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OPTIMIZATION ON FRICTION WELDING OF ALUMINIUM ALLOY 6082 T6 USING RESPONSE SURFACE METHOD

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ABSTRACT

Welding of similar metals with the use of solid state welding has a great demand in many applications. In this study, tensile strength of the friction welding of Aluminium alloy 6082 T6 has been investigated. Various experiments are conducted using design of experiments. The effect of parameter over tensile strength has been analyzed. The composition of weld joint and fracture surface of tensile tested sample were analyzed by using Scanning Electron Microscope which reveals that the increase in friction pressure and forging pressure, the tensile strength has increased.

***Keywords**: Friction Welding, Aluminium Alloy, Optimization*

1. Introduction

The continuous drive friction welding technique is used for joining of two similar metal Aluminum alloy. The 6000 series is mainly alloyed with magnesium and silicon, which results in a hardenable alloy. Al is also of interest in many other applications, such as the topside structures of offshore platforms, railway wagons and in the brewing industry. There is a great demand for friction welding of aluminium alloy 6082 T6 in many areas including cryogenic applications, spacecraft, high vacuum chambers and cooking utensils owing to their superior properties. In this case, it is necessary to join similar metal of aluminum alloy 6082 T6 used for this study. The friction welding method can also be used for joining of the severely plastically deformed materials.

Friction welding method has extensively been used in fabrication industries due to several advantages such as high material saving, low production time and high durability for the weld joint. In the process, heat is generated by conversion of kinetic energy of particle in the specimen into thermal energy at the interfaces of the components during rotation under pressure without any energy from environment. In order to take full advantage of the properties of different metals it is necessary to produce high quality joints between them. Many suggested for the use of 6082T6 and studied their fatigue behavior of the joints in various welding processes. The scope of this work is to find out the optimum condition for friction welding of Aluminium alloy 6082T6.

In this study Friction welding of AA 6082T6 has been investigated. The chemical composition of the workpiece material is presented in Table 1 and its SEM micrograph has been displayed in Fig.1.

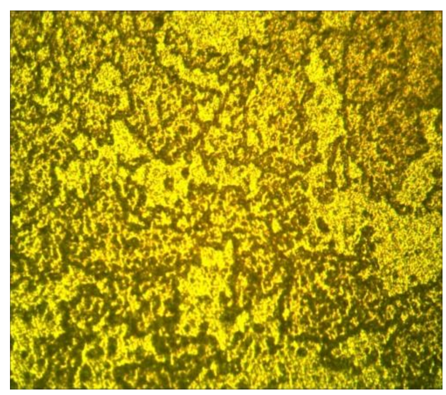

Fig.1 AA6082-T6 Base Metal AT 100 X

Table.1 Chemical composition of base metal AA 6082T6

Element	Al	Mn	Mg	Si	Cr	Fe	Cu
%	97.62	0.55	0.65	0.95	0.008	0.15	0.035

2. Experimental procedure

In this study four process parameters such as Friction pressure, Forging pressure, Friction time and Forging time have been considered. Several trial runs were conducted to determine the range and to fix the level of parameters. The influence of the considered factors as listed in Table 2 has investigated on the Tensile strength of the welds. A set of friction welded joints has been shown in Fig.2

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Table 2 Levels and Factors

FACTORS		Levels				
		-2	-1	0	+1	+2
Friction pressure, kgf	FrP	700	750	800	850	900
Forging pressure, kgf	FoP	400	450	500	550	600
Friction time, sec	FrT	16	18	20	22	24
Forging time, sec	FoT	1	2	3	4	5

Fig.2 Set of Weld joints

2.1 Response surface method

Engineers often wish to determine the values of the process input parameters at which the responses reach their optimum. The optimum could be either a minimum or a maximum of a particular function in terms of the process input parameters. RSM is one of the optimization techniques currently in widespread use in describing the performance of the welding process and finding the optimum of the responses of interest. RSM is a set of mathematical and statistical techniques that are useful for modelling and predicting the response of interest affected by a number of input variables with the aim of optimizing this response [13].

When all independent variables are measurable, controllable and continuous in the experiments, with negligible error, the response surface can be expressed by

$$y = f(x1, x2, \ldots\ldots, xk) \quad (1)$$

k is the number of independent variables. To optimize the response ''y'', it is necessary to find an appropriate approximation for the true functional relationship between the independent variables and the response surface. Usually a second-order polynomial Eq. (2) is used in RSM because it includes various combinations of parameters which could be helpful in finding its exact effect but this is not in the case of first order as it has only limited combination of parameter to be weld.

$$y = b_o + \sum b_i X_i + \sum b_{ii} X^2_{ii} + \sum b_{ij} X_i X_j + \epsilon \quad (2)$$

The test was designed based on a four factors five levels central composite rotatable design with full replication. The reason for selecting central composite is due to the number of experiments is more when compared to other methods. The Friction welding input variables are friction time, friction pressure, forging time and forging pressure. In order to find the range of each process input parameter, trial weld runs were performed by changing one of the process parameters at a time. Absence of clear welding defects, flash formation, a smooth and uniform welded surface with sound face were the criteria of selecting the working ranges. Table 3 shows the process variables along with its Tensile strength of the joint. MINITAB software has been used for analysis purposes.

Table 3 Experimental Results

Exp. No	FrP, kg	FoP, kg	FrT, Sec	FoT, Sec	Tensile Strength, MPa
1	850	450	22	2	135.57
2	800	500	16	3	178.9
3	750	500	18	2	152.25
4	750	500	22	4	138.76
5	800	500	20	5	87.9
6	800	500	20	3	130.76
7	850	450	18	2	53.67
8	750	450	22	2	153.34
9	800	500	20	3	129.89
10	800	500	20	3	183.38
11	850	500	18	2	130.89
12	800	500	20	3	185.65
13	800	600	20	3	120.77
14	750	450	18	4	121.84
15	850	500	18	4	112.25
16	900	500	20	3	143.56
17	850	500	22	2	154.88
18	850	500	22	4	129.45
19	800	500	24	3	127.98
20	800	400	20	3	143.96
21	800	450	20	3	163.53
22	750	500	18	2	125.96
23	750	500	22	2	129.3
24	800	500	20	3	115.43
25	800	500	20	3	123.95
26	750	450	18	4	134.43
27	850	450	22	1	149.93
28	850	500	18	4	148.45
29	700	450	20	4	120.14
30	750	450	22	2	130.67
31	800	500	20	3	129.78

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3. Result and Discussion

3.1Tensile Test

As the tensile strength values obtained from tensometer, the experimental number 2, 10, 12 has the values at higher side. Which indicates as increase in friction pressure and forging pressure, the tensile strength is increased as expectedd.

The fracture surface is analyzed in scanning electron microscope; Due to Mg2Si particle precipitated in the aluminium matrix it gives maximum strength. The fracture surface is in fibrous form; so far it is a ductile.

The second order mathematical model has been made using the MINITAB software as:

TS=2515.01+PFr*3155.24+PFo*1886.9+tFr*55.04+tFo*31.38-PFr*PFr*1536.16-PFo*PFo*923.66-tFr*tFr*8.49-tFo*tFo*4.74

Annova test has been performed on the model in order to justify the significance of the same. The P value shown in table 4 indicated that all the terms are significant. Further the lack of fit term has been low. Hence this model can be efficiently used for prediction purposes.

Table 4 Annova Table

SOURCE	DF	SEQ SS	ADJ MS	F	P
REGRESSION	8	12257.0	1532.13	45.10	0.00
LINEAR	4	2644.5	2566.12	75.54	0.00
SQUARE	4	9612.5	2403.14	70.74	0.00
RESIDUAL ERROR	22	747.3	33.97		
LACK OF FIT	16	677.6	42.35	3.65	0.059
PURE ERROR	6	69.7	11.62		
TOTAL	30	13004.4			

3.2 Optimized parameter

From the above design of experiment results using MINITAB software and the experimental values of the response (Tensile strength) the optimized parameter can be given as below.

Table 5 Optimized parameter

Friction pressure, FrP	900 Kgf
Forging pressure, FoP	550 Kgf
Friction time, FrT	16 Sec
Forging time, FoT	5 Sec

The optimized parameter given above has been the best parameter setting for friction welding of aluminium alloy 6082 T6 .

3.3 SEM analysis

The fibrous surface is examined with electron microscope at a high magnification, it is found that it consists of numerous spherical ‘dimples’, each such depression (hollow) being associated with a hard particle. Each dimple is one- half of a micro-void that formed, and then separated during fracture process.

Normally these dimples are round, or equi-axed in the fibrous central region of cup-and-cone fracture, but are oval shaped or elongated on the shear-lip with the ovals pointing towards the centre of test piece. Such a parabolic shape of dimples is indicative of shear failure. (Fig 3 & 4)

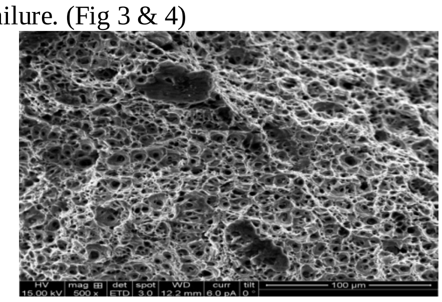

Fig. 3 Fracture surface analysis of tensile tested specimen at 500X

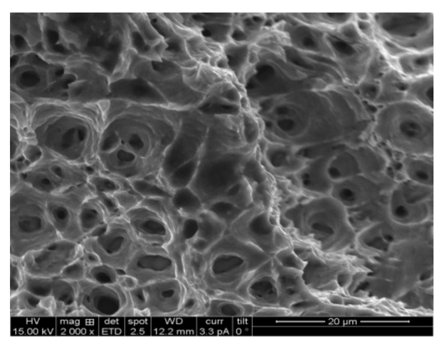

Fig. 4 Fracture surface analysis of tensile tested specimen at 2000X.

4. Conclusion

Similar welding of aluminium alloy has been studied in this work. Experiments were conducted for various combinations of process parameters such as friction pressure, forging pressure, friction time and forging time. The strength of the joint was analyzed by conducting tensile test. Experiments were conducted with DOE concepts to investigate the effect of Friction pressure, Forging pressure, Friction time and Forging time on Tensile strength and microstructure.

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The following observations are made from the studies:

1.Response surface method (RSM) can be effectively used to find optimum condition for friction welding of Aluminium alloy 6082 T6

2.Friction pressure, forging pressure, friction time and forging time have influence on effect of parameters.

3.Which shows the increase in friction pressure and forging pressure, the tensile strength is increased which indicates that it can withstand large amount of plastic deformation.

4.The fracture surface is analyzed in scanning electron microscope, Due to Mg2Si particle precipitated in the aluminium matrix it gives maximum strength the fracture surface is in fibrous form, so far it is a ductile fracture.

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