Experimental and Analysis of Process Parameters of Aluminium Alloys using CNC and VMC

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Abstract-Friction Stir Welding (FSW) is a solid state welding process in which the relative motion between the tool and the work piece produces heat which makes the material of two edges being joined by plastic atomic diffusion. This method relies on the direct conversion of mechanical energy to thermal energy to form the weld without the application of heat from conventional source. The rotational speed of the tools, the axial pressure, welding speed and the tool profile are the principal variables that are controlled in order to provide the necessary combination of heat and pressure to form the weld. These parameters are adjusted so that the interface is heated into the plastic temperature range (plastic state) where welding can take place. During the last stage of welding process, atomic diffusion occurs while the interfaces are in contact, allowing metallurgical bond to form between the two materials. The functional behaviour of the weldments is substantially determined by the nature of the weld strength characterized by the tensile strength, metallurgical behaviour, surface roughness, weld hardness and micro hardness.In this project an attempt is to be made to determine and evaluate the influence of the process parameters of FSW on the weldments. The Brinnel hardness, Tensile strength are considered for investigation by varying tool speed, tool feed and different tool profiles of weld were analyzed. and discussed. Experiments were conducted on Dissimilar Alloys in a CNC Vertical Machining Centre. The output factors were measured in UTM, Brinnel hardness tester. Hence FSW process data base is to be developed for wide variety of metals and alloys for selection of optimum process parameters for efficient weld.

Keywords: Frictions stir welding, Brinnel testing machine, CNC vertical machining centre

I. FRICTION STIR WELDING

Friction stir welding (FSW) is a solid-state joining process which works by mechanically intermixing the two pieces of metal at the place of the join, transforming them into a softened state that allows the metal to be fused using mechanical pressure. Friction Stir Welding (FSW) is a solid state welding process in which the relative motion between the tool and the work piece produces heat which makes the material of two edges being joined by plastic atomic diffusion. This method relies on the direct conversion of mechanical energy to thermal energy to form the weld without the application of heat from conventional source. During the last stage of welding process, atomic diffusion occurs while the interfaces are in contact, allowing metallurgical bond to form between the two materials.

II. METHODOLOGY

A constantly rotated non consumable cylindrical-shouldered tool with a profiled nib is transversely fed at a constant rate into a butt joint between two clamped pieces of butted material. The nib is slightly shorter than the weld depth required, with the tool shoulder riding atop the work surface. Frictional heat is generated between the wear-resistant welding components and the work pieces. This heat, along with that generated by the mechanical mixing process and the adiabatic heat within the material, cause the stirred materials to soften without melting. As the pin is moved forward, a special profile on its leading face forces plasticised material to the rear where clamping force assists in a forged consolidation of the weld.

This process of the tool traversing along the weld line in a plasticised tubular shaft of metal results in severe solid state deformation involving dynamic recrystallization of the base material. Aluminium alloy is difficult to weld by traditional methods, due to high thermal conductivity, resulting in defects like porosity, cracks etc. Hence FSW is being increasingly used. The process is especially well suited to butt and lap joint in aluminium since aluminium is difficult to weld by arc process, but is very simple to weld by FSW.Recently, in many industrial fields, much attention has been focused on aluminium alloys because of various unique properties.
For their practical applications, bonding and welding technologies should also be established in addition to considering issues such as alloy design, microstructure control, plastic forming, casting, and surface treatment. It is very common that friction stir welding (FSW) is an attractive technology for the welding of aluminium and all other alloys. In addition, FSW between dissimilar materials has recently received much attention.
In this study, dissimilar FSW between AA7075 and AA3104 dissimilar aluminium alloy plates will be performed. Then, the influences of the tool rotation speed on surface appearance and tensile properties of the friction stir welded plates will be experimentally investigated.

III. MATERIAL SELECTION

An alloy is a mixture or metallic solid solution composed of two or more elements. Complete solid solution alloys give single solid phase microstructure, while partial solutions give two or more phases that may or may not be homogeneous in distribution, depending on thermal (heat treatment) history. Alloys usually have different properties from those of the component elements.
The mechanical properties of a material are those properties that involve a reaction to an applied load. The mechanical properties of metals determine the range of usefulness of a material and establish the service life that can be expected. Mechanical properties are also used to help classify and identify material.

IV. MACHINE SELECTION

Computer Numerical Control (CNC) is one in which the functions and motions of a machine tool are controlled by means of a prepared program containing coded alphanumeric data. CNC can control the motions of the work piece or tool, the input parameters such as feed, depth of cut, speed, and the functions such as turning spindle on/off, turning coolant on/off. The applications of CNC include both for machine tool as well as non-machine tool areas. In the machine tool category, CNC is widely used for lathe, drill press, milling machine, grinding unit, laser, sheet-metal press working machine, tube bending machine etc. Highly automated machine tools such as turning center and machining center which change the cutting tools automatically under CNC control have been developed. In the non-machine tool category, CNC applications include welding machines (arc and resistance), coordinate measuring machine, electronic assembly, tape laying and filament winding machines for composites etc.

V. FSW TOOL SELECTION

FSW applications require a tool that can withstand temperatures of approximately 900–1000oC at high z- and x-axis loads. The tool must produce consistent weld properties and maintain high abrasion-resistance. The tool has two primary functions one is localized heating and the other one is Material flow.

VI. SAMPLE PREPARATION

Rolled plates of 6mm in thickness were cut into the required size (100 mm x 100 mm x 6 mm) by power hacksaw cutting and milling. Before the welding process, the weld surface of the base material was cleaned. Plate edges to be weld were also prepared so that they are fully parallel to each other. This is to ensure that there is no uneven gap between the plates which may not result in sound welding. Secondly surface preparation was also done so that the surfaces of both the plates are of equal level and footing.

VII. SIMULATION OF CNC PROGRAM

The CNC program for the friction welding operation is fed into the CNC simulation software Cut Viewer Mill to verify the program.

The simulation results were shown in the following figure.

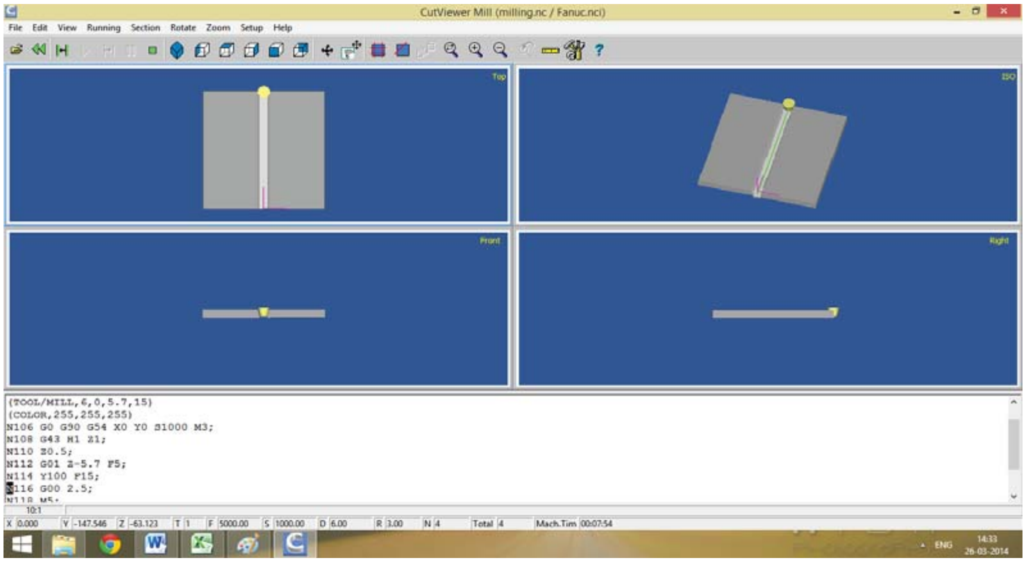


Figure7.1: Simulation of CNC program

VIII. FIXTURE PREPARATION

A fixture is a work-holding or support device used in the manufacturing industry. Fixtures are used to securely locate (position in a specific location or orientation) and support the work, ensuring that all parts produced using the fixture will maintain conformity and interchangeability. Using a fixture improves the economy of production by allowing smooth operation and quick transition from part to part, reducing the requirement for skilled labor by simplifying how work pieces are mounted, and increasing conformity across a production run.Friction Stir Welding (Milling) operations tend to involve large, straight cuts that produce lots of chips and involve varying force and temperature. Locating and supporting areas must usually be large and very sturdy in order to accommodate milling operations; strong clamps are also a requirement. Due to the vibration of the machine, positive stops are preferred over friction for securing the work piece.

IX. WELDING EXPERIMENTATION PROCESS

The friction welding experimentation process starts with cutting the aluminium work pieces according to the required dimensions. After the pieces are cut, each piece from each aluminium alloy is selected and welding is done. The detailed process is discussed below. The work piece of dimension 100*50*6 mm is cut on AA7075 and AA3104 using power hack saw. Then the work pieces are milled to the tolerance limits. The work piece is held using the standard fixture as shown in figure .The work piece is mounted firmly on the bed and checked for flatness. The CNC program is fed into the control panel of the machine. The suitable collet size is chosen for the tool. It is then fitted to the CNC spindle.

The experimental process consists of nine experiments by combining the parameters at three levels. The evaluated parameters and the nine experiments is shown in the table.

Table 9.1: Experimentation table for FSW process

S.NO	SPEED	FEED	TOOL
1	1000	10	C
2	1000	15	CT
3	1000	20	TT

4	1200	10	CT
5	1200	15	TT
6	1200	20	C
7	1400	10	TT
8	1400	15	CT
9	1400	20	C

C-Cylindtical CT-Cylindrical taper TT-Taper thread

Experiment 1: (1000rpm, 10mm/min, Cylindrical (C) Tool)

The speed is set at 1000rpm and the feed is selected as 10mm/min. The tool chosen for this experiment is cylindrical type. The process is carried out by moving the tool along the joining axis of the two aluminium alloys. Thus, the friction welding is carried out in the aluminium alloys for required parameters. Then burrs are removed manually and then it is grinded for good surface finish.

Experiment 2: (1000rpm, 15mm/min, Cylindrical Threaded (CT) Tool)

The speed is set at 1000rpm and the feed is selected as 15mm/min. The tool chosen for this experiment is cylindrical threaded type. The process is carried out by moving the tool along the joining axis of the two aluminium alloys. Thus, the friction welding is carried out in the aluminium alloys for required parameters. Then burrs are removed manually and then it is grinded for good surface finish.

Experiment 3: (1000rpm, 20mm/min, Taper Threaded (TT) Tool)

The speed is set at 1000rpm and the feed is selected as 20mm/min. The tool chosen for this experiment is taper threaded type. The process is carried out by moving the tool along the joining axis of the two aluminium alloys. Thus, the friction welding is carried out in the aluminium alloys for required parameters. Then burrs are removed manually and then it is grinded for good surface finish.

Experiment 4: (1200rpm, 10mm/min, Cylindrical Threaded (CT) Tool)

The speed is set at 1200rpm and the feed is selected as 10mm/min. The tool chosen for this experiment is cylindrical threaded type. The process is carried out by moving the tool along the joining axis of the two aluminium alloys. Thus, the friction welding is carried out in the aluminium alloys for required parameters. Then burrs are removed manually and then it is grinded for good surface finish.

Experiment 5: (1200rpm, 15mm/min, Taper Threaded (TT) Tool)

The speed is set at 1200rpm and the feed is selected as 15mm/min. The tool chosen for this experiment is Taper threaded type. The process is carried out by moving the tool along the joining axis of the two aluminium alloys. Thus, the friction welding is carried out in the aluminium alloys for required parameters. Then burrs are removed manually and then it is grinded for good surface finish.

Experiment 6: (1200rpm, 20mm/min, Cylindrical (C) Tool)

The speed is set at 1000rpm and the feed is selected as 20mm/min. The tool chosen for this experiment is cylindrical type. The process is carried out by moving the tool along the joining axis of the two aluminium alloys. Thus, the friction welding is carried out in the aluminium alloys for required parameters. Then burrs are removed manually and then it is grinded for good surface finish

Experiment 7: (1400rpm, 10mm/min, Cylindrical (C) Tool)

The speed is set at 1400rpm and the feed is selected as 10mm/min. The tool chosen for this experiment is cylindrical type. The process is carried out by moving the tool along the joining axis of the two aluminium alloys.

Thus, the friction welding is carried out in the aluminium alloys for required parameters. Then burrs are removed manually and then it is grinded for good surface finish.

Experiment 8: (1400rpm, 15mm/min, Cylindrical Threaded (CT) Tool)

The speed is set at 1400rpm and the feed is selected as 15mm/min. The tool chosen for this experiment is cylindrical threaded type. The process is carried out by moving the tool along the joining axis of the two aluminium alloys. Thus, the friction welding is carried out in the aluminium alloys for required parameters. Then burrs are removed manually and then it is grinded for good surface finish

Experiment 9: (1400rpm, 20mm/min, Cylindrical (C) Tool)

The speed is set at 1400rpm and the feed is selected as 20mm/min. The tool chosen for this experiment is cylindrical type. The process is carried out by moving the tool along the joining axis of the two aluminium alloys. Thus, the friction welding is carried out in the aluminium alloys for required parameters. Then burrs are removed manually and then it is grinded for good surface finish.

Figure 9.1 Friction stir welded pieces for all 9 experiments

X.TESTING OF WELDED PIECES

The basic test for determination of material behavior is the tensile test. In order to prepare the sample specimen, the welded joints were sliced in traverse direction using a power hacksaw. The standard tensile specimens were prepared as per the dimensions given by ASTM E8 standards.

Figure 10.1: Tensile test specimens before testing

Figure 10.2: Tensile test specimens after testing

XI. SUMMARIZATION OF RESULTS

Sample No.	Tensile Strength (MPa)
1	125.7
2	140.3
3	137.6
4	196.8
5	142.8
6	202.5
7	101.2
8	164.3
9	125.7
BM1 (AA 3104)	139.4
BM2 (AA 7075)	340.7

XII. OPTIMIZATION

In this process three parameters are considered for optimization, the parameters are given optimum values for which desired output variables will be obtained.

PARAMETERS	LEVEL		
	1	2	3
SPEED(rpm)-A	1000	1200	1400
FEED(mm/min)-B	10	15	20
TOOL-C	C	CT	TT

TABLE 12.1 Level and Factors for Taguchi method

12.1 OPTIMIZATION TABLE

In this method two outputs are considered namely Tensile Strength and hardness. The observed values for 9 experiments are shown in table.

S.NO	SPEED	FEED	TOOL	Tensile strength	Hardness
1	1000	10	C	125.7	104.9
2	1000	15	CT	140.3	98.9
3	1000	20	TT	137.6	107
4	1200	10	C	196.8	121
5	1200	15	CT	142.8	83
6	1200	20	TT	202.5	114.7
7	1400	10	C	101.2	87.3
8	1400	15	CT	164.3	95
9	1400	20	TT	125.7	83.9

12.2 Observed value for FSW process

XIII. HARDNESS OPTIMIZATION

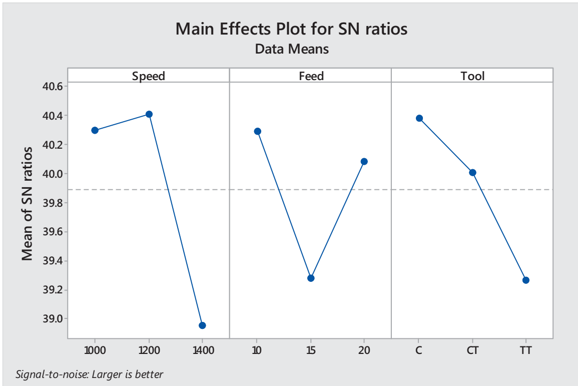
The hardness is optimized by finding the S/N ratio and Means for the values and evaluating as per procedure to find the best

S/N Ratio

The S/N ratio values shown below are derived from Minitab 17 software.

Table 13.1 Response of S/N Ratio for Hardness

LEVEL	SPEED	FEED	TOOL
1	40.30	40.30	40.39
2	40.41	39.28	40.01
3	38.95	40.08	39.26



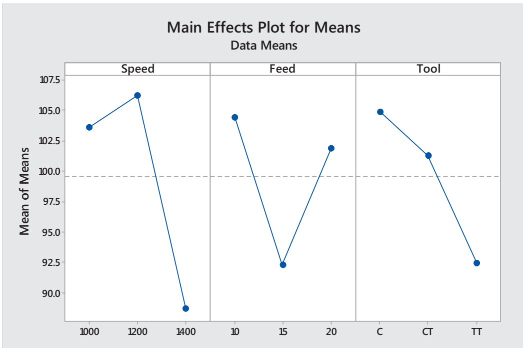
13.1 Graph for S/N Ratio Vs Factor Effects

Mean

The mean for all the nine experiments were found using the Minitab 17 software.

LEVEL	SPEED	FEED	TOOL
1	103.60	104.40	104.87
2	106.23	92.30	101.27
3	88.73	101.87	92.43

Table 13.2 Response of Mean for Hardness



13.2Graph for Mean Vs Factor

From the graphs and tables, we can conclude that best parameters for hardness are 1200 rpm, 10mm/min and cylindrical tool.

ANOVA

LEVEL	FACTOR			TOTAL	X_1^2	X_2^2	X_3^2
	X_1	X_2	X_3				
1	104.9	98.9	107	310.80	11004.01	9781.21	11449
2	121	83	114.7	318.70	14641	6889	13156.09
3	87.3	95	83.9	266.40	7621.29	9025	7039.21
TOTAL	313.20	276.90	305.60	895.90			

13.3 Hardness Values at Three Levels

Source	DOF	Adj. Sum of Squares	Mean Sum of Squares	F-Value	P %
Speed	2	534.2	267.1	1.22	36.51
Feed	2	244.3	122.2	0.56	16.69
Tool	2	245.6	122.8	0.56	16.77
Error	2	439.6	219.8		
Total	8	1463.8			

13.4 Analysis of Variance for Hardness

From the Anova table, we know that the percentage contribution of speed is more with 36.51%.

XIV. TENSILE STRENGTH OPTIMIZATION

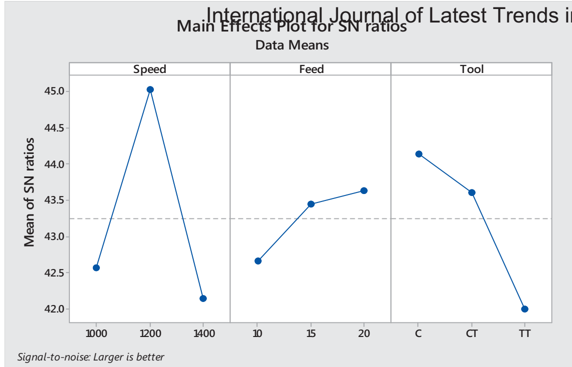
The tensile strength is optimized by finding the S/N ratio and Means for the values and evaluating as per procedure to find the best.

S/N Ratio

The S/N ratio values shown below are derived from Minitab 17 software.

LEVEL	SPEED	FEED	TOOL
1	42.57	42.66	44.14
2	45.03	43.45	43.60
3	42.13	43.63	41.99

14.1 S/N Ratio for Tensile Strength



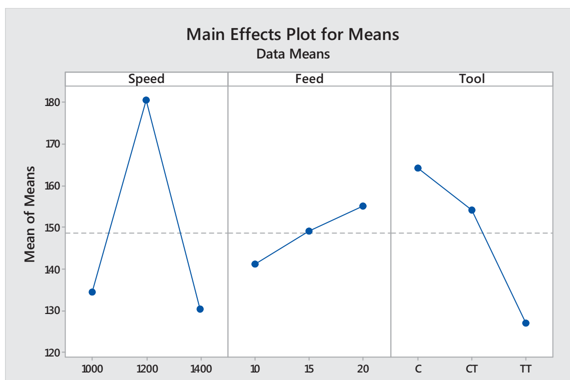
14.1 Graphs for S/N Ratio Vs Factor

MEAN

The mean for all the nine experiments were found using the Minitab 17 software.

LEVEL	SPEED	FEED	TOOL
1	134.5	141.2	164.2
2	180.7	149.1	154.3
3	130.4	155.3	127.2

Table 14.2 Mean for Tensile Strength



14.2 Graphs for Mean Vs Factor

From the graphs and tables, we can conclude that best parameters for hardness are 1200 rpm, 20mm/min and cylindrical tool.

ANOVA

Table 14.3 Tensile Strength Values at Three Levels

LEVEL	FACTOR			TOTAL	X_1^2	X_2^2	X_3^2
	X_1	X_2	X_3				
1	125.7	140.3	137.6	403.60	15800.49	19684.09	18933.76
2	196.8	142.8	202.5	542.10	38730.24	20391.84	41006.25
3	101.2	164.3	125.7	391.20	10241.44	26994.49	15800.49
TOTAL	423.70	447.40	465.80	1336.90			

Table 14..4 Anova for Tensile Strength

Source	DOF	Adj. Sum of Squares	Mean Sum of Squares	F-Value	P %
Speed	2	4678.5	2339.3	0.57	52.01
Feed	2	297	148.5	0.16	3.30
Tool	2	2197.1	1098.6	1.21	24.4
Error	2	1821.4	910.7		
Total	8	8994			

From the Anova table, we know that the percentage contribution of speed is more with 52.01 %.

XV. CONCLUSION

Thus, friction stir welding process has been successfully carried out on dissimilar aluminum alloys of 7075 and 3104. The weldability and mechanical properties of these dissimilar alloys are examined.The best parameters for the speed, feed and tool profile are chosen among 3 levels. It is found out using Taguchi method.For the best hardness nature of the welded area, the suitable parameters are 1200rpm speed, 10mm/min feed and cylindrical tool profile.The percentage contribution of speed is 36.51%, feed is 16.69 %, tool is16.77 % for the hardness property using ANOVA.For the best hardness nature of the welded area, the suitable parameters are 1200rpm speed, 20mm/min feed and cylindrical tool profile.The percentage contribution of speed is 52.01%, feed is 3.30 %, tool is 24.4% for the hardness property using ANOVA.From the experiments carried out, it is concluded that speed is the major factor influencing the mechanical properties like tensile strength and hardness. The best parameters are given by experimental and theoretical work. This can applied for friction stir welding of AA7075 and AA3104 in aerospace and marine applications

REFERENCES

[1] A.P Reynolds, W.J. Arbegast et al., "Material Flow and Average Strain Rates in Friction Stir Welds", presented at the 11th Annual Advanced Aerospace Materials and Processes Conference and Symposium, ASM International, Seattle WA, March 14-15, 2000.

[2] Ahmed Khalid Hussain, Syed Azam Pasha Quadri (2010) Evaluations of parameters of Friction stir welding for Aluminium aa6351 alloy.

[3] Recrystallization mechanisms during friction stir welding/processing of aluminum alloys Scripta Materialia, Volume 58, Issue 5, March 2008, Pages 349-354, T.R. McNelley, S. Swaminathan, J.Q. Su

[4] Influence of Friction Stri Welding on parameter and strength of weldments, April 2009, pages 47-56, by Yousuf ul haq.

[5] P.M.G.P. Moreira, T. Santos, S.M.O. Tavares, V. Richter-Trummer, P. Vilaca, P.M.S.T. de Castro (January 2009) Mechanical and metallurgical characterizations of friction stir welding joints of AA6061-T6 with AA6082-T6.

[6] Fersini, A. Pirondi ;Fatigue behaviour of Al2024-T3 friction stir welded lap joints

[7] R. Nandan, T. DebRoy, H.K.D.H. Bhadeshia Recent advances in friction-stir welding – Process, weldment structure and properties.

[8] N. Bhanodaya Kiran Babu1, A. Prabhu Kumar, M. Joseph Davidson Friction Stir Welding Of AA 6061 Aluminium Alloy.

[9] Y.J. Kwon, I. Shigematsu, N. Saito (2008) Dissimilar frictions stir welding between magnesium and aluminum alloys.

[10] M.Jayaraman, R.Subramaniam, V.balasubramanian, A.K.Lakshminarayanan, ‘Optimization of process parameters for frication stir welding of cast aluminium alloy A319 by Taguchi method’- JS & IR, Vol.68, January 2009.

[11] .IIT Mumbai Lecture Notes ‘Module 5 Design for reliability and quality’.