Conference Paper

Process Optimization of Friction Welded Spot Aluminum Alloy Using ANOVA

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Abstract

The parameter of angular speed, depth of tool, and time of dwell of friction welded spot was studied on the alloy of aluminium. To do so, the impact from parameters was investigated through tensile shear test on the welded alloy and using the design of experiment (L8). ANOVA is then used to see important factors and contributions via main effects plots. It was found that angular speed of tool had a big impact on tensile shear load with 45 %, time of dwell 34 %, depth of tool 10 %. The angular speed of 1 400 rpm, time of dwell 9 s, and depth of tool 3.5 mm were the optimal parameters in this study.

Keywords: Light material welding, Optimize weld process, Weld softened material

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1. Introduction

Weight in a car is an issue to reduce fuel usage. Aluminium is a good material for a light car. Friction welded spot [1], is good for joining aluminium because reducing distortion and energy, as well as defects [2].

Refer to the Figure 1 process composes of plunging, stirring, and retracting [3]. When the tool is moved down into the workpiece is plunging. When the tool was stopped at a specific depth and stirred in the workpiece is stirring [4--9]. When the tool was retracted to the original position is retracting.

The issue in FSSW is the defect of weld caused by wrong parameters [9]. Therefore, parameters play a big role [11].

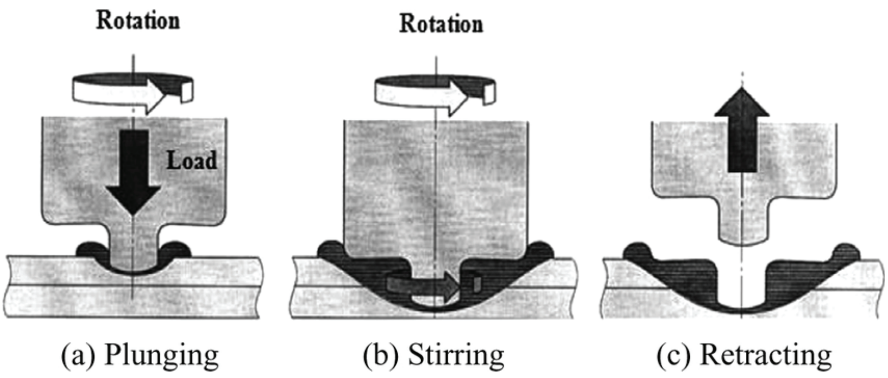


Figure 1: (a) Plunging, (b) Stirring, and (c) Retreating, [10].

2. Methodology

The study method was study of the literature, experiment of design, the test of tensile shear, and analysis of ANOVA [12]. The study flow was displayed in Figure 2.

2.1. Experiment of Design

The experiment of design L-8 was managed firstly for parameter setting [13], with factors of three and levels of two (Table 1) [14]. Then, ANOVA was done to analyze the test data [15].

TABLE 1: Factors of three and levels of two.

Factors	Low level	High level
Angular speed (rpm)	1 000	1 400
Depth of tool (mm)	2.5	3.5
Time of dwell (s)	5	9

2.2. Preparation for sample

This is a preparation session of samples used to weld and test. The dimension of samples was referred to standard of JIS Z3136:1999 as shown in Figure 3.a. For tool, K100 tool steel with 5 mm of diameter and 2 mm of length with cylindrical pin [16]. The diameter of the shoulder was 12 mm (Figure 3.b).

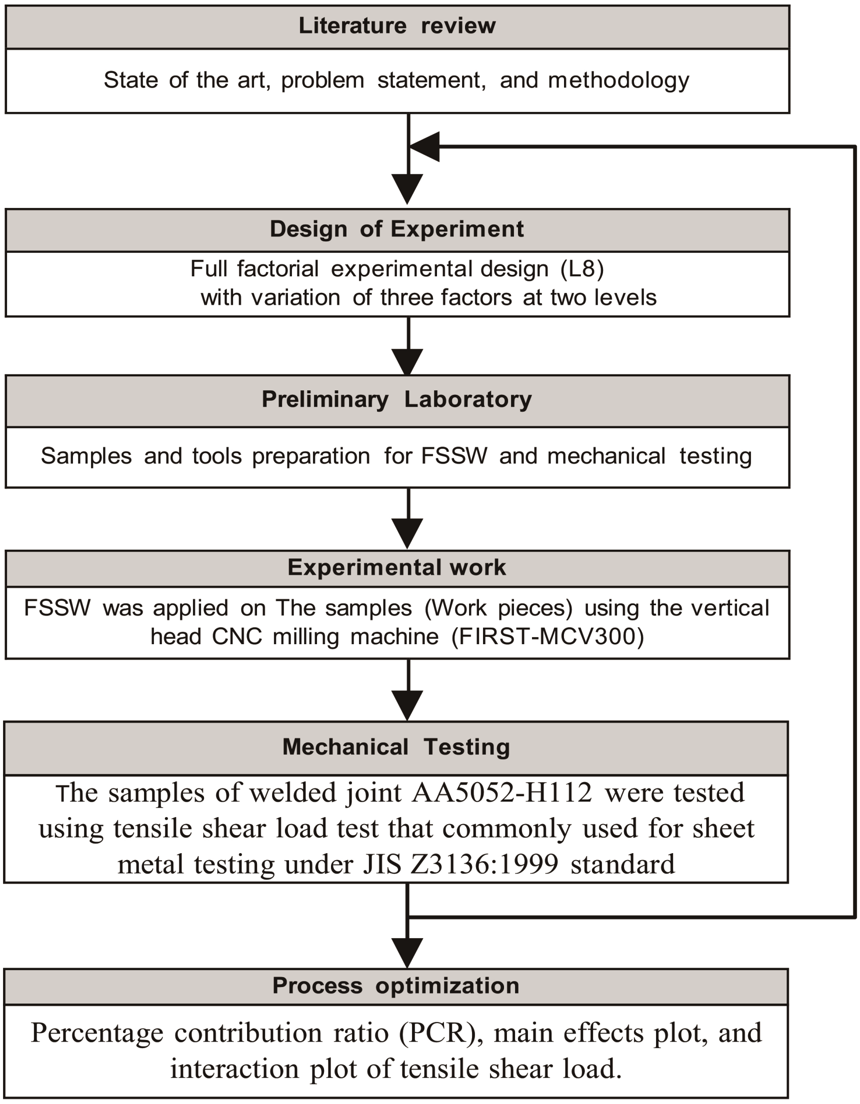


Figure 2: The study flow.

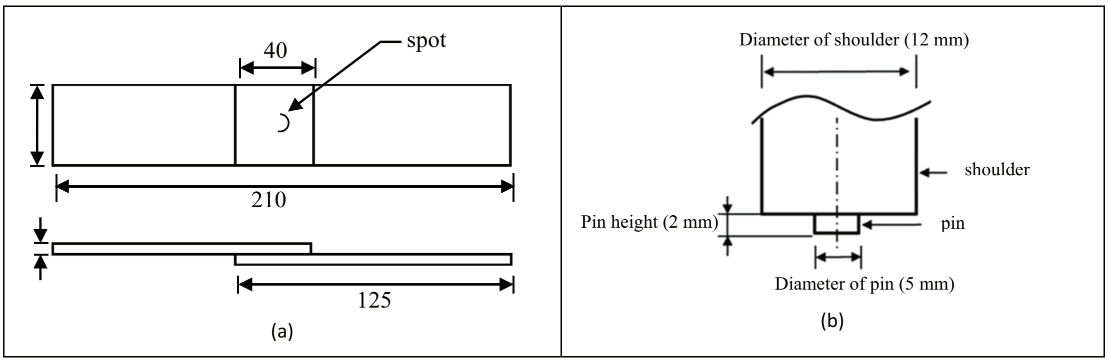


Figure 3: a) Sample geometry, b) tool geometry.

Table 2: Test results.

Parameters					
No. Test	CCD	Ang. Speed (rpm)	Depth of tool (mm)	Dwell of time (s)	Load of Tensile (N)
1	Factorial	1 000	2.5	5	2 923
2	Factorial	1 400	2.5	5	3 846
3	Factorial	1 000	3.5	5	3 179
4	Factorial	1 400	3.5	5	3 980
5	Factorial	1 000	2.5	9	3 369
6	Factorial	1 400	2.5	9	4 387
7	Factorial	1 000	3.5	9	4 255
8	Factorial	1 400	3.5	9	4 650

2.3. Welding and test

The CNC milling machine was employed for the experiment. The angular speed was set at 1 000 rpm and 1 400 rpm respectively. The depths of tool were at 2.5 mm and 3.5 mm respectively. The time of dwell was at 5 s and 9 s respectively. A crosshead speed of tensile shear load was 1 mm s^{-1} via Instron universal testing machine with room temperature.

3. Result and discussion

The data obtained from the test can be seen in Table 2. It showed that with a higher parameter the highest loads reached up to 4 600 N. Using the lowest parameters, the lowest loads increased around 2 900 N.

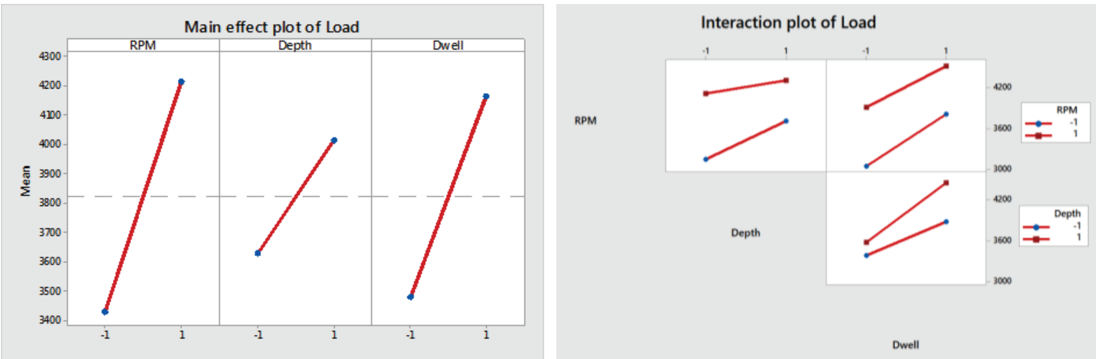
The ANOVA results in Table 3 shows contribution of 45 % of angular speed of spindle. The depth of tool was 10 %, and the time of dwell 34 % respectively. The main effects plot was shown in Figure 4. The bigger tensile shear (4 650N) was reached with 1 400 rpm angular speed, depth of tool 3.5 mm, and dwell of time of 9 s. Close results can be found at [17, 18].

4. Conclusion

All three parameters (angular speed, depth of tool, time of dwell) have been analyzed and were found impact on the tensile shear load via an experimental design matrix (L8). From ANOVA, the angular speed offered an impact on the load of 45 %, time of dwell

Table 3: ANOVA results.

Source	Sum of Squares	DF	Mean Square	F Value	Prob> F	% PCR	% PCR
Mode	2 613 300	6	435 550	745.253 9	0.028 0	significant	
Rpm	1 230 096	1	1 230 096	39.206 25	0.101	0.453 258	45 %
Deep	296 065	1	296 065	9.436 335	0.2	0.100 084	10 %
Dwell	933 661	1	933 661	29.758 12	0.115	0.341 171	34 %
Rpm*Deep	69 378	1	69 378	2.211 251	0.377	0.014 37	1 %
Rpm*Dwell	12 090	1	12 090	0.385 339	0.646	0.007 29	1 %
Deep*Dwell	72 010	1	72 010	2.295 139	0.371	0.015 365	2 %
Residual	31 375	1	3.11E-08				
Cor Total	2 644 676	7	***Significant at 5 % level**				
Std. Dev.	0.000 176		R-Squared		0.988 1		
Mean	0.536 057		Adjusted R-Squared		0.917 0		



(a) (b)

Figure 4: (a) Main effect plot; (b) Interaction plot.

(34 %) and depth of tool (10 %). The optimal parameters were an angular speed of 1400 rpm, time of dwell 9 s, and 3.5 mm of the depth of tool.

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