Data Article

Data set on prediction of friction stir welding parameters to achieve maximum strength of AA2014-T6 aluminium alloy joints

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ABSTRACT

Statistical tools such as design of experiments (DoE), analysis of variance (ANOVA) were used to develop the empirical relationship, to predict the ultimate tensile strength of the joint at the 95% percent confidence level. Response surface graph and contour plots were constructed using response surface methodology (RSM) concept. From this investigation, it is found that the joint fabricated with a tool rotational speed of 1500 rpm, welding speed of 40 mm/min, tool tilt angle of 1.5° and tool shoulder diameter of 6 mm, exhibited maximum tensile strength of 380 MPa.

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1. Data

The data presented in this paper illustrate optimizing friction stir welding parameters to attain maximum strength of AA2014-T6 aluminium alloy. The following parameters were used such as tool rotational speed (N), welding speed (S), shoulder diameter (D) and tool tilt angle (Q) [1,2]. Data for fixing feasible working range of each parameters are presented in Table 1. FSW parameters and its working range are presented in Table 2. Design matrix and its data, calculated data of co efficient, ANOVA data, validation data are presented in Tables 3–6 respectively. Fig. 1 represented fabricated joints using experimental data. Fig. 2 shows predicted and actual data. The perturbation data are provided in Fig. 3 and Effect of process parameters and its response as shown in Fig. 4.

2. Experimental design, materials, and methods

2.1. Feasible working limit of FSW parameters

Different combinations of FSW parameters were used to carry out the trial experiments. This was done by changing any one of the factors from minimum to maximum, while keeping the other parameter at constant values (Table 1). The feasible working limits of the individual parameters were identified by inspecting tunnel, lack of fill, warm holes' defects, top surface of the weld, macrostructure for a smooth appearance without any visible macro level defects such as pinhole and root defect. The chosen levels of the selected process parameters are presented in Table 2.
2.2. FSW experiments and UTS evaluation

The FSW joints were fabricated as per the conditions dictated by the design matrix (Table 3) at random order [2,3]. A tool with a flat concave shoulder and tapered pin were used in FSW. A computer numerical controlled FSW machine was used to fabricate the joints. At each condition, three specimens

| Process parameters                  | Parameters range | Macrograph | Name of the defect         | Reason for defect                                                                 |
|-------------------------------------|------------------|------------|-----------------------------|----------------------------------------------------------------------------------|
| Tool rotational speed (N)           | N > 1700 rpm     | AS RS 2 mm | Cluster of worm hole        | Excess heat input                                                                |
| Tool rotational speed (N)           | N < 1300 rpm     | AS RS 2 mm | Lack of fill                | Insufficient heat input causes less plastic material flow                         |
| Welding speed (S)                   | S > 60 mm/min    | AS RS 2 mm | Tunnel defect               | Low plasticized material transportation                                           |
| Welding speed (S)                   | S < 20 mm/min    | AS RS 2 mm | Warm hole                   | High heat input produced                                                          |
| Tool shoulder diameter (D)          | D > 8 mm         | AS RS 2 mm | Cluster of worm holes       | Excess heat input due to large area of contact                                     |
| Tool shoulder diameter (D)          | D < 4 mm         | AS RS 2 mm | Tunnel defect               | Low heat generation produced insufficient plasticized material transportation    |
| Tool tilt angle (Q)                 | Q > 2.5          | AS RS 2 mm | Cluster of warm hole        | High forging pressure produced more strain hardening                               |
| Tool tilt angle (Q)                 | Q < 0.5          | AS RS 2 mm | Lack of fill                | Insufficient forging force resulted low plasticized material flow and consolidation |
were fabricated and some of the fabricated FSW joints are displayed in Fig. 1. The data of tensile strength were recorded and presented in Table 3. The RSM has been used to predict the maximum tensile strength \[4\] of butt joints of AA2014 aluminum alloy in terms of the important FSW parameters.

### 2.3. Developing a mathematical relationship

\[
\text{Tensile Strength of FSW joint} = f (N, S, D, Q) \tag{1}
\]
The significance of each co-efficient was calculated from student t-test and p-values, which are listed in Table 4, The final empirical relationship was constructed using only these co-efficient [5,6] and the developed empirical relationship of FSW joints is given below.
Fig. 1. Photograph of fabricated FSW joints.

Fig. 2. Actual Vs predicted tensile strength

Fig. 3. Perturbation graph.
a-b) Interaction effect between tool rotational speed and welding speed

c-d) Interaction effect between tool rotational speed and shoulder diameter

e-f) Interaction effect between tool rotational speed and tilt angle

Fig. 4. Response surface graph.
g-h) Interaction effect between welding speed and shoulder diameter

i-j) Interaction effect between welding speed and tool tilt angle

k-l) Interaction effect between shoulder diameter and tool tilt angle

Fig. 4. (continued)
UTS = \[+369.16+9.58\ (N)+10.58\ (S)+12.25\ (D)+13.75\ (Q)-7.0\ (ND)+7.75\ (S\ D)-8.87\ (D\ Q)-34.1\ (N^2)\]
\[-29.1\ (S^2)-7.2\ (D^2)-35.22\ (Q^2)\] MPa (2)

The adequacy of the developed model is tested by ANOVA. The test results of the ANOVA are given in Table 5; the desired confidence level was 95%. The relationship may be considered to be adequate. Fig. 2 shows the correlation graph of predicted and actual tensile strength of FSW joints, it could indicate the deviation between the actual and predicted UTS is low. Each predicted data matches with the experimental data is well shown in Fig. 2.

The Fisher's F-test with a very low probability value demonstrates a very high significance of the regression model. The goodness of fit of the model is fitted by the determination coefficient (R²). The coefficient of determination was calculated to be 0.9884 in response which implies that 98.8% of the experimental values confirm the compatibility with data as predicted by the model. Fig. 3 illustrates the perturbation plot for the response tensile strength of FSW joints.

2.4. Optimizing FSW parameters

By analyzing the response surface and contour plots as shown in Fig. 4(a–k), the maximum achievable tensile strength is found to be 377.21 MPa. The corresponding parameters that yield this maximum value are tool rotational speed of 1505 rpm, welding speed of 43.08 mm/min, tool shoulder of 6.95 mm and tool tilt angle of 1.53°. The higher F ratio value implies that the respective levels are more significant.

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