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Optimization of Heating Process Parameters of Friction Stir Welding Joint on Aluminium Alloy Aa2024

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Research Article

Abstract

In this research, frictions stir welding of aluminum alloy AA2024 and welding with its similar plate having a cross section of 100 x 50 x 5 mm. The work piece is heating with variation of temperature with its variation of holding time and cooled it in water. Heat treated work-piece is welded by friction stir welding process with variation of tool rotation speed and other parameters are constant for all experiment. For experiment design using the selected control parameters are Temperature, holding time and tool rotation speed and the three control parameters each are three levels has been designing the experiment based on L9 Orthogonal Array (OA). After welding, specimen is tested for mechanical properties such as tensile strength and Charpy Test respectively. The 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 are optimized.

Keywords: - Friction Stir welding (FSW), Aluminum alloy 2024, Tensile Strength, Charpy test.

1. Introduction

In frictions stir welding (FSW) process heat generated by friction between the surface of the plates and the contact surface of a special tool, composed of two main parts that is shoulder and pin. Shoulder is responsible for the generation of heat and for containing the plasticized material in the weld zone, while pin mixes the material of the components to be welded, thus creating a joint. This allows for producing defect-free welds characterized by good mechanical and corrosion properties [1].

The advantages of FSW are due to the fact that the process is carried out with the material to be welded in the solid state. Avoiding melting prevents the production of defects, due, for instance, to the presence of oxygen in the melting bath, and limits the negative effects of material metallurgical transformations and changes strictly connected with changes of phase. Finally, the reduced thermal flux, with respect to traditional fusion welding operations, results in a reduction in residual stress state in the joints and, consequently, in distortions in the final products.

A high thermal and electrical conductivity cause problems in fusion and resistance welding of aluminum alloys. Friction stir welding (FSW) is a solid-state welding process and it considered the most significant development in metal joining techniques in the last decades, it was invented by The Welding Institute (TWI) of UK as a solid-state joining technique, and it was initially applied to aluminum alloys [3]. Aluminum is the most prominent candidate to meet the challenges for future automotive regarding high strength/weight ratio, corrosion resistance, emissions, safety, and sustainability. However, the extended application of this welding process in industry still requires accurate knowledge of the joining mechanism, and the metallurgical and mechanical transformations it induces in the base materials. Actually, the effectiveness of the obtained joint is strongly dependent on several operating parameters [4].

1.1 Background Work

Aditya et.al [1] studied frictional heat generated results in thermal softening of the material which is a plastic deformation of the two materials. Chandu et.al [2] studied about the mechanical properties of aluminum welds and its alloy which are obtained by using frictional stir welding technique. Chiteka [3] analyses the tool material used for fsw, The most important factor is the selection of friction stir welding/processing (FSW/P) tool material which is important task which results in the quality of the weld produced at the end. Devaiah et.al [4] investigate about the Fusion welding process of aluminum and its alloys, which tends to degrade its mechanical strength near welding zone due to its high thermal diffusivity and the high melting point. El-Keran et.al [5] work on heat is generated by the friction between the workpiece and the tool. The effect of the welding parameters such as tool rotation speed, welding speed, tool tilt angle and tool design are taken which provides reviews of the FSW of similar and dissimilar aluminum alloys, FSW benefits and its applications. Ghazvinloo and Shadfar [6] investigated heat is created by using friction between a rotating tool and the base material used for weld. Heidarzadeh et.al [7] observed to achieve a defect-free butt joint of dissimilar metals by friction stir welding technique with having various parameters, like tool material, geometry, tool rotational speed, feed rate and tilt angel. Lastly Optimum values of tool rotation speed and feed rate are optimized for the best quality of the butt joint. Kumar et.al [8] presented the benefits in the welding of aluminum and its alloys. Friction Stir Welding (FSW) plays a vital role in joining process in the aerospace, railway and ship building industries especially in the welding of aluminum and its alloys. The process uses non-consumable spinning tool which generate frictional heat in the work piece zone. Prashanthi et.al [9] observed tool head pin which usually rotates at high rpm, travels down the length of contacting metal plates, creating a highly deformation zone through the force and the frictional heating. Reddy et.al [10] investigated the Friction stir welding technique, which is a new solid phase joining process having high energy efficient, versatile and environment friendly in nature. Shrivas et. al [11] found the strength effected by temperature in Friction stir welding (FSW) join by high-speed rotation of FSW tool which develops high temperature on tool. Shrivas et. al [12] presented the work on same grade of aluminium material would be welded by friction stir welding on low speed of rotation by using H13 tool. Minimized rotational speed of FSW tool will give the optimum welding strength under preheated water-cooled work piece. From the result it is clear that increasing the Temperature of work-piece with water cooled medium increases the strength. Shrivas et. al [13] focusing on dissimilar alloys (AA4018 -AA8011) with heat treatment hardening effect revolution is found in aluminum alloys, which helps in producing friction heat so that the mechanical strength of the joint can increase. Singh et. al [14] Reviewed about the work done on friction stir welding process using different varying parameters and optimize.

2. Methodology

In this experiment 5 mm sheet of aluminium alloy AA 2024 plates are used to join by Friction Stir Welding. Initially the sheet are cut to convert for welding pieces by power hacksaw, and made in proper size with dimension as 100 x 50 x 5 mm. The tool for friction stir welding is taken H13 material. The friction stir welding setup is arranged on vertical milling machine as shown in Fig 1. Then the work pieces treated with given process parameters are shown in Table 1, then it is fixed in the fixture on moving table of vertical milling machine for welding.

The rotating tool was then plunged into the work piece till the shoulder touches the surface of work piece.

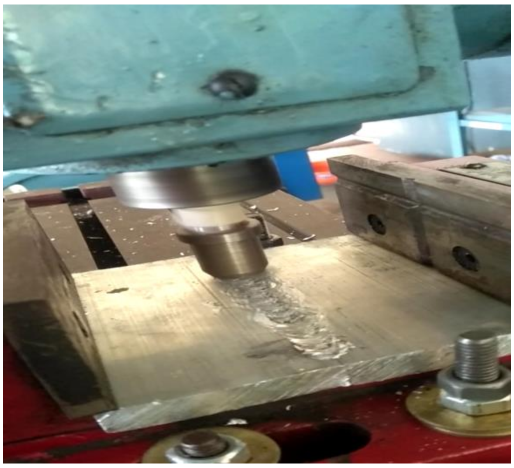

Fig 1 FSW Process

Table 1 Process parameter

Factor	Level 1	Level 2	Level 3
TEMPERATURE (IN °C)	200	250	300
HOLDING TIME (IN MINUTE)	20	30	45
Tool Speed in rpm	600	800	1000

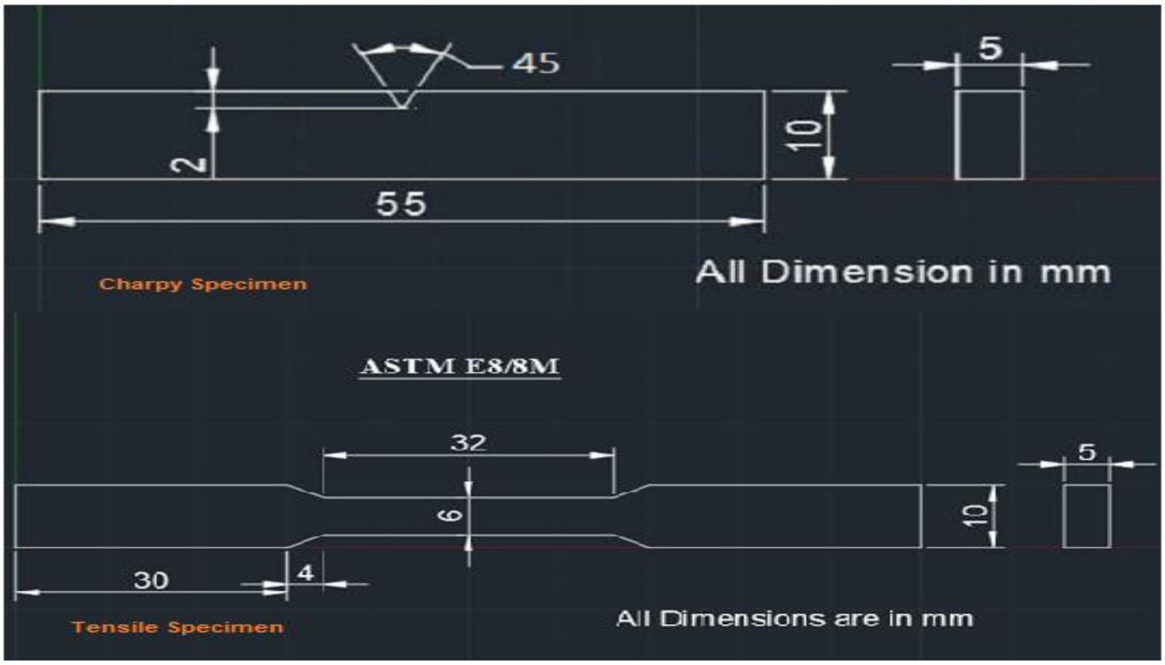

Fig 2 Testing Specimen

Table 2 Responses of Test

Sl. No.	TEMPERATURE (T) (°C)	HOLDING TIME (HT) (MINUTE)	Tool Speed (S) (rpm)	Tensile test (Ts) Mpa	Charpy Test (Ct) Joule
1	200	20	600	177	36
2	200	30	800	188	62
3	200	45	1000	174	37
4	250	20	800	186	38
5	250	30	1000	178	74
6	250	45	600	183	44
7	300	20	1000	173	37
8	300	30	600	208	62
9	300	45	800	193	32

Welding was performed on the 18 samples suggested by L9 orthogonal Array then it is cut as per ASTM standard for tensile test and charpy test as shown in Fig. 2 tested to response for tensile and Charpy impact test with respected machine as shown in Table 2. Nine 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.

2.1 Optimization Technique

Tensile strength and impact strength give variation of parameters for their best strength and it create multi-objective problem which is solve by grey relation analysis. For lower-the-better criterion follow equation 1 and for higher the better criteria follow equation 2, the normalized data can be expressed by equation (1)

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

$$X_i = \frac{(y)_i - min(y)_i}{\max(y)_i - \min(y)_i} \qquad \ldots\ldots(2)$$

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

Then overall grey relational grade is determined by averaging the grey relational coefficient corresponding to selected responses. The overall performance distinctive of the multiple response process depends on the calculated grey relational grade. The calculation of the grey relational coefficient and the weight of each quality characteristic is determined by equation (3):

$$G_i = \frac{L_{min} + \varepsilon L_{max}}{L_i(k) + \varepsilon L_{max}} \qquad \ldots\ldots\ldots(3)$$

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 (4)

$$Grg_i = \frac{1}{n}\sum_{j=1}^{n} G_i(j) \qquad \ldots\ldots\ldots\ldots\ldots\ldots(4)$$

Where n is the number of process responses. The lower value of the grey relational grade represents the reference sequence Grg_i. As mentioned before, the reference sequence Grg_i is the best process response in the experimental layout is taken whose grey relation grade is maximum.

3. Results and discussion

3.1 Optimization Calculation

Grey relation analysis calculation is shown in Table 3 which shows that the higher value of

GRG is seventh experiment which gives the best possible parameter and ANOVA Table 4 again shows the lowered P value is holding time so it is clear that feed is the significant parameter in drilling operation corresponding to the responses taken in this work. The final optimize parameter are temperature is 300^{o}C holding time is 20 min and the tool rotation speed is 1000 rpm has been optimized. As per the Signal to noise ratio graph the best possible parameter of these responses are temperature is 200^{o}C holding time is 20 min and the tool rotation speed is 1000 rpm has been optimize as shown in Fig 3.

Table 3 Grey Analysis

Sl. No.	Xi Ts	Xi Ct	Gi Ts	Gi Ct	GRG
1	0.861111	0.904762	0.782609	0.84	0.811304
2	0.555556	0.285714	0.529412	0.411765	0.470588
3	0.944444	0.880952	0.9	0.807692	0.853846
4	0.611111	0.857143	0.5625	0.777778	0.670139
5	0.833333	0	0.75	0.333333	0.541667
6	0.694444	0.714286	0.62069	0.636364	0.628527
7	**0.972222**	**0.880952**	**0.947368**	**0.807692**	**0.87753**
8	0	0.285714	0.333333	0.411765	0.372549
9	0.416667	1	0.461538	1	0.730769

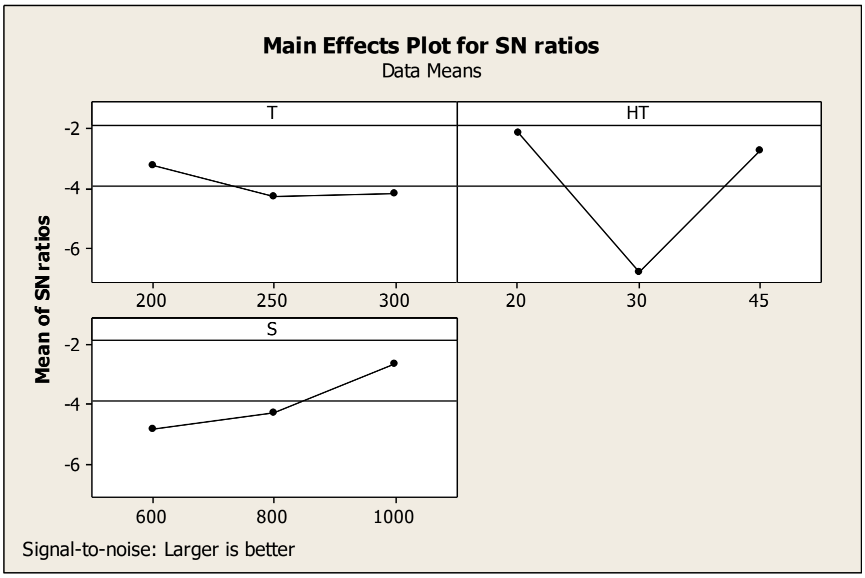

Fig 3 Optimum Parameters

Table 4 Analysis of Variance for Means

Source	DF	Seq SS	Adj SS	Adj MS	F	P
T	2	0.014555	0.014555	0.007278	2.47	0.288
HT	2	0.184046	0.184046	0.092023	31.29	0.031
S	2	0.041883	0.041883	0.020941	7.12	0.123
Residual Error	2	0.005881	0.005881	0.002941		
Total	8	0.246366				

Calculation and optimum graph has given similar value of holding time and tool speed rotation but there is deviation in temperature.

Conclusions

Welding Parameters for two similar grades aluminum plate passing from heat treatment with variation to rotating tool parameter has done successfully. The optimization by Gery relation analysis gives optimum result are work-piece is heated in oven at 300°C for 20 minute holding time. The heated plates are cooled in water. After cooling the plates are welded using friction stir welding machine with 1000 rpm tool rotation speed with 20 mm/min welding speed. While the optimum graph has only variation in temperature it shows that 200°C with all optimize parameters gives optimum result. ANOVA analysis predict that holding time is the significant factor.

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