporating advanced techniques to enhance joint functionality and performance.

PROBLEM STATEMENT AND OBJECTIVES

Problem Statement

In this project analysis of Friction stir spot welding joints of Aluminum 6061+10% Fly ash composite material and Copper alloy material are welded with varying parameters speed, dwell time and pin depth of the tool and here the hardness, tensile/shear load and micro structure were analyzed [4–6].

Objectives

- The main objective of this study is to evaluate how different friction stir spot welding parameters influence hardness and tensile shear strength, while identifying the most suitable combination of settings for improved joint performance.
- Here the process parameters selected are speed of the tool, dwell time and the tool pin depth.
- The achieved outputs parameters are the hardness, tensile shear load and micro structure study.
- Taguchi's method is used for the design of experiments using L18 orthogonal array and ANOVA method is used for finding the contribution of each process parameter (Figure 1–3).
- To present the FSW on composite material with cooper alloy and study its parameters and properties (Table 1, 2).

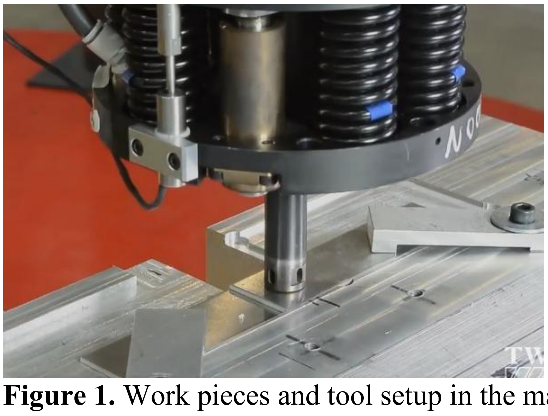


Figure 1. Work pieces and tool setup in the machine.

Figure 2. Work pieces before conducting tensile/shear load test.

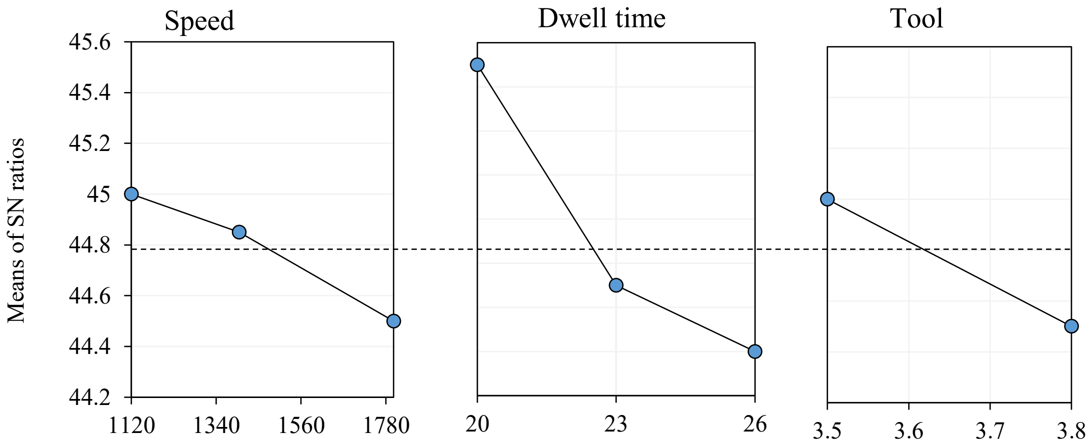
Table 1. Process parameters used for FSSW.

S.N.	Process parameters	Level 1	Level 2	Level 3
1	Speed (rpm)	1120	1400	1800
2	Dwell time (sec)	20	23	26
3	Tool (pin depth - mm)	2.5	2.8	--

Table 2. Hardness test results.

Runs	Impression 1	Impression 2	Impression 3	Average hardness value
1	199.4	226.8	213.4	213.2
2	192.2	177.9	179.3	183.113
3	180.8	167	178.8	175.733
4	224.6	190.6	186.2	200.467
5	136.1	142.6	156.7	145.133
6	139.5	186.7	145.4	157.2
7	219.7	219.3	195.4	211.467
8	187.4	203.5	113.2	168.033
9	215.8	200.7	207	207.833
10	182.3	165.4	131.7	159.8
11	128.7	180.5	140.3	150.833
12	137.9	145.2	180.3	154.467
13	149.7	189.3	161.4	166.8
14	188.5	188.5	206.4	194.467
15	163.6	149.9	139.7	150.067
16	149.9	117.3	125	130.733
17	190.3	183.6	218.7	197.533
18	185.4	163.6	184.3	177.767

EXPERIMENTS CONDUCTED FSSW



Signal-to-noise; Larger is better

Figure 3. Effect of machining parameters on hardness for S/N ratio for larger is better.

Table 3. Results of tensile/shear load test.

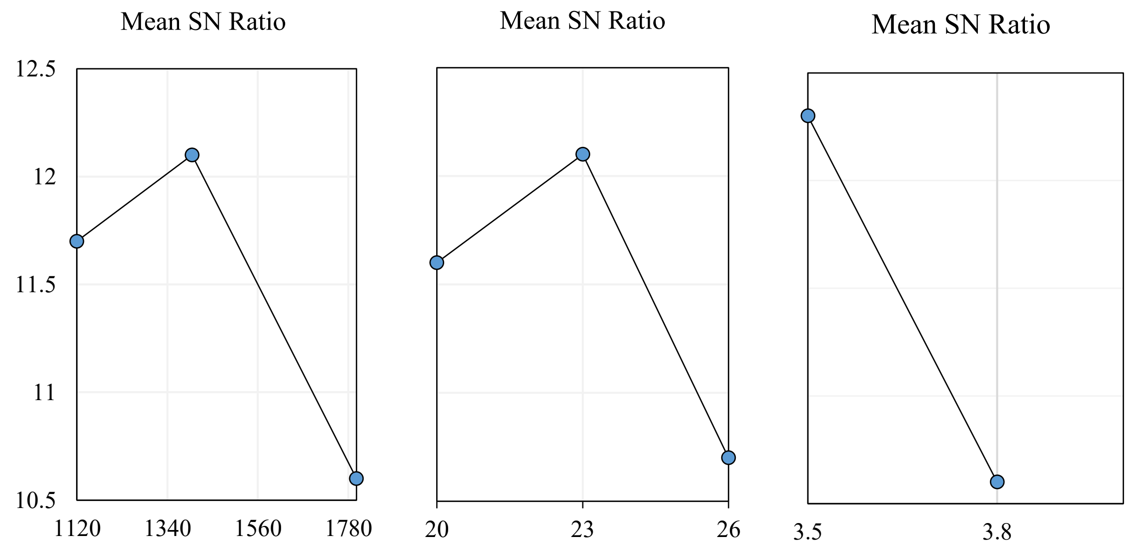
RUNS	SPEED (RPM)	DWELL TIME (sec)	TOOL DEPTH (mm)	TENSILE SHEAR LOAD RESULT (kN)
1	1120	20	2.5	5.12
2	1120	20	2.8	3.46
3	1120	23	2.5	4.26
4	1120	23	2.8	3.2
5	1120	26	2.5	4.02
6	1120	26	2.8	3.3
7	1400	20	2.5	4.7
8	1400	20	2.8	3.5
9	1400	23	2.5	4.68
10	1400	23	2.8	3.8
11	1400	26	2.5	4.08
12	1400	26	2.8	3.52
13	1800	20	2.5	3.82
14	1800	20	2.8	2.8
15	1800	23	2.5	3.44
16	1800	23	2.8	4.96
17	1800	26	2.5	3.46
18	1800	26	2.8	2.44

TENSILE / SHEAR LOAD TEST

Here the specimen has been after the welding process is done for the 18 runs. Here the measurements have been carried out using MCS/UT 20T machine (Figure 4). The results obtained are mentioned in the below Table 3.

FRACTURE SEM ANALYSIS

Here the fracture SEM analysis is done the work piece parameters speed 1120 rpm and dwell time is 20sec and the tool is 2.5mm [7–13]. at very low magnification. As we can see there are stripes at the sources in the fracture visible when micro fracture characteristics are determined as show in the fig below. And we can even observe there is no slag inclusion defects on the image below (Figure 5–9).



Signal-to-noise; Larger is better

Figure 4. Effect of machining parameters on tensile for S/N ratio for larger is better.

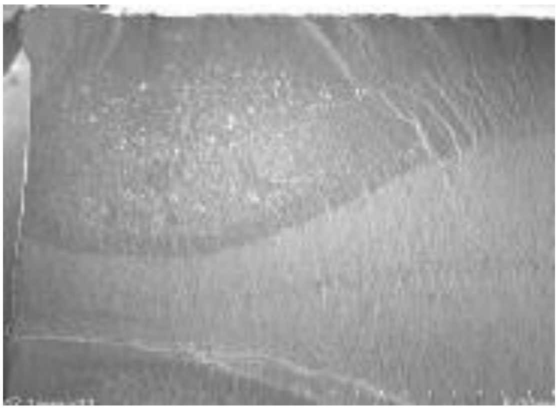


Figure 5. Micro morphology of the material at 10X magnification.

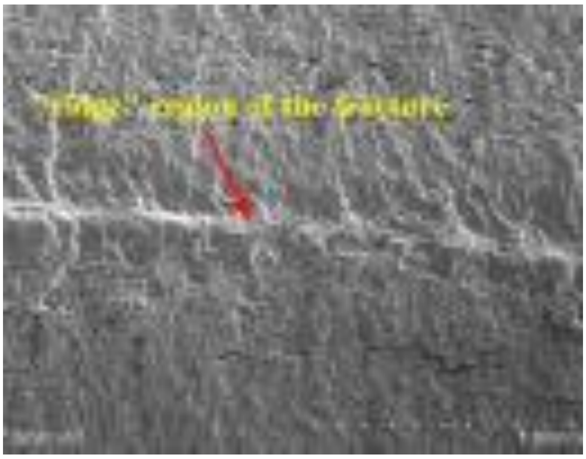


Figure 6. Micro morphology of the material at 55X magnification.

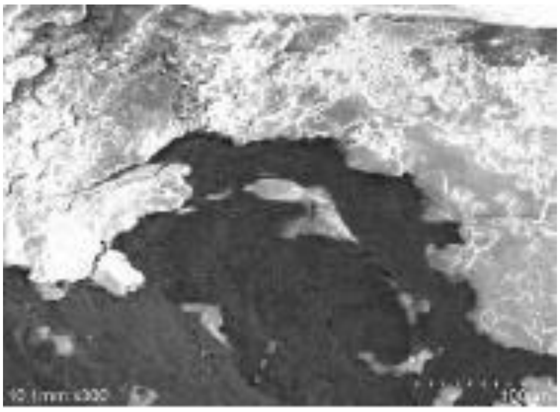


Figure 7. Fractures observed at 300X magnification.

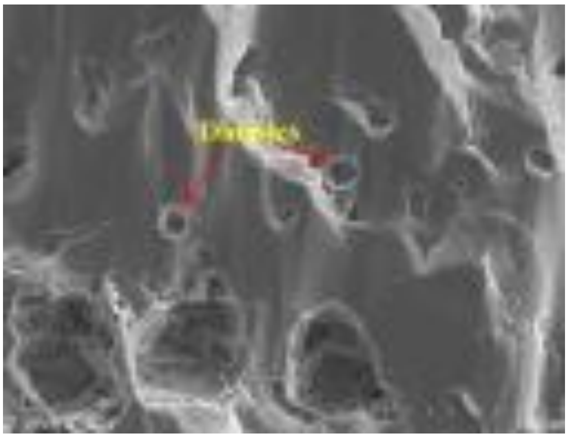


Figure 8. Fractures observed at 1000X magnification.

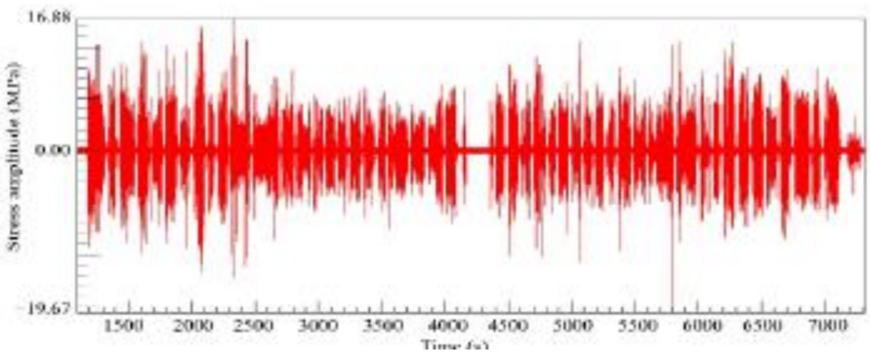


Figure 9. Stress Vs time.

CONCLUSION

Experiments are conducted on the Aluminum alloy 6061+10% fly ash composite material with cooper alloy pieces by varying parameters. The study considers multiple process variables, including rotational speeds of 1120 rpm, 1400 rpm, and 1800 rpm. Dwell duration is set at 20, 23, and 26 seconds, while tool penetration depths of 2.5 mm and 2.8 mm are selected. Parameter optimization is carried out using the Taguchi method with an L18 orthogonal array to identify suitable working conditions. Optimization is done in Minitab software. Here hardness and tensile shear load parameters are considered for the optimization process.

By observing the experimental results and by optimizing the parameters, the following conclusions can be made:

From the experimental results, the following conclusions can be made:

1. The optimum process parameters obtained for maximum tensile/shear load are speed 1120 rpm and dwell time is 20sec and the tool is 2.5mm.
2. The optimum process parameters obtained for maximum hardness are speed 1120 rpm and dwell time is 20 sec. and the tool is 2.5 mm.
3. From ANOVA analysis the major percentage contribution for tensile load are speed*dwell time interaction – 13.51 % and tool is 28.55 %
4. From ANOVA analysis the major percentage contribution for hardness are speed*dwell time interaction – 45.75% and for dwell time is 19.95%
5. From the graph it is observed that, increase of the tool depth showed decreases both hardness and tensile shear load.

From the fracture analysis we can observe the basic stripes like cracks at 1000X magnification. As it is very negligible and even there is no loose inclusions even at the 10X and 1000X magnification. When we have compared the stress Vs time result, here the stress is very adequate with respect to time taken to develop the max stress on the FSW regions. So by this we can conclude that when fly ash is mixed the HRD is better optimized and verified with the fracture SEM analysis in which the optimized parameters are at speed 1120 rpm and dwell time is 20sec and the tool is 2.5mm

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