IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 14, Issue 3 Ver. V. (May - June 2017), PP 64-67
www.iosrjournals.org

Parameter Prediction of Friction Stir Welding Aluminium Alloy by Anova Technique

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Abstract: *Friction stir welding can be controlled by different parameters like rotational speed, feed rate and welding medium. In this research, friction stir welding of marine grade Aluminium alloy 5083 is investigated and is welded with high strength Aluminium alloy 2024 T3. Friction stir welding (FSW) was selected for the joining of lap and butt welded parts having 150 x 50 x 5mm thick sheets each. The present work shows that composite materials have highest effect on mechanical properties of the specimens taken from welded zone. They were tested for mechanical properties such as tensile strength and Rockwell hardness respectively. The parameter for Charpy impact test and tensile stress predict the significant by ANOVA analysis.*
Keywords*: Friction Stir welding (FSW), Aluminium alloy, Tensile Strength, Rockwell Hardness.*

I. Introduction

Butt welding Aluminium alloys has received much of the focus. Butt welding materials of different thickness as well as tapered sections can also be performed. FSW can be used in some applications to reduce weight by replacing fasteners and reducing part count, which can actually reduce costs. It is necessary first to discuss the convention used for referring to locations within friction stir welds. Since friction stir welds are asymmetrical, it is necessary to accurately convey which side is intended when referring to specific locations within a weld with respect to the tool rotation and feed directions. The following convention will be used in the discussions to follow. The opposite side, where the motion of the surface of the welding tool opposes the feed direction, is referred to as the retreating side. A terminology convention that is also used refers to the advancing and retreating sides as the shear side and the flow side, but since this convention makes assumptions about the material flow, the more generic terminology will be used here.

There are two tool speeds to be considered in friction-stir welding; how fast the tool rotates and how quickly it traverses the interface. These two parameters have considerable importance and must be chosen with care to ensure a successful and efficient welding cycle. The relationship between the welding speeds and the heat input during welding is complex but, in general, it can be said that increasing the rotation speed or decreasing the traverse speed will result in a hotter weld. In order to produce a successful weld it is necessary that the material surrounding the tool is hot enough to enable the extensive plastic flow required and minimize the forces acting on the tool.

II. Review Work

Kumbhar and Bhanumurthy (2012) carried out experiment in FSW to join Aluminium alloys AA6061 and AA5052 at various combinations of tool rotation speeds and tool transverse speed. It was seen that the interdiffusion of the alloying elements and development of similar orientations in the nugget could have contributed of the better tensile properties of the friction stir welded AA5052-AA6061 specimen.[1]

Studies were performed by **Litwinski** to examine the effect of travel speed on the tensile properties of FSW samples. Samples were naturally and artificially aged for various times from one hour to over two and a half years. The longest natural aging at 2.5 years resulted in higher strength and elongation than the natural aging for shorter times. Increasing travel speed was also found to increase ultimate and yield strengths in all types of aging. [2]

Lee et al. Aluminium alloy 356 samples were friction stir welded at 1600 rpm rotational speed, a feed rate ranging between 87 to 342 mm/min and an angle of 3^0 with respect to the welded plate. It was also noted that all the specimens were fractured at the unaffected base material rather than the welded material [3].

Masayuki Aonuma and Kazuhiro Nakata (2012) joined ZK60 magnesium alloy and titanium by friction stir welding. In this study the effect of alloying elements on the microstructure of the joint was examined. It was found that Zn and Zr of alloying elements of Mg-ZnZr alloy improved the tensile strength of titanium and magnesium joints by forming the thin reaction layer at the joint interface.[4]

McQueen et al. investigated the effect of friction stir welding on Aluminium alloy 6065 in terms of mechanical properties and microstructure. The only unsatisfying result in McQueen et al.'s study is that the ductility decreased to below 50% of the unprocessed alloy.[5]

III. Objective Of Work

Many of the problems associated with cooling from the liquid phase are avoided with friction stir welding because it is a solid state process. While this welding process typically produces welds which are as strong and ductile as the parent material, certain welding parameters have been found to produce a sharp decrease in strength and ductility in the welds. This problem has been attributed to a retained or residual oxide defect, caused by incomplete breakup of the oxide layer during welding, but the exact cause are not known and needed to be determined.

IV. Methodology

Although research has previously been conducted on the FSW behaviour of aluminium alloys, very little work has been done on inhomogeneous welds. The sample preparation procedure followed in this study is also presented including polishing and etching. Aluminium Alloy 5083 and 2024 T3 will be taken with typical composition shown in Table 1. In an effort to reduce weight, AA 5083 was developed to replace much of the AA 2024 T3 in use on the space shuttle.

Table 1: Component of Aluminium Alloy

Component	AA 5083 %	AA 2024 T3 %
Magnesium (Mg)	4.00 - 4.90	1.2-1.8
Manganese (Mn)	0.40 - 1.00	0.3-0.9
Iron (Fe)	0.40	0.1-0.5
Silicon (Si)	0.0 - 0.40	0.1-0.5
Titanium (Ti)	0.05 - 0.25	0.0-0.15
Chromium (Cr)	0.05 - 0.25	0.0-0.1
Copper (Cu)	0.10	3.8-4.9
Zinc (Zn)	0.0 - 0.10	0.1-0.3
Other (Each)	0.0 - 0.05	0.1-0.15
Aluminium (Al)	92.2-94.6	90.7-94.7
Zirconium (Zr)	---------	0 to 0.2

V. Process Work

Design of experiment (DOE) is important as a formal way of maximizing information gained while minimizing resources required. It has more to offer than 'one change at a time' experimental methods, because it allows a judgment on the significance to the output of input variables acting alone, as well input variables acting in combination with one another. The specimens used in this work are made of marine grade Aluminium alloy 5083 and 2024 T3 specifications and compositions are discussed in Table 1. The samples used are 150 mm in length, 50 mm in width and 5 mm thick. The specimens used are cut from 5 mm sheets; holes are drilled on the sides of the specimen to allow clamping it in the specially designed tank for submerged friction stir processing.Perform friction stir weld on two dissimilar Aluminium Alloy as per the generation of design of experiment (DOE). Measure the Tensile Test and Charpy Test of weld joint and predict the parameter by ANOVA test. Tensile strength of the FSW joints were evaluated by conducting test on Universal Testing Machine and Charpy Test results is presented in Table2.

Table 2: Response Table

S No.	RS	WS	SD	(T) N/mm^2	(I) MPa
1	400	40	18	179	53
2	400	45	19	184	58
3	400	50	20	186	59
4	450	40	19	178	63
5	450	45	20	182	58
6	450	50	18	186	67
7	500	40	20	193	62
8	500	45	18	197	59
9	500	50	19	189	64

Anova result for tensile test are shown in table 3 and their result of efficient parameter are shown in fig 1

Table 3: ANOVA result of Tensile Test

S	DF	Seq SS	Adj SS	Adj MS	F	P
RS	2	222.00	222.00	111.00	6.80	0.128
WS	2	32.67	32.67	16.33	1.00	0.500
SD	2	24.67	24.67	12.33	0.76	0.570
RE	2	32.67	32.67	16.33		
Total	8	312.00				

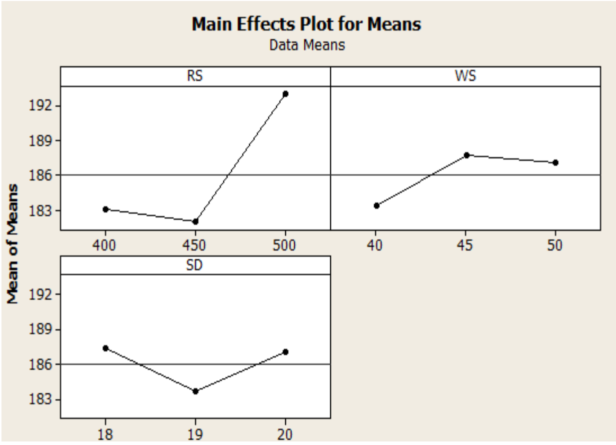

Fig 1 Mean Effect plot of Tensile Test

ANOVA result for Tensile Test are shown in table 4 and their result of efficient parameter are shown in fig 2

Table 4 ANOVA result of Impact Test

S	DF	Seq SS	Adj SS	Adj MS	F	P
RS	2	62.000	62.00	31.000	2.58	0.279
WS	2	42.000	42.00	21.000	1.75	0.364
SD	2	8.000	8.000	4.000	0.33	0.750
RE	2	24.000	24.00	12.000		
Total	8	136.000				

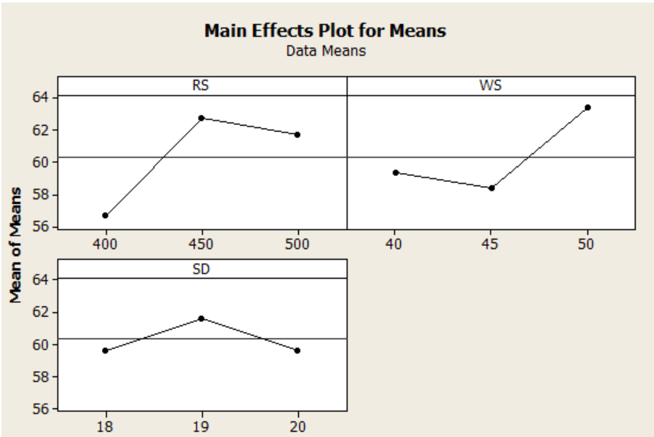

Fig 2 Mean Effect plot of Impact Test

As seen in the fig 1 the optimum parameter for tensile stress are rotational speed is 500rpm, welding speed is 45 mm/min and shoulder diameter is 18mm. For impact test their optimum parameter is different that is rotational speed is 450rpm, welding speed is 50 mm/min and shoulder diameter is 19mm. in both case seen that all parameter are different for its individual outputso for prediction rotational speed, welding speed and shoulder diameter select the lowest P value from the table 3 and table 4. The lowest P value for rotational speed as comparing in both tableis 0.128 for tensile stress so 500rpm is predicted for rotational speed. Similarly welding speed is predicted 50mm/min and for shoulder diameter are 18. ANOVA prediction results for its individual parameter are shown in Table 5.

Table 5 Individual Parameter

Strength	RS	WS	SD
Tensile	500	45	18
Hardness	450	50	19

VI. Conclusion

Perform friction stir weld on two dissimilar Aluminium Alloy as per the generation of design of experiment. Measure the tensile test and charpy test of weld joint as per DOE. Finally predict the parameter for optimum welding. Future work can be proceed on these work to optimize the factor and their level by some advance optimizing technique.

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