Optimization on Friction Welding of Aluminium Alloy 6082 T6 and Austenitic Stainless steel 304

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Abstract **-** The Austenitic stainless steel 304 and Aluminium alloy 6082 T6 were friction welded. The welded samples were prepared for tensile test. The optimization of welding parameter is found by design of experiments. The effect of parameter over tensile strength is analyzed. The present work was focused on optimization of Aluminium alloy-Stainless steel welds. Many intermetallic compounds are formed at the interface. This may lead to have a difference in mechanical properties of weld joints with respect to the varying parameters.
Keywords - Friction welding, Austenitic stainless steel, Aluminum alloy.

I. INTRODUCTION

The continuous drive friction welding technique is used for joining of two dissimilar metals viz Austenitic Stainless Steel and aluminium alloy. These materials are used in the application of Automobile and Aircraft.

The different stages in the friction welding process are shown in fig I. The friction welding method can also be used for joining of the severely plastically deformed materials [1]. Many works have been done for studying of mechanical and microstructure properties [2, 3] of the joint obtained by friction welding of similar and dissimilar materials.Both theoretical and experimental studies on effect of friction welding parameters on properties of steel have been reported in the literature.

In our study the mechanical property of Austenitic stainless steel304 and Aluminum alloy 6082 T6 were observed.

II. EXPERIMENTAL PROCEDURE

The austenitic stainless steel of length 76mm and Aluminium alloy of length 79mm were taken for analysis each of diameter 12mm.

A. Response Surface Method

Engineers often wish to determine the values of the process input parameters at which the responses reach their optimum. 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. When all independent variables are measurable, controllable and continuous in the experiments, with negligible error, the response surface can be expressed by

$$y = f(x1, x2, \ldots\ldots, x_k) \quad \text{----------------} \quad (1)$$

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.

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

The test was designed based on a four factors-five levels central composite rotatable design with full replication. The Friction welding input variables are friction time t_{Fr}, friction pressure P_{Fr}, forging timet_{FO}, forging pressure P_{Fo} as shown below in table 1.

Table 1 Chemical composition of the studied alloy

EXP.NO	FRICTION PRESSURE, PA	FORGING PRESSURE, PA	FRICTION TIME, SEC	FORGING TIME, SEC
1	78.15	78.15	2	2
2	95.46	78.15	2	2
3	78.15	95.46	2	2
4	95.46	95.46	2	2
5	78.15	78.15	4	2
6	95.46	78.15	4	2
7	78.15	95.46	4	2
8	95.46	95.46	4	2
9	78.15	78.15	2	4
10	95.46	78.15	2	4
11	78.15	95.46	2	4

12	95.46	95.46	2	4
13	78.15	78.15	4	4
14	95.46	78.15	4	4
15	78.15	95.46	4	4
16	95.46	95.46	4	4
17	69.42	86.78	3	3
18	104.14	86.78	3	3
19	86.78	69.42	3	3
20	86.78	104.14	3	3
21	86.78	86.78	1	3
22	86.78	86.78	5	3
23	86.78	86.78	3	1
24	86.78	86.78	3	5
25	86.78	86.78	3	3
26	86.78	86.78	3	3
27	86.78	86.78	3	3
28	86.78	86.78	3	3
29	86.78	86.78	3	3
30	86.78	86.78	3	3
31	86.78	86.78	3	3

Table 2 Mechanical property of the studied alloy

	C	Si	Mn	Cr	Ni	Ph	Al	Mg
Austenitic stainless steel 304	0.48-0.58	0.25	8-10	20-23	3.25-4.5	0.05	-	
	C	Si	Mn	Cr	Ni	Ph	Al	Mg
Aluminium alloy 6082 T6	-	0.7-1.3	0.4-1.00	0.25 Max	-	-	95.2-98.3	0.6-1.00

Table 3 Welded input variables

MECHANICAL PROPERTY	SS304	AA6082-T6
Tensile Strength, MPa	727	241
Yield Strength, MPa	684	212
Micro hardness, Hv	310	104

By performing various trials the maximum and minimum range of welding parameters for Aluminium alloy 6082 T6 and Austenitic stainless steel 304 were found and given below in table 4.

Table 4 Factors and levels

FACTORS	-2	-1	0	+1	+2
P_{Fr}	0.8	0.9	1.00	1.1	1.2
P_{Fo}	0.8	0.9	1.00	1.1	1.2
t_{Fr}	1	2	3	4	5
t_{Fo}	1	2	3	4	5

Fig 1 Specimen of welded joints (Exp No. 6)

III. RESULTS

A. Tensile Test

The tensile testing was carried out in the Universal Testing Machine of 100KN capacity.

Table 5 Tensile strength of welded joints

EXP NO.	TENSILE STRENGTH, MPa	PEAK LOAD, kN
1	155	9.85
2	167	10.615
3	157	11.055
4	174	9.97
5	165	11.585
6	186	14.945
7	166	10.555
8	178	11.35
9	153	9.73
10	170	10.835
11	175	10.87
12	183	11.63
13	162	11.85
14	186	10.285
15	170	13.26
16	178	10.81
17	125	12.995
18	165	11.215
19	155	10.11
20	184	10.03
21	162	7.9
22	183	11.7
23	177	11.995
24	198	11.265
25	203	10.21
26	204	12.995
27	208	13.26
28	207	13.19
29	210	13.43
30	208	13.26
31	213	13.68

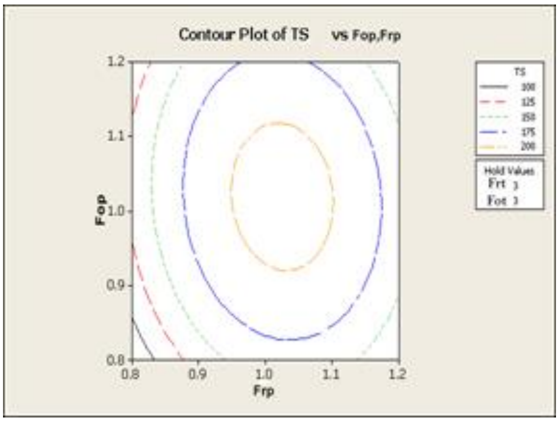

Fig 2 Contour Plots for TS VsFrp, Fop

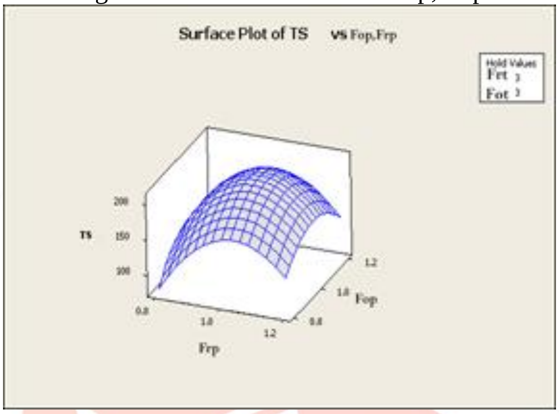

Fig 2 surface plots for TS VsFrp, Fop

B. 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 6 Optimized parameter

Friction pressure, P_{Fr}	95.46	Pa
Forging pressure, P_{Fo}	78.15	Pa
Friction time, t_{Fr}	4	Sec
Forging time, t_{Fo}	2	Sec

The optimized parameter given above can be the best parameter condition for friction welding of aluminium alloy 6082 T6 and stainless steel 304.

C. *Effect Of Parameter*

The friction time t_{Fr}, friction pressure P_{Fr}, forging timet_{FO}, forging pressure $P_{Fo}$are varied at different combination and welding was performed.

Table 7 Experimental data for effect of parameter

Exp.No	FRICTION, PRESSURE, Pa	FORGING PRESSURE, Pa	FRICTION TIME, Sec	FORGING TIME, Sec
1	78.15	78.15	4	2
2	95.46	78.15	4	2
3	112.81	78.15	4	2
4	95.46	60.74	4	2
5	95.46	78.15	4	2
6	95.46	95.46	4	2
7	95.46	78.15	2	2
8	95.46	78.15	4	2
9	95.46	78.15	6	2
10	95.46	78.15	4	1
11	95.46	78.15	4	2
12	95.46	78.15	4	3

- **Effect Of Friction Pressure, P_{fr}:**

The effect of friction pressure over tensile property of weld joint is shown below. As the friction pressure increases the tensile strength decreased and for further increase in friction pressure the tensile strength increased as in the below Figure 4.

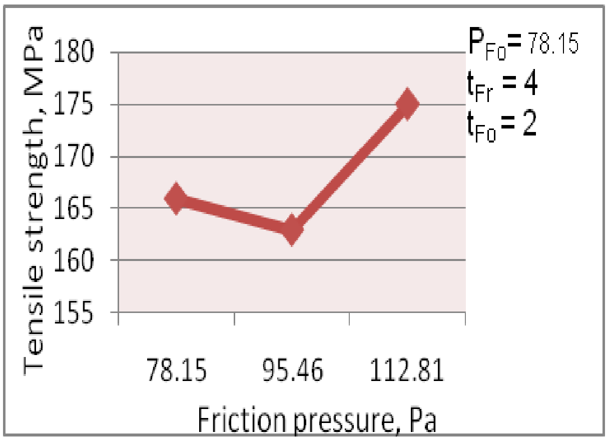

Fig 4 TS Vs Friction pressure

- **Effect of Forging Pressure, Pfo:**
  The effect of forging pressure over tensile property of weld joint is shown below. As the forging pressure increases the tensile strength increased and for further increase in forging pressure the tensile strength decreased as in the below figure 5.

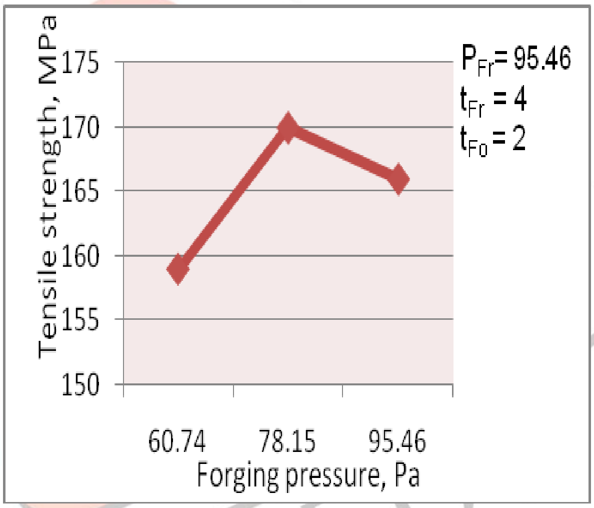

Fig 5 TS Vs Forging pressure

- **Effect of Friction Time, Tfr:**
  The effect of friction time over tensile property of weld joint is shown below. As the friction time increases the tensile strength increased and for further increase in friction time the tensile strength decreased as in the below figure 6.

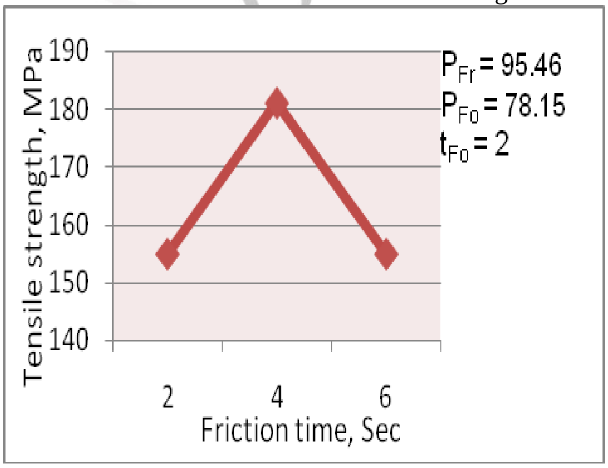

Fig 6 TS Vs Friction time

- **Effect of Forging Time, Tfo:**
  The effect of forging time over tensile property of weld joint is shown below. As the forging time increases the tensile strength decreased and for further increase in forging time the tensile strength increased.

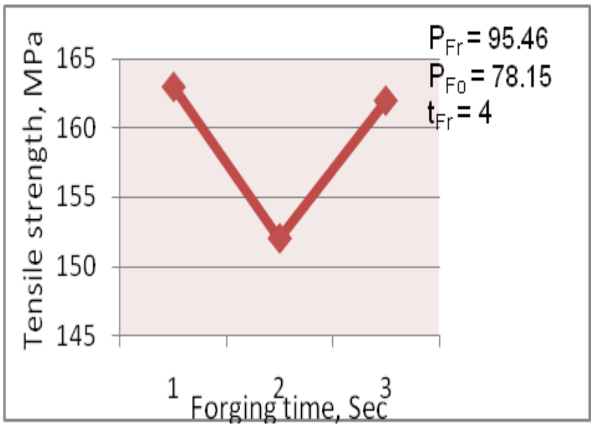

Fig 7 TS Vs Forging time

IV. DISCUSSION

TheTensile strength being the response had a great effect by varying parameter combinations. The friction pressure made tensile strength decreased and increased due to the formation of finer to coarser to grain structure as in the Figure. The forging pressure made tensile strength increased and decreased due to formation of coarser to finer grain structure as in the figure.

As the friction time increased the tensile strength increased and decreased due to the formation of coarser to finer grain structure as in the figure. And as the forging time increased the tensile strength decreased.

V. CONCLUSION

Dissimilar welding of Austenitic Stainless steel and Aluminium alloy was studied in this project. Experiments were conducted for various combinations of friction pressure, forging pressure, friction time and forging time. The strength of the joint was analyzed by tensile test.

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 and Austenitic Stainless steel 304.
2. The optimum condition is found to be P_{Fr}=95.46, P_{Fo}=78.15, t_{Fr}=4, t_{Fo}=2.
3. The tensile strength for welded joints increased as friction time and forging pressures increased and on further increase, the strength decreased.
4. The tensile strength for welded joints decreased as friction pressure and forging time decreased and on further increase, the strength increased
5. The Microstructure analysis showed the difference in grain structure which resulted in higher and lower tensile strengths for welded joints.

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