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Process Parameter Optimization of Friction STIR Welding of Aluminium Alloy 7075

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ABSTRACT

Friction stir welding is among the most important processes in assembly operations for Aerospace Engineering. The success of the process in terms of providing weld joints of good quality, good corrosion resistance, affordable price and high strength depends on the process commission used in the setup. This work aims at optimizing weld parameters of similar joints on Friction welding. The effect of control parameters such Tool spindle speed and weld speed were analyzed on Al 7075 alloy. Experimental design was developed by orthogonal design and the tensile strength and hardness were observed. The results shows that rotational speed contains major impact then the weld speed. The impact and significance were determined from the results for the effective welding process and the quality of weld joints.

***Keywords**:— Friction stir welding, Spindle rotational speed, Speed of Welding.*

I. INTRODUCTION

Aluminium alloys are widely used in ship hulls, deckhouses, and hatch covers of commercial ships. Ladders, railings, gratings, windows, and the other applications. The advantages of weight saving in many types of marine vessels are increased payload and decreased power requirement. The shipbuilding and aerospace industry has made use of the high-strength. Aluminium alloys such as AL 7075 welded in order to obtain the minimum tensile strength requirements.

Hirata et al. (2016) find the influences of Friction Stirparameters on the AA 5083. The shoulder diameter, pin diameter and the tool inclination angle were studied and the impact of these process parameters were evaluated the results shown the yield strength increased slightly with a decrease in Rt /V and also the tensile strength were same under different FSW condition. Barmouz et al (2015) matrix composites through FSP and reported that the processing speed is the parameter influencing the distribution of the SiC particle in the copper matrix. Further it is reported that the size of the reinforce role in achieving good quality surfaces. Nano sized SiC particles were embedded on the Copper matrix surface by FSP and concluded that the sized SiC particles yielded finer grains and lower wear rate compared to macro size SiC particles. Wenke Pan et al. (2013) has done research the Friction Stir Welding (FSW) is a complex thermal-mechanical process. Numerical models have been used to calculate the thermal field, distortion and residual stress in welded components but some modelling parameters such as film coefficient and thermal radiation of the work pieces may be technically difficult and/or expensive to measure experimentally. By comparing the FEM numerical results with experimental results, the FSW process thermal parameters have been successfully identified. This automatic parameters characterization procedure could be used for the FSW process optimization.

S.Senthil Kumaran et al, In their paper they provide the optimization of friction welding of tube to plate using an external tool by hybrid approach. The material used is pure commercial grade aluminum. The variable parameters are tool rotation speed, pin clearance and shoulder diameter and they are optimized for tensile strength. Xiawei Yang et al, [9] In their paper the finite element modelling of friction welding of GH469 super alloy has investigated using ABACUS software. The friction co-efficient of the super alloy is obtained using different parameters like friction load, friction velocity and specimen temperature. The von mises stress and equivalent plastic strain of linear friction welding is analyzed in different welding times. The surface temperature fields of joint are experimentally observed using infrared thermal imaging instrument. And finally the microstructure of weld joints is investigated using the temperature of the simulated joints.

C.Bennett et al, [10] in This paper presents the finite element modeling of two CrMoV tubes joint by inertia friction welding using deform-2D software and also studies the effect of solid-state phase transformation. The model is verified by the experimental test of the welded materials such as upset and rotational velocity and thermal data collected from the process using embedded thermocouples. The value of residual stress from the finite element model is compared with the experimental measurements obtained from the welded component using the hole drilling technique. The comparison results of the phase transformation and residual stress show good agreement between the values generated by the model and the experimental values.

Yanni Wei et al, [11] In their paper presents the investigation of interdiffusion and intermetallic compounds in Al-Cu joint by friction welding. Scanning electron microscope, energy-dispersive X-ray spectroscopy and X-ray powder diffraction are used to analyze the microstructure and compositions of the composites. An infrared camera is used to observe the surface temperature. For different welding parameter the suggested interface temperatures are in range of 648~723 K. As the interdiffusion coefficients could reach $7.8 \times 10{-}12$ m2/s, there is extraordinarily rapid interdiffusion between Al and Cu. EDS and XRD identified the presence of intermetallic phases Al2Cu and Al4Cu9. The effective Gibbs free energy change of formation model is used to predict the Al-Cu formation at solid-state interface, and with the combination of kinetic factors show that Al2Cu (Al side) and Al4Cu9 (Cu side) appeared first.

Experimental Work

The main objective of the present investigation is to study the effect of FSW parameters on tensile and hardness properties of AL 7075 alloy and the mechanical properties of FSW joints of AL 7075 alloy. The experimental work was planned in the following sequence

Identification of chemical composition and mechanical properties of AL 7075;

Fabrication of square butt joints of AL 7075 alloy using FSW process;

Evaluation of transverse tensile strength and hardness properties of the fabricated joints;

Develop empirical relationships to predict tensile properties of FSW joints of AL 7075 alloy incorporating respective process parameters;

The chemical composition was obtained by vacuum spectrometer and the chemical composition (in weight %) of the selected alloy is presented in Table 4.1.

Table 1: Chemical composition (wt %) of the base metal

ELEMENT	CONTENT
Mg	0.8–1.2
Al	Bal.
Zn	0.25
Si	0.4–0.8
Fe	0.7
Cu	0.15–0.4
Mn	0.15
Ca	–
Ti	0.15
Cr	0.04–0.35
Other	0.15

The mechanical properties of selected A7075 Al specimens were extracted from the mid length of the joint as per the ASTM E8M-04 guidelines. Comfort tensile strength were studied by the specimen to identify tensile strength, yield strength and percentage of elongation. Tensile test was carried out in 100 kN, electro-mechanical controlled, universal testing machine (Make: FIE-Bluestar, India; Model: UNITEK-94100). The 0.2% offset yield strength and the percentage of elongation was also evaluated and the values are presented in Table 4.2. the experimental specimens of 6 mm thick AL7075 grade aluminium alloy were selected for this study. The butt joint of 300 mm x 150 mm x 6 mm were select to joining process. The welding direction was normal to the extrusion direction.Tensile strength test specimens were selected as per ASTM E8M-04 standard and transverse tensile properties like Ultimate strength, Yeild strength, and Elongation of the stir welded joints are evaluated by the universal testing machine.

Table 2. Mechanical properties of the base metal

Yield strength (MPa)	Ultimate tensile strength (MPa)	Elongation (%)	Reduction in cross - sectional area (%)	Hardness (Hv) at 0.05 kg load
274	370	6.2	14.3	135

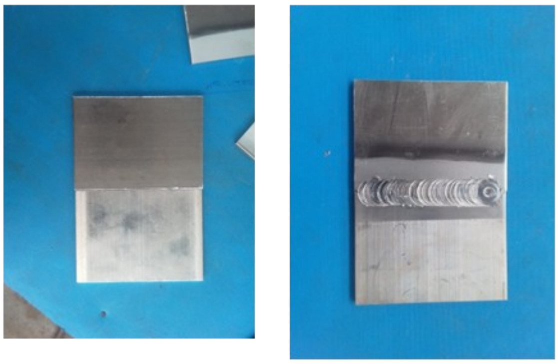
The experimental trials were formulated as per design of experiments, the variable parameters such as rotational speed and welding speed were framed as L16 orthogonal design. The measured variables are Tensile strength, Yield strength, elongation and Hardness.

The friction stir welding process is used for welding on similar materials such as Al7075. The Al7075 Alloy was used many commercial and industrial applications because excellent mechanical property with low density. Measured readings of tensile and hardness tests are given as input to the analysis. The variable parameters are displayed in Table 3.

Table 3. FSW parameters and their levels.

Sr	Parameters	Unit	Levels			
1	Tool Rotational speed	rpm	600	700	800	900
2	Welding speed	mm/ min.	10	20	30	40

Figure 1. Friction welding machine



Weld before Weld after

III. RESULTS AND DISCUSSION

The specimens which has been welded as per the parameter setup mentioned in L16 array is tested for tensile strength. Their corresponding tensile strength values are tabulated in the Table 4. The selected design metrics according to a Taguchi design orthogonal array (OA) with the tensile strength are shown in Table 3. It was the two factor four levels containing 16 sets of actual conditions run which allowed the assessment of the effects the factors on the UTS, YS, and E. The value of the output is organized in Table 3. The selected design metrics according to a Taguchi design orthogonal array (OA) with the tensile strength are shown in Table 3. From the above results and graph it is concluded that maximum Tensile strength of 362 MPa is achieved for the weld parameter of Welding speed 10 min/min.

Figure 2.Welded Specimen

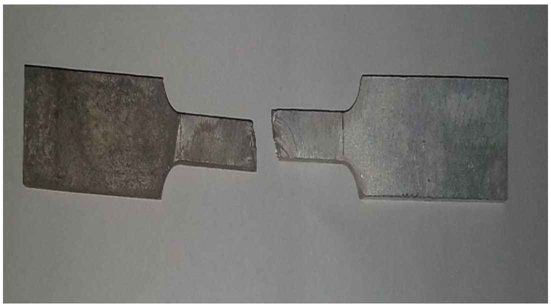


Figure 3. Tested Weld Joint

The selected design metrics according to a Taguchi design orthogonal array (OA) with the hardness by vickers are shown in Table 5. From the results it is concluded that maximum Hardness value of 122 is achieved at the weld zone from the weld parameter of rotational speed of 700 rpm and welding speed of 10 mm/min.

Table 4. Matrix and assessed mechanical properties.

Exp. No	TRS (rpm)	WS (mm/ min.)	YS (MPa)	UTS (MPa)	E%
1	600	10	252	361	6.1
2	600	20	249	356	5.5
3	600	30	248	347	5.4
4	600	40	246	342	5.2
5	700	10	261	349	6.5
6	700	20	258	334	5.6
7	700	30	252	337	5.5
8	700	40	264	341	5.1
9	800	10	263	311	7.1
10	800	20	260	306	6.6
11	800	30	256	293	5.9
12	800	40	251	285	5.4
13	900	10	271	362	6.1
14	900	20	269	361	5.6
15	900	30	267	347	5.4
16	900	40	265	358	5.0

Table 5.Matrix and assessed mechanical properties.

Exp. No	TRS (rpm)	WS (mm/min.)	Hardness	Hardness	Hardness
			Base	HAZ	WZ
1	600	10	118	112	110
2	600	20	122	110	112
3	600	30	126	112	114
4	600	40	139	115	118
5	700	10	121	98	116
6	700	20	125	95	115
7	700	30	129	109	114
8	700	40	134	112	122
9	800	10	116	107	109
10	800	20	123	112	113
11	800	30	129	116	116
12	800	40	133	115	118
13	900	10	124	115	112
14	900	20	131	113	108
15	900	30	133	114	113
16	900	40	134	118	117

IV. CONCLUSION

From this study, it is understood that friction welding joints are prone to defects, due to improper flow of metal and insufficient consolidation of metal in the welded region. In this paper was established that various factors affect quality and strength of joints welded by friction welding process. These factors were include rotational speed and welding speed. Factorial design of experiments have shown based on orthogonal design, that rotational speed have most significant than the welding speed. The observed results shown clearly the impact of rotational speed on weld strength and hardness. The maximum value of rotational speed as 900 rpm were achieved maximum strength from the observed values. The hardness of stir zone is higher than the base metal, irrespective of the tool pin profiles used. The joint done by friction welding process exhibited superior tensile properties and hardness and this work identified and explore that the the rotational speed of the tool plays a major role in the tensile strength of FSW joint.

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