IARJSET

ISSN (Online) 2393-8021
ISSN (Print) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

Vol. 8, Issue 5, May 2021

DOI: 10.17148/IARJSET.2021.85118

EXPERIMENTAL INVESTIGATION ON IMPROVING WELD STRENGTH OF DISSIMILAR MATERIALS AND OPTIMIZING THE PROCESS PARAMETERS

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Abstract: Friction stir welding, a solid state joining technique, is widely being used for joining Aluminium alloys for aerospace, marine automotive and many other applications of commercial importance. The recent trend is to join dissimilar materials to take advantage of low cost material in places where high strength high cost material is not needed. In this work, joining of dissimilar aluminium alloys (AA5052 & AA7075) in friction stir welding process (FSW) technique. The process parameters were optimized using Taguchi L_9 orthogonal design of experiments. The parameters considered were tool rotational speed, tool translational speed and plunge depth. The optimum process parameters were decided with reference to tensile strength of the joint. The expected optimal value of tensile strength is confirmed with the confirmation run using optimum parameters. This study shows that disorder free, excessive performing welded joints may be produced with the optimum process parameters. Based at the experimental data, empirical relations representing the parameters correspond to every output characteristic have been developed using simple regression method.

I. INTRODUCTION

Welding is a fabrication or sculptural process that joins material usually metals or thermoplastics by causing coalescence. This is often done by melting the workpieces and adding a filler material to form a pool of molten material that cools to become a strong joint. Many different energy sources can be used for welding, including a gas flame, an electric arc, friction stir welding, a laser, an electron beam, friction and ultrasound. Friction stir welding process, is considered to be the significant development over the past two decades, which was invented and validated at the welding institute, United Kingdom in the year 1991. Many researches continue to develop new FSW methods for gaining greater understanding of weld quality properties.

II. MATERIALS

Many specific properties of aluminium alloys including light weight, good structural strength, and superior corrosion resistance enable them to be applied for structural parts. The weldability of aluminium alloys varies significantly depending on the chemical composition of the alloy used.

2.1 5052- ALUMINIUM ALLOY

5052 aluminium is popular because it is one of the most versatile aluminium alloys. Among 5052 aluminium's benefits are good weldability, very good resistance to corrosion, and high fatigue strength. it shows up in marine environments because of its resistance to corrosion, in architecture exposed to high vibration because of its high fatigue strength, and in pressure vessels and containers because of its good weldability. Aluminium 5052 also happens to be the strongest non-heat-treatable sheet and plate in common use. 5052 isn't just easily welded and highly corrosion-resistant, it is also tough and strong. It has good drawing properties and a high rate of work hardening. Its overall versatility, not to mention excellent value, makes it one of the most serviceable alloys available.

2.2 7075- ALUMINIUM ALLOY

7075 aluminium alloy (AA7075) is an aluminium alloy, with zinc as the primary alloying element. It has excellent mechanical properties and exhibits good ductility, high strength, toughness, and good resistance to fatigue. It is more susceptible to embrittlement than many other aluminium alloys because of micro segregation, but has significantly better corrosion resistance than the alloys from the 2000 series. It is one of the most commonly used aluminium alloys for

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highly stressed structural applications and has been extensively used in aircraft structural parts. 7075 aluminium alloy's composition roughly includes 5.6–6.1% zinc, 2.1–2.5% magnesium, 1.2–1.6% copper, and less than a half percent of silicon, iron, manganese, titanium, chromium, and other metals.

Table 1 Physical Properties of AA5052 and AA7075

SI.NO	PROPERTIES	VALUE	
		AA5052	AA7075
1	Density	2.68 g/cm^3	2.81 g/cm^3
2	Melting Point	607°C	477°C
3	Electrical Resistivity	0.049 Ω.cm	5150 Ω.cm
4	Thermal Conductivity	138 W/m.K	130 - 150 W/m.K
5	Modulus of Elasticity	70.3 GPa	71.7 GPa

Table 2 Mechanical Properties of AA5052 and AA7075

SI.NO	PROPERTY	VALUE	
		AA5052	AA7075
1	Hardness (Brinell)	60	87
2	Ultimate tensile strength	228 MPa	572 MPa
3	Tensile yield strength	193 MPa	503 MPa
4	Elongation	12 %	11 %
5	Shear strength	138 MPa	331 MPa
6	Fatigue strength	117 MPa	159 MPa

III.METHODOLOGY

3.1 FABRICATION OF THE COMPOSITE MATERIAL

The experiments were conducted on a vertical milling machine where a tool is mounted in an arbor with a suitable collate. The vertical tool head can be moved along the vertical guide way (Z-axis), the horizontal bed can be moved along X and Y axis. The aluminium alloys (AA5052 and AA7075) has chosen for the study were 6mm thick plate of commercially available aluminium alloy. The weld faces of the test plates are machined and clamped in horizontal bed with zero root gaps aligned with the centre line of the FSW tool with the help of a specially designed fixture and back plate needs to be tightly clamped to one another.

The Aluminium alloy plates (AA5052 and AA7075) have been cut into the required size (100×75×6mm) by power hacksaw cutting, butt joint was configured. Before welding the plates, side and edge preparation done to fabricate FSW joints.

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The non-consumable tools made of high carbon steel have been used to fabricate the joints. The tool dimensions are shown in Figure 1 One pin profiles and shoulder profile, has been used to fabricate the joints.

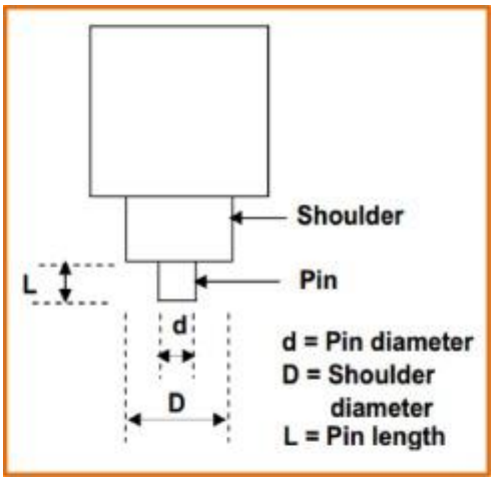

Fig 1 FSW Tool

D = 18mm — D = Shoulder diameter

d = 6mm — d = pin diameter

L = 5.5mm — L = Pin length

Table 3 Welding Parameters and Levels

Parameters	Level1	Level2	Level3
Spindle speed	900	1350	1800
Welding speed	65	100	135
Plunge depth	0.10	0.15	0.20

The plates used in the present study were AA5052 and AA7075 having thickness 6mm are joined. Nine joints has been produced according to L9 orthogonal array experiment.

Fig 2 Experimental Setup

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Fig 3 Welded Specimen

IV. RESULTS AND DISCUSSION

4.1 TENSILE TEST

The welded joints were sliced using power hacksaw and then machined to required dimension to prepare tensile specimen. Specimens are taken in the transverse direction of the weld. The specimen is loaded and tensile specimen undergoes deformation. The tensile test of butt joint was conducted by using a universal testing machine of 1000 kN capacity.

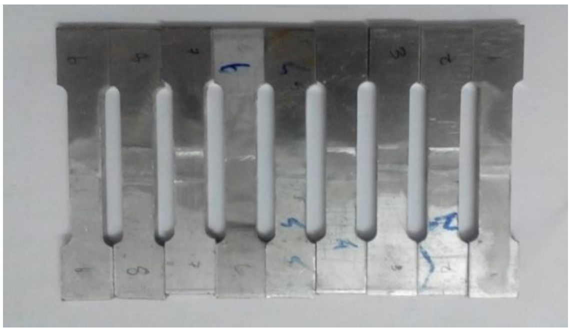

Fig 4 Specimen for before tensile test

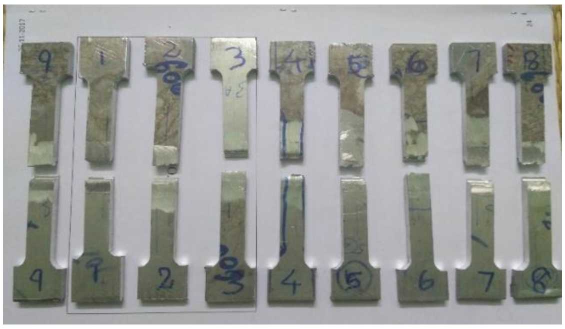

Fig 5 Specimen for after tensile test

4.2 HARDNESS TEST

The welded joints were sliced using power hacksaw and then machined to required dimensions, (20 mm X 20 mm X 6 mm) Specimens are taken in normal direction of the weld. The specimen is loaded and hardness specimen undergoes indentation. The hardness test of butt joint was conducted using a Vicker's hardness testing machine.

Fig 6 Hardness test Specimens

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Table 4 Tensile and Hardness Results

Exp no.	Spindle speed (rpm)	Welding speed (mm/s)	Plunge Depth (mm)	Ultimate Tensile Strength (N/mm^2)	Hardness value at centre of the fusion zone (HV)
1	900	65	0.10	140	94
2	900	100	0.15	126	85
3	900	135	0.20	119	78
4	1350	65	0.15	129	93
5	1350	100	0.20	148	99
6	1350	135	0.10	121	80
7	1800	65	0.20	113	76
8	1800	100	0.10	117	77
9	1800	135	0.15	124	81

4.3 MAIN EFFECT PLOT FOR TENSILE AND HARDNESS

The main effect plot is the graph of the average or means of response at each level of the factor or input parameter. The main effect plot helps one to determine the influence of individual input parameters on the responses measured, by disregarding the effect of any other input parameter present. The main effect plots of each response are explained below.

Table 5 Main Effect on Tensile Strength (S/N Ratio)

Parameter	Level 1	Level 2	Level 3	Delta	Rank
Spindle speed	42.15	42.42	41.43	0.99	1
Welding speed	42.07	42.26	41.68	0.58	2
Plunge Depth	41.98	42.03	41.99	0.05	3

Table 6 Main Effect on Hardness (S/N Ratio)

Parameter	Level 1	Level 2	Level3	Delta	Rank
Spindle speed	38.63	39.11	37.84	1.28	1

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Welding speed	**38.82**	**38.74**	**38.02**	**0.79**	**2**
Plunge Depth	**38.42**	**38.71**	**38.46**	**0.29**	**3**

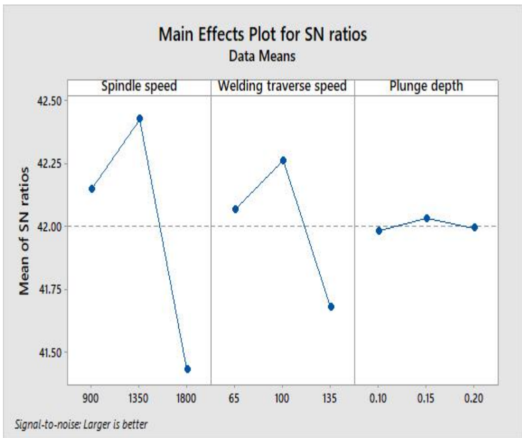

Fig 7 Main Effect Plot for Tensile (S/N Ratio)

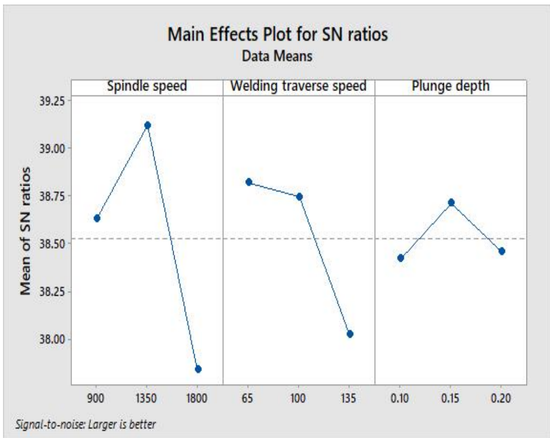

Fig 8 Main Effect Plot for Hardness (S/N Ratio)

4.4 RESPONSE TABLE FOR OUTPUTS OF TENSILE AND HARDNESS

Response table can also indicate which process parameters has greater influence on the responses measured by giving the process parameter a rank. Also one can infer the optimal condition from the response table of tensile strength.

Table 7 Main Effect on Tensile Strength (means)

Parameter	Level 1	Level 2	Level3	Delta	Rank
Spindle speed	**128.3**	**132.7**	**118.0**	**14.7**	**1**
Welding speed	**127.3**	**130.3**	**121.3**	**9.0**	**2**
Plunge Depth	**126.0**	**126.3**	**126.7**	**0.7**	**3**

Table 8 Main Effect on Hardness (means)

Parameter	Level 1	Level 2	Level3	Delta	Rank
Spindle speed	**85.67**	**90.67**	**78.00**	**12.67**	**1**
Welding speed	**87.67**	**87.00**	**79.67**	**8.00**	**2**
Plunge Depth	**83.67**	**86.33**	**84.33**	**2.67**	**3**

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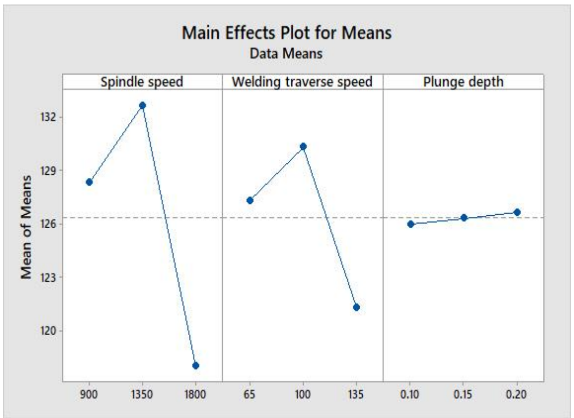

Fig 9 Main Effect Plot for Tensile (Means)

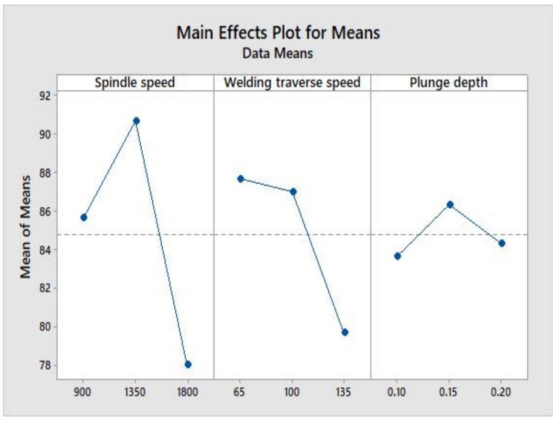

Fig 10 Main Effect Plot for Hardness (Means)

V. CONCLUSION

Tensile strength and hardness of friction stir welded dissimilar aluminium alloy have been evaluated under different conditions using Taguchi experimental design.

- Spindle Speed has found to be the most dominant parameter which affects tensile strength and hardness. The other parameters which influence the tensile strength and hardness in order of ranking are welding speed, Plunge Depth.
- The Spindle Speed (S = 42.15 %) is the most influencing factor in determining the tensile strength of the sample followed by Welding traverse speed (W = 42.07 %) and Plunge Depth (P = 42.03 %).
- The Spindle Speed (S = 39.11 %) is the most influencing factor in determining the hardness of the sample followed by Welding traverse speed (W = 38.02 %) and Spindle speed (P = 38.42 %).
- Optimum condition for high tensile strength and hardness are found to be Spindle speed= 1350 rpm, Welding traverse speed =100 mm/min, Plunge Depth= 0.20mm by Taguchi analysis.

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