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 1400 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

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 When the tool was retracted to the original position is retracting.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].
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].

| 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.

| 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 | 0.028    | significant |
| Rpm          | 1 230 096      | 1  | 1 230 096     | 39.206  | 0.101    | 45 %  |
| Deep         | 296 065        | 1  | 296 065       | 9.436   | 0.2      | 10 %  |
| Dwell        | 933 661        | 1  | 933 661       | 29.758  | 0.115    | 34 %  |
| Rpm*Deep     | 69 378         | 1  | 69 378        | 2.211   | 0.377    | 1 %   |
| Rpm*Dwell    | 12 090         | 1  | 12 090        | 0.385   | 0.646    | 1 %   |
| Deep*Dwell   | 72 010         | 1  | 72 010        | 2.295   | 0.371    | 1 %   |
| Residual     | 31 375         | 1  | 3.11E-08      |         |          |       |
| Cor Total    | 2 644 676      | 7  |               |         |          | 1 %   |
| Std. Dev.    | 0.000 176      |     | R-Squared     | 0.988   |          |       |
| Mean         | 0.536 057      |     | Adjusted R-Squared | 0.917 |          |       |

*Significant at 5 % level

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.

Acknowledgements

The author acknowledged the support funding for this research through Penelitian Hibah BINUS 2018 from Bina Nusantara University with contract number 014/VR.RTT/III/2018. Authors also thankful to Pancasila University in Indonesia, and UiTM Shah Alam in Malaysia, for a great support in this study.
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