

# Optimization of Process Parameters for Friction Stir Welding of Dissimilar Aluminium Alloy AA6061 to AA5183 using TOPSIS Technique

Shubham Shukla, Himanshu Shukla

**Abstract:** Friction stir welding has proven to be the most promising solid state joining process. It can be used to get high weldability in joining of high strength aerospace aluminium alloys and other metallic alloys which used to be low with traditional fusion welding process. This paper emphasises on finding the optimum process parameter for friction stir welding of dissimilar aluminium alloy AA6061 to AA5183 using multi criteria decision making method (MCDM). Friction stir welding was done at different tool rotational speed and transverse velocity and mechanical properties such as tensile strength, percentage elongation and hardness were studied for each weld specimen. Finally optimization was done using TOPSIS (Technique of Ordered Preference by Similarity to Ideal Solution). The result revealed that the tool rotational speed of 1200 rpm and welding speed of 80mm/min are the optimum welding parameters.

**Keywords :** Friction stir welding, TOPSIS, Process parameter

## I. INTRODUCTION

Solid state welding for joining of two dissimilar aluminium alloys has gained a great acceptance in the recent decades. Because of its various advantages over traditional fusion welding used for joining of dissimilar aluminium alloy.

Solid state welding help in overcoming various welding defects like porosity, segregation etc. Joining of two dissimilar metal is a difficult task as both the metal have different chemical composition and mechanical properties. Friction stir welding is most successful solid state welding technique for this task. In friction stir welding two metal plates are joined by a non consumable rotating –translating tool which has a specially designed pin at its bottom. The shoulder of the tool rubs against the workpiece. Thus the tool help in heating of the workpiece to a temperature at which plastic deformation takes place and movement of the material from the leading face of the pin to the trailing face. In friction stir welding the major process parameters are tool geometry, transverse speed and rotational speed of the tool

which determine the superiority of weld joint. Hence it is required to select the best welding parameters.

M.V.R.Durga Prasad and Kiran Kumar Namala(1) did the parameter optimization for friction stir welding of dissimilar aluminium alloy AA5083 To AA6061 with process parameters as tool rotational speed, welding speed, and tool tilt angle by using Taguchi's approach L9 array. The experimental study showed that the welding speed had the maximum influence on percentage elongation and effect of hardness at weld zone. The tool rotational speed had least influence on the percentage elongation and effect of hardness, the tool tilt angle has major influence and the welding speed has least influence on hardness at HAZ.

M. Koilraj, V.Sundereswaran, S. Vijyan did friction stir welding of dissimilar aluminium alloy AA2219 To AA5083 and investigated the optimum process parameter using Taguchi technique. The parameter considered in were tool rotational speed, transverse speed, tool pin geometry and D/d ratio, the result revealed that the optimum welding parameters were tool rotational speed of 700rpm transverse speed of 15mm/min and D/d ratio of 3. The cylindrical thread pin tool profile was found to be the best and the failure occurs at heat affected zone of AA5083. From the above mentioned studies it is clear that a number of research study has been done in parameter optimization in friction stir welding of dissimilar aluminium alloy. But the method of parameter optimization used is Taguchi technique which is good for optimization of single objective, but it is not favourable for multi objective optimization. For the optimization of multiple objective, techniques like TOPSIS can be used. In this study friction stir welding of two dissimilar AA6061 to AA5183 is done at different tool rotational speed and transverse velocity. The mechanical properties considered are percentage elongation tensile strength and hardness, finally the parameter optimization is done by TOPSOS. In TOPSOS the optimum solution is the one which has smallest Euclidian distance from the ideal solution and largest from the negative ideal solution. It has high consistency, less computation effort and provide more realistic form of.

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modelling.

## II. EXPERIMENTAL PROCEDURE

Two plates of AA6061 and AA5183 of thickness 3mm were cut into dimension of 200x100mm using shear cutting machine and were welded by friction stir welding process. The process parameter are shown in the table 1 and the weld samples are shown in fig. 1 below.

**Table 1 : Process parameters values**

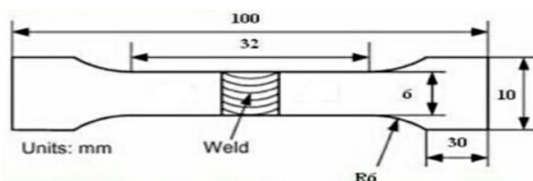
Welded sample	Tool rotational speed (rpm)	Tool transverse speed
1	1500	80
2	1500	160
3	1200	160
4	900	160
5	900	80
6	1200	120
7	1200	80
8	1800	80
9	1500	120
10	900	120



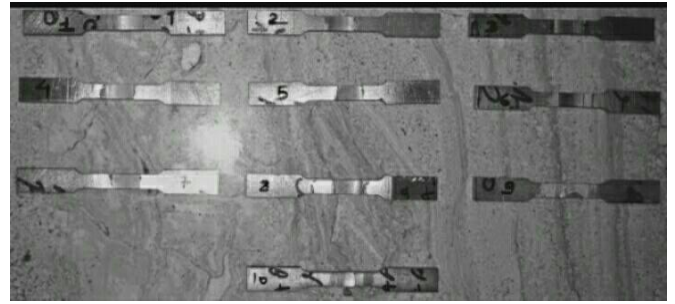
**Figure 1: Weld samples after friction stir welding**

### 1. Tensile test

Tensile test samples were made according to ASTM E8, on wire cut EDM machine with dimension of 32mm gauge length, 6mm width and overall length of 100mm. The tensile test specimen is shown in the figure below.



**Figure 2: Dimensions of tensile test sample**



**Figure 3 : Tensile test sample before tensile test.**

Tensile test was performed to evaluate the values of tensile strength and percentage elongation. The results of the tensile test are shown in the table 2 and graph below.



**Figure 4: Tensile test samples after tensile test.**

**Table 2: Tensile strength and percentage elongation values**

Weld sample	Tensile strength (N/mm <sup>2</sup> )	Percentage elongation
1	142.68	7.18
2	172.41	12.5
3	178.35	12.18
4	59.45	6.25
5	130.80	16.25
6	178.36	10.94
7	148.63	12.5
8	178.35	13.44
9	166.47	8.75
10	160.52	11.25

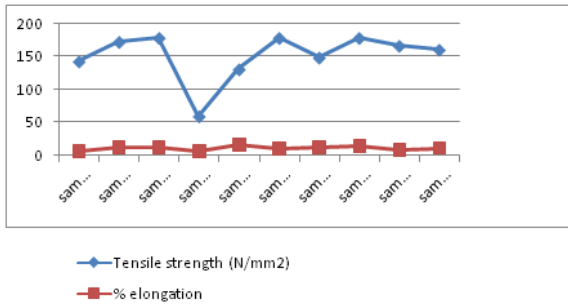


Figure 5: Tensile strength and percentage elongation of weld samples.

**Hardness Test**

The weld sample were undergone Vicker’s hardness test .the result of the test are shown in the table 3 below.

Table 3: Hardness values.

Weld sample	Hardness (HV)
1	62
2	59
3	61
4	53
5	62
6	57
7	60
8	59
9	64
10	56

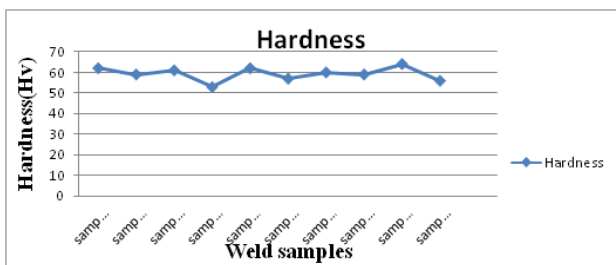


Figure 6: Hardness of weld sample.

The process parameters were summarized in table 4.

Table 4: Summarized values of process parameters

Weld sample	Tool rotational speed (rpm)	Tool transverse speed	Tensile Strength (N/mm <sup>2</sup> )	Percentage elongation	Hardness (HV)
1	1500	80	142.68	7.18	62
2	1500	160	172.41	12.5	59
3	1200	160	178.35	12.18	61
4	900	160	59.45	6.25	53
5	900	80	130.80	16.25	62

6	1200	120	178.36	10.94	57
7	1200	80	148.63	12.5	60
8	1800	80	178.35	13.44	59
9	1500	120	166.47	8.75	64
10	900	120	160.52	11.25	56

**TOPSIS**

The following steps explain the procedure followed as follows.

**STEP 1:** Normalization of the values by using the equation1, table 5 shows the values square summation square root and table 6 shows normalized decision matrix.

**Equation 1**

$$n_{ij} = a_{ij} / \sqrt{\sum_{i=1}^m a_{ij}^2}$$

where i=1,2,3...10 and j= 1,2and 3. (i= No of sample, j= values obtained in each mechanical test, a<sub>ij</sub>= i<sup>th</sup> value of j<sup>th</sup> experimental run.)

Table 5: values of squared summation and square root

weld sample	Tensile strength (N/mm <sup>2</sup> )	Percentage elongation	Hardness (HV)
1	142.68	7.18	62
2	172.41	12.5	59
3	178.35	12.18	61
4	59.45	6.25	53
5	130.8	16.25	62
6	178.36	10.94	57
7	148.63	12.5	60
8	178.35	13.44	59
9	166.47	8.75	64
10	160.52	11.25	56
sum of square	241725.3	1318.972	35261
square root	491.6556	36.31765	187.7791

Table 6: Normalized decision matrix

Tensile strength (N/mm <sup>2</sup> )	Percentage elongation	Hardness (HV)
0.290203	0.1977	0.330175
0.350672	0.344185	0.314199



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0.362754	0.335374	0.32485
0.120918	0.172093	0.282246
0.26604	0.447441	0.330175
0.362774	0.301231	0.919355
0.302305	0.344185	0.967742
0.362754	0.370068	0.314199
0.338591	0.24093	0.340826
0.326489	0.309767	0.298223

**STEP 2:** Weight normalized decision matrix was made using equation 2 as shown in table 7 and the weights are assigned to each value so that their sum is 1...Hence the value of the assigned weight is 0.333.

**Equation 2**

$$r_{ij} = w_j \cdot n_{ij}$$

**Table 7: Weight normalized decision matrix**

Tensile strength (N/mm <sup>2</sup> )	Percentage elongation	Hardness (HV)
0.087061	0.05931	0.099053
0.105202	0.103256	0.09426
0.108826	0.100612	0.097455
0.036275	0.051628	0.084674
0.079812	0.134232	0.099053
0.108832	0.090369	0.275806
0.090692	0.103256	0.290323
0.108826	0.11102	0.09426
0.101577	0.072279	0.102248
0.097947	0.09293	0.089467

**STEP 3:** Ideal best (K<sup>+</sup>) and the ideal worst (K<sup>-</sup>) values were determined using equation 3 as shown in table 8.

**Equation 3**

$$K^+ = \{ \text{Max}(r_{ij}) \mid j \in J \mid i=1, 2, 3, \dots, 9 \}$$

**Equation 4**

$$K^- = \{ \text{min}(r_{ij}) \mid j \in J \mid i=1, 2, 3, \dots, 9 \} \quad J = \text{Beneficial attributes}$$

**Table 8: Ideal best and Ideal worst values**

solution	Tensile strength (N/mm <sup>2</sup> )	Percentage elongation	Hardness (HV)
Ideal best (K <sub>j</sub> <sup>+</sup> )	0.108832	0.134232	0.290323
Ideal worst (K <sub>j</sub> <sup>-</sup> )	0.036275	0.051628	0.089467

**STEP 4:** Euclidian distance was calculated from ideal best and ideal worst solution using the equation 5, 6, as shown in table 9

**Equation 5**

$$S^+ = \sqrt{\sum_{i=1}^{10} (r_{ij} - R_j^+)^2}$$

**Equation 6**

$$S^- = \sqrt{\sum_{i=1}^{10} (r_{ij} - R_j^-)^2}$$

where, i= 1,2,3...10 and j= 1,2,3

**Table 9: values of Euclidian distance**

weld sample	S <sup>+</sup>	S <sup>-</sup>
1	0.206571	0.05225
2	0.198528	0.086251
3	0.195776	0.087903
4	0.233194	0.929078
5	0.193459	0.093866
6	0.046202	0.203686
7	0.035897	0.214405
8	0.197433	0.093883
9	0.198149	0.069672
10	0.205347	0.074224

**STEP 5:** Performance score is calculated using equation 7 and ranking is done, as shown in table 10

**Equation 7**

$$X_i = s^- / (s^- - s^+)$$

**Table 10: Values of performance score and ranking**

Weld sample	Performance score	Rank
1	0.201878	10
2	0.30287	7
3	0.309867	6
4	0.799364	3
5	0.326689	4
6	0.815107	2
7	0.856584	1
8	0.322274	5

9	0.260144	9
10	0.265493	8

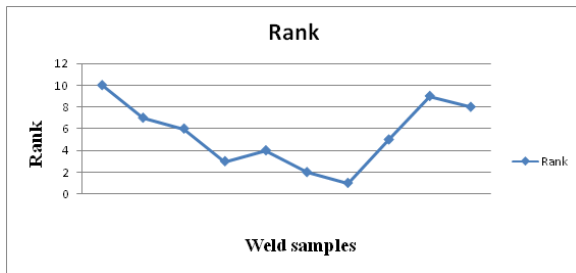


Figure 7: Ranking of weld sample .

### III. CONCLUSION

The experimental study concluded that the weld sample 7 with a tool rotational speed of 1200rpm ,transverse speed of 80 mm/min, tensile strength of 148.63 (N/mm<sup>2</sup>) , percentage elongation of 12.5 , and hardness of 60 Hv had optimum values of process parameters and mechanical properties.

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