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OPTIMIZATION OF FRICTION STIR WELDING PROCESS PARAMETER OF TWO DIFFERENT GRADE MATERIAL

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Friction stir welding can be controlled by different parameters these parameters are optimized for welding of two different grade material that is aluminum alloy 6082 and aluminum alloy 5083. Friction stir welding (FSW) was selected for the joining of lap and butt welded parts having 100 x 50 x 5mm thick sheets each. They were tested for mechanical properties such as tensile strength and Charpy Test respectively. In this experiment using the selected control parameters are Rotational speed, Welding speed, and Tool Tilt Angle. The three control parameters each are three levels has been designing the experiment based on full factorial method. These results show that Charpy impact test and tensile stress increased with increase the parameter level. The optimum process parameters for the maximum tensile strength and Charpy impact joints were predicted by Grey Relation analysis.

Introduction

The friction stir welding (FSW) process offers the possibility of joining the metallic materials which are difficult to impossible to join by conventional welding techniques. Most of these materials are lightweight metals and their alloys, such as aluminum, which has good corrosion resistance, stiffness to mass ratio (ratio of elasticity modulus and density) and strength to weight ratio. Bearing in mind the increase of usage in civil engineering and transport industry, including shipbuilding and airplane industry, aluminum alloys and their joining procedures are gaining more and more attention. Friction stir welding process uses a non-consumable rotating tool consisting of a pin extending below a shoulder that is forced into the adjacent mating edges of the workpieces. The heat input, the forging action and the stirring action of the tool induces a plastic flow in the material, forming a solid state weld [1]. To ensure a successful and efficient welding cycle the tool speed and tool geometry must be chosen with care, as both of these parameters are considered important.[6] Friction Stir Welding (FSW) is a hot – shear joining process in which a non-consumable rotating tool plunges into the rigidly clamped workpiece and moves along the joint to be welded [1]. If the weld is carried out too quickly, however, defects will be present in the weld. When a defect is found in an industrial weld, the part is rejected, causing unwarranted downtime. The process is depicted schematically in fig 1.

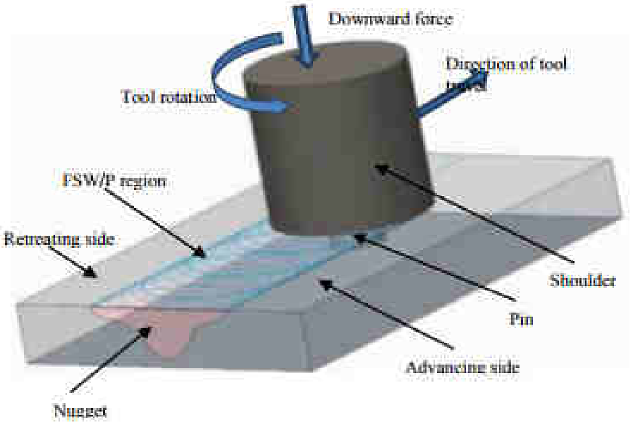

Fig 1 Schematic Drawing of friction stir welding [5]

Gap analysis and objective

This gap has been attributed to a retained or residual oxide defect, caused by the incomplete breakup of the oxide layer during welding, but the exact cause is not known and needed to be determined. Through literature review determined the processing parameters that most influenced the formation of the welds. The main objective of the present study on "Experimental investigations and analysis of Friction Stir Welding of aluminum alloys" is to predict the tensile strength of friction stir welded 6082 and 5083 aluminum alloy incorporating. The developed mathematical model can be effectively used to optimize the friction stir welding process parameters which produce mechanically lower defect free welds. The butt-welded samples, in particular, were included for comparison purposes with the Self Reacting samples. With this information, we should be able to provide input parameter to help reduce the likelihood of failures caused by this phenomenon and predict strong weld in terms of strength and toughness. The objectives which are going to perform in this thesis are:

1. Select the parameters for stir welding to join aluminum alloy of different grade.
2. Design the experiment according to the parameters and their level selected.
3. Perform friction stir weld on two different grade aluminum alloys as per the generation of the design of the experiment.
4. Measure the strength and roughness via tensile test and Charpy test of the weld joint.
5. Apply multi-objective technique to optimize the welding parameters.

Method and Material

The friction stir welded (FSW) Aluminium alloy 6082 is welded with high strength aluminum alloy 5083 welded plate. The flat plates of 10 mm thickness, Aluminium alloy 6082 and 5083 have been cut to the required size (100mm×50mm) by power hacksaw cutting and milling. The initial joint configuration is obtained by securing the plates in position using mechanical clamps. The direction of welding is normal to the rolling direction. Single pass welding procedure has been used to fabricate the joints. An indigenously designed and developed machine used FSW 3T-300-NC (3000 rpm; 25 KN) has been used to fabricate the joints. The above-mentioned geometry of tool pin profile and process parameters have been used to fabricate the joints. The rotational speed best performance level is 400 to 500 rpm, welding speed is in between 40-50 mm/min and the shoulder diameter is perform in 18-

20 mm. So the final parameters are shown in table 1.

Table 1 Process parameter

Factor	Level 1	Level 2	Level 3
Rotational Speed RPM (RS)	1100	1300	1500
Welding Speed mm/min (WS)	35	40	45
Tool Tilt Angle (TTA) Degree	1	1.5	2

The present experimental investigation deals with the analysis of the experiment by the Full Factorial methodology. A process designed with this goal will produce more consistent output is shown in table 2.

Table 2 Full Factorial design of the experiments.

S. No.	RS	WS	TTA
1	1100	35	1
2	1100	35	1.5
3	1100	35	2
4	1100	40	1
5	1100	40	1.5
6	1100	40	2
7	1100	45	1
8	1100	45	1.5
9	1100	45	2
10	1300	35	1
11	1300	35	1.5
12	1300	35	2
13	1300	40	1
14	1300	40	1.5
15	1300	40	2
16	1300	45	1
17	1300	45	1.5
18	1300	45	2
19	1500	35	1
20	1500	35	1.5
21	1500	35	2
22	1500	40	1
23	1500	40	1.5
24	1500	40	2
25	1500	45	1
26	1500	45	1.5
27	1500	45	2

Experiment and Analysis: In this experiment 10 mm sheet of aluminum alloy 6082 & aluminum alloy 5083 is used to join by Friction Stir Welding. For doing this H13 is used as material for welding with 20mm shoulder diameter, 6mm pin diameter & 4.7 mm pin length. Initially, the pieces are cut at power hacksaw and made in proper size with dimension as 100 x 50mm by using a Milling machine. After giving feed to the rotating tool along the centreline, the welding was completed as shown in fig 1. The tensile test was performed on the 27 samples suggested by the full factorial method. Charpy impact test was performed on izod Charpy test machine tensile and Charpy specimen are prepared as per ASTM standard E8 and E23 respectively.

Fig 5.1 FSW Process

Twenty Seven tensile and charpy test specimens were fabricated as per the American Society for Testing of Materials (ASTM E8) and ASTM E23 standards to evaluate the tensile strength of the joints. The tensile strength of the FSW joints was evaluated by conducting a test on the universal testing machine and Charpy test results are presented in Table 2.

Table 2 Response Table

S. No.	RS	WS	TTA	Tensile test (T) N/mm^2	Charpy Test (I) MPa
1	1100	35	1	134	55
2	1100	35	1.5	139	56
3	1100	35	2	127	57.5
4	1100	40	1	123	58
5	1100	40	1.5	123	59.5
6	1100	40	2	151	58.5
7	1100	45	1	114	54.25
8	1100	45	1.5	141	54.75
9	1100	45	2	144	56
10	1300	35	1	113	56.75
11	1300	35	1.5	118	58.5
12	1300	35	2	119	59.5
13	1300	40	1	139	53.5
14	1300	40	1.5	152	54.5
15	1300	40	2	147	57.5
16	1300	45	1	124	56.5
17	1300	45	1.5	136	58.75
18	1300	45	2	128	59.5

19	1500	35	1	129	55
20	1500	35	1.5	140	54.5
21	1500	35	2	148	58
22	1500	40	1	131	58.5
23	1500	40	1.5	140	57
24	1500	40	2	158	56.75
25	1500	45	1	131	55.25
26	1500	45	1.5	152	54.25
27	1500	45	2	134	58.25

Optimization

The grey means the primitive data with poor, incomplete, and uncertain information in the grey systematic theory; the incomplete relation of information among these data is called the grey relation. First, the grey relation analysis was carried out to normalize the responses; surface roughness and chemical wear were normalized by given equation (1).

For higher-the-better criterion, the normalized data can be expressed as

$$X_i = \frac{(y)_i - min(y)_i}{\max(y)_i - \min(y)_i} \qquad \ldots..(1)$$

$$where\ i = 1,2 \ldots..n$$

The calculation of the grey relational coefficient and the weight of each quality characteristic is determined by equation (2):

$$G_i = \frac{L_{min} + \varepsilon L_{max}}{L_i(k) + \varepsilon L_{max}} \qquad \ldots\ldots..(2)$$

Where L_{min} is the global minimum, L_{max} is the global maximum and ε is distinguish coefficient which is taken in between 0 to 1 in this case 0.5 weight is taken.

Grey relation grade can be calculated by equation (3)

$$GRG = \frac{1}{n}\sum_{j=1}^{n} G_i(j) \qquad \ldots\ldots\ldots\ldots\ldots\ldots(3)$$

Where n is the number of process responses. The lower value of the grey relational grade represents the reference sequence GRG. As mentioned before, the reference sequence GRG is the best process response in the experimental layout. The lower value of the grey relational grade means that the corresponding cutting parameter is closer to optimal. The grey analysis result of GRG is shown in table 2, table 3 and mean effect plot is shown in fig 3.

Table 3 Grey Relation Grade

S. No.	RS	WS	TTA	GRG
1	1100	35	1	0.441935
2	1100	35	1.5	0.501854
3	1100	35	2	0.51028
4	1100	40	1	0.528986
5	1100	40	1.5	0.695652
6	1100	40	2	0.756356
7	1100	45	1	0.350991
8	1100	45	1.5	0.478359
9	1100	45	2	0.538988
10	1300	35	1	0.427536
11	1300	35	1.5	0.555

12	1300	35	2	0.682927
13	1300	40	1	0.437751
14	1300	40	1.5	0.582237
15	1300	40	2	0.635821
16	1300	45	1	0.449115
17	1300	45	1.5	0.652809
18	1300	45	2	0.714286
19	1500	35	1	0.418447
20	1500	35	1.5	0.465278
21	1500	35	2	0.679487
22	1500	40	1	0.602273
23	1500	40	1.5	0.550505
24	**1500**	**40**	**2**	**0.76087**
25	1500	45	1	0.434169
26	1500	45	1.5	0.576555
27	1500	45	2	0.594877

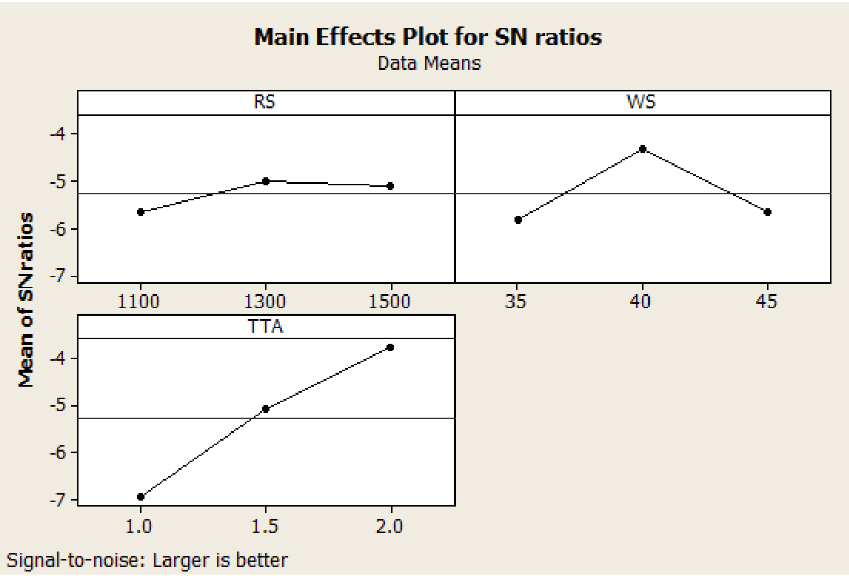

Fig 3 Mean Effect Plot of GRG

Conclusion

Aluminum alloy AA6082 and AA 5083 will be welding by friction stir weld employing different process parameters as obtain full factorial design. Their influence on mechanical properties of developed joints will investigate in terms of tensile strength and impact test. Tensile strength and impact test will create multiple objective problems it can be solved by Grey relation method and best process parameter come out for stir welding.

- Welding joint of two different grades has to be made successfully.
- The tensile strength of the joints large extent depends on the rotational speed. As rotational speed increased, the heat input per unit length of the joint increased resulted in inferior tensile properties due to rise in temperature.
- By Grey Relation method the optimal setting is obtained under the level and the factor considered is rotational speed

1500rpm, welding speed is 40mm/min and tool tilt angle is 2.

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