Optimization Studies on Friction Welded Aluminium Alloys

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Abstract - This research deals with an approach for optimizing the friction welding (FRW). It is a process that is being used in industry for rod, pipe and tube joining purposes especially in the Automobile and Aerospace industry. The complicated behavior of this process is analyzed to set the optimum parameters to get good quality weld. Furthermore, four important process parameters, namely friction load (FR_L), forging load (FO_L), friction time (FR_T) and forging time (FO_T) are considered as the factors influencing the quality of the joints. The setting of welding parameters was determined using Taguchi experimental design method and L9 orthogonal array was chosen. The output parameter considered in this approach is the tensile strength of the weld.

Keywords - Dissimilar Aluminium Alloys, Friction Welding, Taguchi method.

I. INTRODUCTION

Friction welding is a solid state welding process. Solid state welding are those welding process in which no external heat is applied or no molten or plastic state involves. In this type of welding, welding occurs due to external pressure applied into the solid state. In friction welding process, either the plates or work pieces to be joint are in either rotating or moving relative to one another. This relative movement produces friction which displaces material plastically on contact surface. A high pressure forced applied till completed the weld. This welding is used to joint steel bars, tubes up to 100 mm diameter. Although, much work has been done on FRW using different materials M.Vigneshwar et. al. [1] proposed dissimilar aluminium alloy joints using FRW. X.Song et. al. [2] In the present study, the residual stresses distribution in the Linear Friction Welded (LFW) pieces were studied using Finite Element (FE) simulation and high energy synchrotron X-ray diffraction.

C.Meengam et. al. [3] The purpose of this study is to evaluate the welding characteristic of friction welded similar joints of SSM7075 aluminum alloys. Friction welding methods were investigated by joining parameters as follows: rotational speed of 1200, 1400, 1600, and 1800 rpm, burn of length of 2.5, 3.0, and 3.5 mm, feed rate of 0.2 mm/min, and welding time for 15 seconds respectively. The results of the investigation have shown that joining parameters with rotational speed of 1800 rpm, burn of length of 3.5 mm, and 15 seconds of welding time can produce a very good weld with the highest joint strength at 104.53 MPa. S.R.SundaraBharathi et. al. [4] deals with Joining of similar and dissimilar combinations of aluminium alloys 2024 and 6061 were performed using friction welding technique. N Rajesh Jesudoss Hynes and P Shenbaga Velu [5] objective of this study is to carry out an experimental investigation in order to study the behaviour of dissimilar joints. The microscopic structure at the welded joint interface was analyzed using an optical microscopy and scanning electron microscope. It was found that, by increasing the value of friction time, the value of the tensile strength increases and the result of tensile strength is found to be 120 MPa at a friction time of 10 s. PengLi et. al [6] In this paper, continuous drive friction welding of copper to alumina was conducted using 2.5 mm thick AA1100 aluminum as interlayer. The effects of friction pressure and friction time on the tensile strength of joints were evaluated, and the interface microstructure evolution and fracture morphologies were also analyzed.

II. PROPOSED ALGORITHM

The Taguchi method involves reducing the variation in a process through robust design of experiments. The overall objective of the method is to produce high quality product at low cost to the manufacturer. The Taguchi method was developed by Genichi Taguchi. He developed a method for designing experiments to investigate how different parameters affect the mean and variance of a process performance characteristic that defines how well the process is functioning. The experimental design proposed by Taguchi involves using orthogonal arrays to organize the parameters affecting the process and the levels at which they should be varied. Instead of having to test all possible combinations like the factorial design, the Taguchi method tests pairs of combinations. This allows for the collection of the necessary data to determine which factors most affect the product quality with a minimum amount of experimentation, thus saving time and resources. The Taguchi method is best used when there is an intermediate number of variables (3 to 50), few interactions between variables, and when only a few variables contribute significantly.

Orthogonal arrays are special standard experimental design that requires only a small number of experimental trials to find the main factors effects on output. Before selecting an orthogonal array, the minimum number of experiments to be conducted is to be fixed based on the formula below

$$\mathbf{N\ Taguchi = 1 + NV\ (L - 1)}$$

Where, N Taguchi = Number of experiments to be conducted

NV = Number of parameters
L = Number of levels in this work
NV = 4 and L = 3,

Hence

N Taguchi = 1+ 4 (3-1) = 9 Experiments

Hence at least 9 experiments are to be conducted. Based on this orthogonal array (OA) is to be selected which has at least 9 rows i.e., 9 experimental runs.

The following standard orthogonal arrays are commonly used to design experiments:

2-Level Arrays: L4, L8, L12, L16, L32
3-Level Arrays: L9, L18, L27
4-Level Arrays: L16, L32

In this work L9 is sufficient. It would require a total of 27 experiments to optimize the parameters. Taguchi experimental design of experiments suggests L9 orthogonal array, where 9 experiments are sufficient to optimize the parameters. Based on main factor, the variables are assigned at columns, as stipulated by orthogonal array. The last column can be kept dummy, but no row should be left out. Once the orthogonal array is selected, the experiments are selected as per the level combinations. It is important that all experiments are conducted. The performance parameter (output) is noted for each experimental run for analysis.

Based on literature survey and preliminary investigations, the following four parameters i.e. friction load (FR_L), forging load (FO_L), friction time (FR_T) and forging time (FO_T) were chosen as input parameters. Table 1 shows different levels of these control parameters considered for welding operation. In the present work the performance of Friction Welding is measured by the tensile strength of the weld joint.

Table 1: Different level of the control parameters

PARAMETERS	LEVEL 1	LEVEL 2	LEVEL 3
Friction Load (FR_L), kg	850	900	950
Forging Load (FR_L), kg	900	950	1000
Friction Time(FR_L), Sec	18	20	22
Forging Time (FR_L), Sec	3	4	5

In the present work Taguchi's parameter design approach is used to study the effect of process parameters on the various responses of the FRW process. For better weld joint higher tensile strength is always desired. Hence, tensile strength has been categorized as "larger-the-better" type problem. The signal to noise ratio η (Vc) in this case has been calculated as follows:

$$\begin{aligned} S/N \text{ ratio} &= \eta\,(Vc) \\ &= -10 \log 10 \text{ (mean square reciprocal of tensile strength)} \qquad (1). \end{aligned}$$

III. EXPERIMENT AND RESULT

On the basis of input factors and their levels, an orthogonal array (L9) consists of 9 experimental runs has been employed for modeling the FRW process. The 9 experiments were performed on Friction welding machine. For each experimental run, the specified input parameter combination was set and the welding was done. The tensile strength for each work piece was measured using universal tensile testing machine is calculated. Table 2 shows the design matrix and experimental design for L9 orthogonal array for DOE taguchi method

Table 2: Design matrix and experimental design

Sample No	Coded value				Actual value			
	A	B	C	D	FR_L (kg)	FO_L (kg)	FR_T (sec)	FO_T (sec)
1	1	1	1	1	850	900	18	3
2	1	2	2	2	850	950	20	4
3	1	3	3	3	850	1000	22	5
4	2	1	2	3	900	900	20	5
5	2	2	3	1	900	950	22	3
6	2	3	1	2	900	1000	18	4
7	3	1	3	2	950	900	22	4
8	3	2	1	3	950	950	18	5
9	3	3	2	1	950	1000	20	3

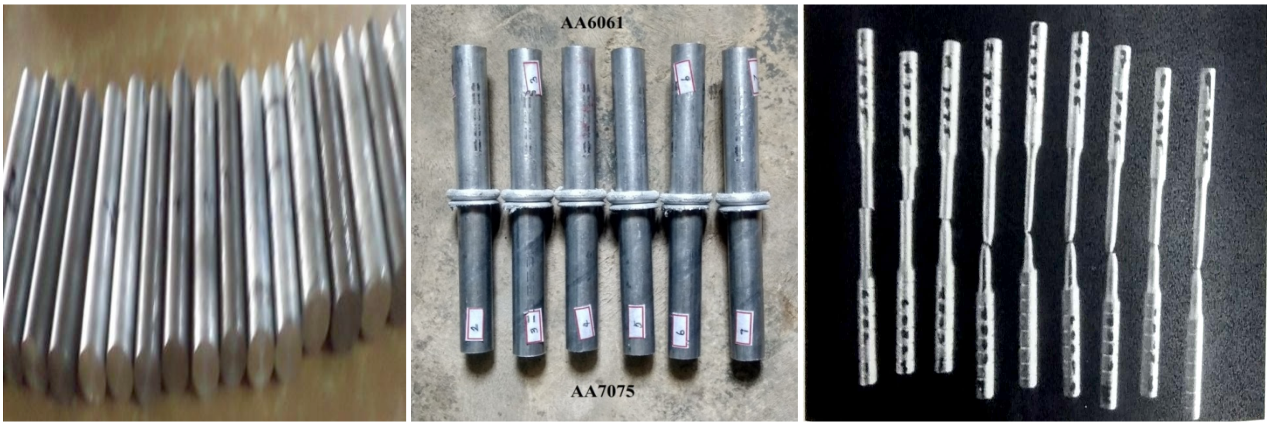

Figure 1: Work pieces before welding, after welding and after tensile test

A defect free dissimilar joint of AA6061 and AA7075 is made by friction welding procedure by varying the friction load, forging load, friction time and forging time and keeping rotational speed constant. The visual examination exhibits the flash width, which increases with increase in the friction time. The deformation of flash is observed to be more on AA6061 side than AA7075 due to high thermal conductivity.

Table 4.1 Burn off length

Sample No	Burn off length
1	5
2	4
3	6
4	10
5	8
6	6
7	7
8	8
9	6

In the present study all the designs, plots and analysis have been carried out using Minitab statistical software. The experimental results for tensile strength with S/N values are given in Table 3.

Table 3: Set of experiments with their S/N ratio values.

Sample No	Ultimate Tensile Strength (MPa)	S/N Values
1	141	42.9844
2	149	43.4637
3	**174**	**44.8110**
4	136	42.6708
5	152	43.6369
6	135	42.6067
7	134	42.5421
8	147	43.3463
9	156	43.8625

Table 4: Response Table for Signal to Noise Ratios Larger is better

Level	FR_L	FO_L	FR_T	FO_T
1	**43.75**	42.73	42.98	43.49
2	42.97	43.48	43.33	42.87
3	43.25	**43.76**	**43.66**	**43.61**
Delta	0.78	1.03	0.68	0.74
Rank	2	1	4	3

IV. EFFECT ON TENSILE STRENGTH

Figure 2 shows the S/N ratio graph where the centre line is the value of the total mean of the S/N ratio. Basically, the larger the S/N ratio, the better is the quality characteristic for the tensile strength. The response of S/N ratio with respect to tensile strength indicates the forging load to be the most significant parameter that controls the weld tensile strength where's the friction load, forging time & friction time are less significant in this regard.

Figure 2 shows variation of S/N ratio with respect to the forging load. As the forging load increases the weld strength also increases. Also friction time increases the weld strength were increased.

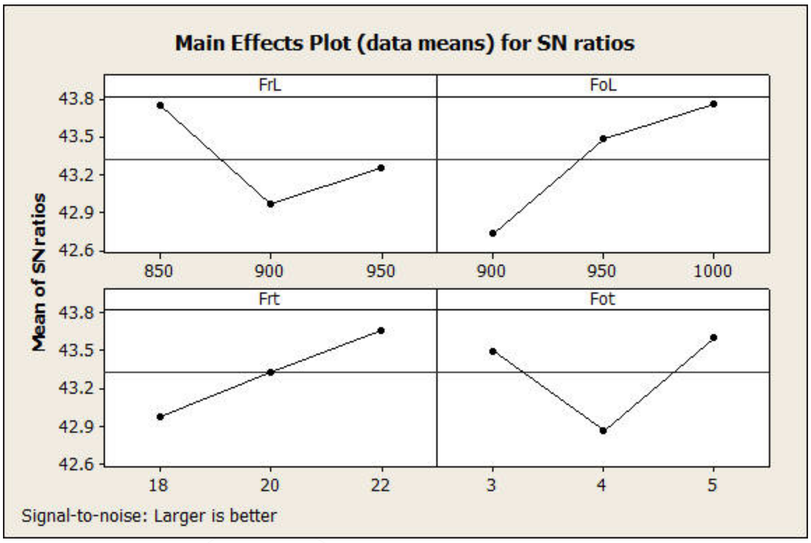

Figure 2: Main effect plots for S/N ratio (Tensile Strength) with FR_L, FO_L, FR_T and FO_T

V. CONCLUSION

Experiments are performed using Taguchi's design of experiment methodology. The effects of the process parameters viz. friction load, forging load, friction time and forging time were studied. The response of S/N ratio with respect to tensile strength indicates the forging load to be the most significant parameter that controls the weld tensile strength where's the friction load, forging time and friction time are comparatively less significant in this regard. Table 5 shows that the optimum parameter which is gives the best strength of the weld for dissimilar aluminium alloys of friction welding.

Table 5: Optimum parameters for Dissimilar AA of FRW

PARAMETERS	OPTIMIZED VALUE
Friction Load (FR_L), kg	850
Forging Load (FR_L), kg	1000
Friction Time(FR_L), Sec	22
Forging Time (FR_L), Sec	5

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