ISSN (Online) 2456-1290

International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)
Vol 2, Issue 10, October 2017

Taguchi Optimization Process Parameters in Friction Stir Welding of Aluminium 6351 and pure Copper (Dissimilar Metals)

[1] M. Uma Mahesh, [2] Bhiksha Gugulothu
[1] M.Tech Student, [2] Associate Professor
[1][2] Department of Mechanical Engineering, Malla Reddy Engineering College (Autonomous), Dhulapally, Maisammaguda, Hyderabad-500100, India

***Abstract*- Friction Stir Welding (FSW) is considered to be the most significant development in metal joining during last decade. This technique is an energy efficient, eco-friendly for different alloys. In the present work an effort has been made to join the Al 6351 and Pure copper material (Dissimilar) by FSW technique and the effects of critical process parameters on mechanical properties i.e. Ultimate tensile strength, impact test and hardness (HV) of friction stir welded have been studied. Three process parameters i.e., tool rotational speed, Feed and tilt angle were taken as process variables. Taguchi L9 Orthogonal Array method was selected for conducting the experiments. Experiments were performed at rotational speeds of 900, 1100 and 1400 rpm/min, Feed of 16, 20 and 25 mm/min and tilt angle of 0, 1 and 20. For generating graphs and analyzing them software Mini Tab 18 was used. Tilt angle is the most significant process parameter for the weld. The maximum Ultimate tensile strength, Impact strength, hardness values were 81.86 N/mm2, 6Joule and 59.88 were observed for the welded joint of Al 6351 and with combination of pure copper.**

***Key words*- FSW, Minitab18, Taguchi Method, ANOVA**

1. INTRODUCTION

A newly merging process, FSW produces no fumes, and also uses no filler material. But also it can join aluminium alloys, copper, magnesium, zinc, steels, and titanium. Friction stir welding produce a welds that is harder than the base material. Friction stir welding is a type of new Merging process that has been used for high production since 1996 year. Melting not occurs and merges takes place below the melting temperature of the material, a high quality weld is created. The characteristic greatly reduces the effects of concentrated heat input, including distortion, and eliminates solidification defects. Fsw also is high efficient, no fumes produces, and also no usage of filler materials, which can say this is eco friendly technique process.

2. LITERATURE REVIEW

Bhatt et al. studied the consistent rotational speed of tool and geometry of same tool. Change in the traverse speed of tool has total results on temperature and flow stress in FSW of AA 7050-T7451 aluminium [1].

Thomas et al. described the results of micro structure analysis, hardness test measurements and tensile test measurements of Friction stir welded (FSW) sheets of two different grade of aluminium alloys Al Mg4.5Mn0.7

(AA5083) and AlZn6Mg2Cu (AA7075). The macro structures and micro structures of FSW welds are similar to these produced by hot working. They strongly depend on sheet thickness, as do also their tensile properties. The variation of

Hardness through weld path. The width is small in alloy AA 5083 and more important in AA 7075. The strength of FSW welds in AA5083 and AA7075 6mm thickness sheets are as higher as 100% and 72% respectively of parent material strength [2].

Hidetoshi Fujii and Cri Ling. studied the effect of the profile of the tool on the mechanical characteristics and micro structures of welded aluminium plates that are 5mm thick. He maintained that the simplest profile without threads and the ordinary profile with threads along with triangular prism shaped profile be used for welding three types of aluminium alloys. This 1050-H 24 metal defines to unpaired is minimum and a tool without threads produces the weld with maximum mechanical characteristics. In the case of 6061-T6 the power to resist impairment is minimum and the profile of the tool has minimum effect on the micro structures and mechanical characteristics of metals. If the speed of rotation (rpm) is as low as 600 rpm, the profile of the tool has no notable effect on the micro structures and mechanical characteristics of the joints [3].

Lee W.B. et al. worked on the shared substances of dissimilarly developed Al alloys by FSW as per the set position of materials. According to them, the mechanical substances of the weld primarily relied on the materials located at the retreating side since the microstructure of the stir zone primarily consisted of the materials located at the retreating side. A356 Al alloy was used and formed 6061 Al alloy which was 140mm long, 70mm wide and 4mm thick. To determine hardness of the stir zone, test specimens were sectioned in the longitudinal direction to the weld line with an EDM. Micro-structured changes from the weld zone to the unaffected basic metal were evaluated with OM and SEM.

From the various print reactions of the materials 6061 AL seemed darker in colour then A356 Al alloys in the stir zone. If A356 Al alloys were set at the retreating side, more light coloured areas which were calculated as A356 Al alloys, held the bigger part in the stir zone. If 6061 metal Al alloys were set at the retreating one side, the micro structure of the stirred zone would primarily consists of 6061 Al alloys. Thus the micro structure of the stirred zone would primarily rely on the materials set at the retreating side and some amount of material at the advancing side.

The main results obtained shows that the micro structures of differently formed A356/6061 Al joint were the combined structures of two materials. The onion ring design resembling lamellar structure was observed in the stir zone. The microstructure of the stir zone primarily consisted of the material set at the retreating side. The mechanical substances of the stir zone indicated greater value when 6061 Al alloys were set at the retreating side [4].

Wert J.A. et al. studies the micro structures of FSW joints between an aluminium base metal matrix compared and a massive aluminium alloy. They stated that microstructures in FS welds between the massive AA2024 and AA2014 strengthened with 20 Vol% form A1203 bring to light that the smallest layers of each material are approximately 0.1 mm thick. Therefore it is clear that the materials keep their individuality in the weld zone. The complicated macro interfaces can be noticed between material fields. If the harder material is on the advancing side of the tool, the extent of the macro interface is larger. The movement of the material is affected by the comparative hardness eutectic melting is also displayed by the welds. The liquid phase has the conventional form of grain boundary films in the thermo-mechanical process one. Particle strings and incomplete broken zones have been noticed. Eutectic melting may also cause them [5].

Cavaliere P. et al. conducted an investigation of micro structural and mechanical action of 2024-7075 aluminium alloy plates combined by FSW. The microstructure that was the result of FSW process was investigated by using OM and SEM welded or tested samples after the crack happened. The main result obtained was that the different 2024 and 7075 aluminium alloys in the form of 25mm thick plates were positively connected by FSW. Sample fracture surfaces were analyzed after testing through SEM microscope correcting the errors in the topology and location following friction stir process and microscopic mechanisms that happened during high stress impairments and breakdown [6].

Chao J. et al. studied the influence of FSW on the active characteristics of AA2024-T3 and AA7075-T7351. Active compact stress-strain curves were obtained from AA 2024-T3 and AA 7075- T7351 aluminium alloys and their welds generated through FSW process. The experimental results obtained were that the FSW would diminish the yield stress of the weld metal below that of the base metal. However, the two materials display the results of the strain rate. Yield stresses of both the base and FS welded material of AA 2024-T3 displayed rate sensitivity. In addition, AA 7075-T7351 base metal had some rate reliance. But no influence of rate was noticed for AA 7075-T7351 FS welded material up to the strain rate of 500 / sec. FSW lessened the yield stress of AA 2024-T3 as well as AA 7051 under high strain rate as well as quasistatic loading states [7].

Chen C.M. et al. studied combination of Al 6061 alloy and AISI 1018 steel through fusion and solid state welding. This was taken from FSW with a variable counterbalance of the location of the probe relating to line of the butt. Metallographic analysis by OM, EDM, and the application of X-ray diffraction technique was carried out. It was noticed that inter metallic phases All3 Fe4 and A15Fe2 are in the weld zone [8].

Liu et al. in their research paper discussed the friction stir weld ability of the 2017-T351 aluminium alloy and determine optimum welding parameters, the relations between welding parameters and tensile properties of the joints. Researcher founded that the tensile properties and fracture locations of the joints are commonly affected by the welding technique parameters. When the optimum revolutions per pitch is 0.07mm/rev correspondence to the rotation speed of 1500rpm and the weld speed of 100mm/min, the maximum UTS of the joints is equivalents to the 82% that of the base material. Though the voids-free joints are fractured near or at the interface between the weld nugget and the thermo-mechanically affected zone (TMAZ) on the advancing side, the fracture occurs at the weld centre when the void defects exist in the joints [9].

HuseyinUzun et al. investigated that the joining of dissimilar Al 6013-T4 alloy and X5CrNi18-10 stainless steel was carried out using friction stir welding (FSR) technique. The microstructures, Hardness tests and fatigue structured properties of FS welded metal 6013 material Al alloy to stainless steel have been examined. Optical microscopic was used to characterize the micro structures of the weld nugget, the heat affected zone (HAZ), thermo mechanical affected zone (TMAZ) and the base materials [10].

Cavaliere et al. (2005) investigate that the mechanical and micro structural properties of dissimilar alloys 2024 and 7075 Aluminium metal plates joined by (FSW). The two sheets, aligned with perpendicular rolling directions, have been successfully welded consequently the welded sheets have been tested under tension at room temperature in order to analyze the mechanical response with respect to the parent materials [11].

Chen et al. (2008) Al–Si alloy and pure titanium were lap joined using friction stir welding technology. Microstructure and tensile properties of joints were examined. The maximum failure load of joints reached 62% of Al–Si alloy base metal with the joints fractured at the interface. X-ray seen results showed that new phase of TiAl3 formed at the interface. The micro structured revolution and the joining capable mechanism of Aluminium titanium joints were systematically briefly described [12].

Moreira et al. (2008) Studied that mechanical and metallurgical characterization of friction stir welded butt joints of aluminium alloy 6061-T6 with 6082-T6 was carried out. For comparing, similar material joints made each one of the other two alloys were used. The joining work includes micro structured examinee, micro hardness, tensile and bending tests of all joints. An approximate finite element model of the joint, taking into account the spatial dependence of the tensile strength properties, was made, modeling a bending test of the weld ments. This determines shows that the friction stir welded dissimilar metal joint present intermediate mechanical properties when compared with each parent material. In tensile tests the dissimilar joint displayed intermediate properties. For instance in the hardness profile the lowest values were obtained in the AA 6082-T6 alloy plate side where rupture occurred, and in the nugget all type of joints present similar values [13].

Kumaran et al. In this study research numerous advancements have been occurring in the field of materials processing. Friction weld is an important solid-state joining technique. In this research project, friction welding of tube-to-tube plate using an external tool (FWTPET) has been performed, and the process parameters have been prioritized using Taguchi's L27 orthogonal array. Genetic algorithm (GA) is used to optimize the welding process parameters. The practical significance of applying GA to FWTPET process has been validated by means of computing the deviation between predicted and experimentally obtained welding process parameters [14].

Guo et.al investigated that the Dissimilar AA 6061 and AA 7075 alloys have been friction welded with a different process parameters. In particular, the effects of materials position and welding speed on the material flow, microstructure, micro hardness distribution and tensile property of the joints were investigated. It as seen revealed that material mix is much affective when AA 6061 alloy was located on the advancing side and multiple vortexes centers formed vertically in the nugget [15].

Shen et.al (2013) identified that the FSW technique is considered to offers advantages over other fusion welding in terms of dissimilar joining. However, some other challenges still exihibits in the butt FSW of dissimilar Ti and Al metals. The present base research employs a modification of butt joint configuration into the FSW (friction stir welding) of Ti 6Al 4V alloy to Al 6Mg alloy with a special probe plunge setup, aim to obtain a high quality Al to Ti joint, avoid butt flaws or Al melting, and reduce the tool shoulder attrition. Under different (FSW) process parameters, the examinations and analyses of macro / micro structures, mechanical tensile properties and fracto-graphics of the dissimilar joints were conducted comparatively [16].

Mofid et al., (2012) found that the formation of Inter metallic compounds Al3Mg2 and Al12Mg17 and Al2Mg3 in the stir zone of dissimilar welds affects the 36 mechanical properties of the joint significantly. This research employs the usage of (SFSW) submerged friction stir welding under water as an alternative and improved method for creating fine grained welds, and hence, to alleviate formation of inter metallic phases. A constantly tool rotation per rate of 300 rpm and travel speed of 50mm/min was used. The air welded specimen had a relatively larger volume fraction of inter metallic compound, higher peak temperature in stir zone and significantly higher hardness in the weld center. This matter suggested that the submerged FS weld under water resulted in lower peak temperature and because of lower heat input inter metallic compounds formation was limited [17].

Maggiolino and schmid (2008) did a difference between the corrosion resistance of AA 6060-T5 and AA 6082-T6 jointed surfaces via friction Stirred Welding technique (FSW) and Metal Inert Gas (MIG). This test was conducted keeping the weld and polishes samples in an acid salt solution. The corrosion resistance was detected through 39 morphological analysis of the surface. The attack was localized an index referred to the density was used for the comparison. The result indicated that the joint welded via Friction Stir (FS) is more resistant than that welded via Metal Inert Gas technique joints [18].

Cabello et al. (2008) made a complete study on micro structures and mechanical characteristics of fusion welds TIG and solid state welds (FSW) of Al – 4.5 Mg –0.26 Sc heat-treatable Aluminum alloys. The corresponding mechanical properties are evaluated through micro-hardness measurements and tensile tests. The effect of a post-weld heat treatment on both microstructures and mechanical properties is further examined. The results suggest that hardening precipitates are comparative more affected by the TIG welding than by the FSW process. This results in a substantial reduction of mechanical properties of TIG welds that can be partially recovered through a post-weld heat treatment [19].

Sarsilmaz and Çaydaş (2008) applied the full factorial experimental design to study the effect of friction-stir welding (FSW) parameters such as spindle rotational speed, traverse speed, and stirrer geometry on mechanical properties of AA 1050/AA 5083 alloy. Ultimate tensile strength (UTS) and hardness of welded joints were determined for this purpose. Analysis of variance (ANOVA) and main effect plot were used to determine the significant parameters and set the optimal level for each parameter. A linear regression equation was derived to predict each output characteristic [20].

3. EXPERIMENTAL DETAILS

Different experimental and analytical approaches have been identified for studying the result of the process characteristics on the mechanical and metallurgical substances of the welded joints. In this chapter the provisions and methods adopted are detailed.
Besides equipment, the present chapter gives an account of the tool geometry in fig 3.2 and base metal plates in fig 3.3 adopted to perform the FSW process, the levels of conducting the FSW process and the means of testing which are required to examine the excellence of the parts welded in fig 3.4. The detailed experimental plan is shown in Figure 3.3. The experimental plates having 100 mm length X 75 mm height X 6 mm thickness size have been fabricated from aluminum 6351 and pure copper plates using vertical milling machine. The FSW machine specification is shown in table 3.1. Mechanical properties of the parent material are provided in Tables 3.2, 3.3 for aluminum 6351 and pure copper and table 3.4 shows for Hardness Test for Aluminium-6351(Parent metal), 3.5 for Hardness Test for Pure-Copper (parent metal), 3.6 for impact test for Al-6351 (parent metal) and 3.7 shows that impact test for pure copper (parent metal). The experiment is performed using FSW machine presented in Figure 3.1 to weld the joint. Welding is done by a single pass.

Figure 3.1 FSW Machine

Table 3.1 Specifications of FSW machine:

Vertical Milling Machine		FN2EV
Overall dimensions (L×W)	mm	1520x310
Clamping area (L×W)	mm	1350x310
Power operated table traverses	mm	800
Longitudinal	mm	265x400
Max. safe weight on table	Kg	600
Number of speeds	N	18
Speed range	rpm	35.5-1800
Main Motor	KW/rpm	5.5/1500
Feed Motor	KW/rpm	1.5/1500
Space required (L×B×H)	mm	255x196x197

ISSN (Online) 2456-1290

International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)
Vol 2, Issue 10, October 2017

Figure 3.2 Fsw tool

Table 3.2 Ultimate Tensile Test for Aluminium-6351 (parent material)

Input data	Units	Results
Specimen Type		Flat
Specimen Width	mm	12.47
Specimen Thickness	mm	6
C/S Area	mm^2	74.82
Original Gauge Length	mm	50
Final Gauge Length	mm	59.2
Ultimate Load	KN	20.160
Ultimate Tensile Strength	N/mm^2	269.447
Elongation	%	18.400
Yield Load	KN	15.200
Yield Stress	N/mm^2	203.154

Table 3.3 Ultimate Tensile Test for pure copper (parent material)

Input data	Units	Results
Specimen Type		Flat
Specimen Width	mm	12.43
Specimen Thickness	mm	5.4
C/S Area	mm^2	67.122
Original Gauge Length	mm	50
Final Gauge Length	mm	57.43
Ultimate Load	KN	18.320
Ultimate Tensile Strength	N/mm^2	272.944
Elongation	%	14.860
Yield Load	KN	15.000
Yield Stress	N/mm^2	223.480

Table 3.4: Hardness Test for Aluminium-6351 (Parent metal)

Sl. No	Location	Observed Values in HV			
		Impression 1	Impression 2	Impression 3	Average
1	On surface	56	54.9	54.9	55.27

Table 3.5: Hardness Test for Pure-Copper (parent metal)

Sl. No	Location	Observed Values in HV			
		Impression 1	Impression 2	Impression 3	Average
1	On surface	88.3	88.3	87.8	88.13

Table 3.6: Impact Test for Aluminium-6351 (parent metal)

Sl. No	Location	Observed Values in Joules			
		Impact 1	Impact 2	Impact 3	Average
1	Longitudinal direction	58	0	0	58

Table 3.7: Impact Test for pure copper (parent metal)

Sl. No	Location	Observed Values in Joules			
		Impact 1	Impact 2	Impact 3	Average
1	Longitudinal direction	82	0	0	82

Figure 3.3. The experimental plate of FSW

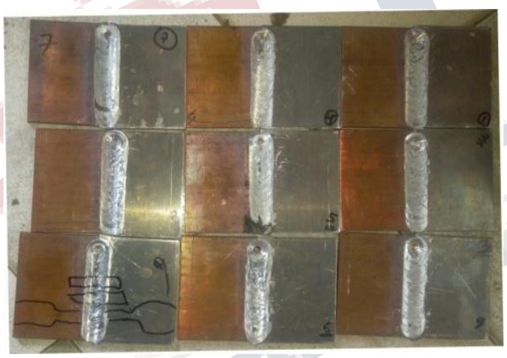

Figure 3.4. Al 6351-Pure copper (Joint) welded by FSW

Figure: 3.5 Weldability for Ultimate Tensile Specimen

Figure: 3.6 Ultimate Tensile Specimen after Failure

Figure: 3.7 Impact Specimen before Failure

Figure: 3.8 Impact Specimen after Failure

Figure: 3.9 Hardness Machine

Table 3.8 process parameters of FSW

S. N O.	SPEED (N)	FEED (f)	TILT ANGLE (α)	UTS (N/mm^2)	HV	IMPACT TEST (Joules)
1	900	16	0	56.932	65.77	2
2	900	20	1	48.869	63.90	2
3	900	25	2	80.446	54.00	6
4	1100	16	1	113.398	55.43	2
5	1100	20	2	36.148	63.83	4
6	1100	25	0	45.479	58.90	2
7	1400	16	2	70.740	68.40	4
8	1400	20	0	38.562	53.60	2
9	1400	25	1	41.573	61.43	2

4. RESULTS AND DISCUSSION

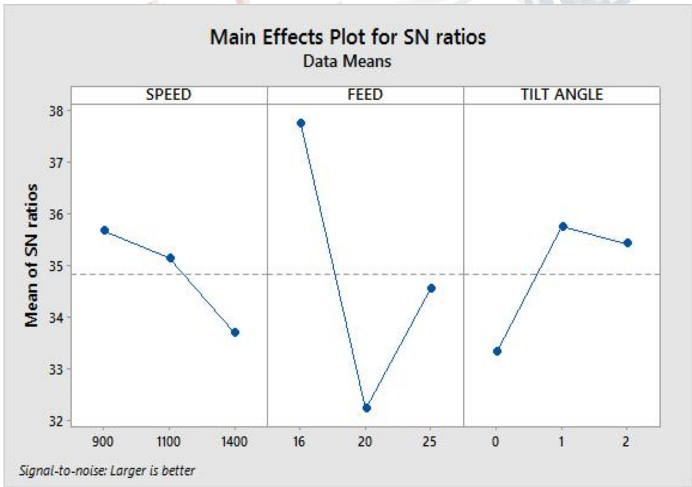

Fig4.1 Effect of FSW process parameters on UTS

A1 (Speed) =900Rpm, B1 (Feed Rate) =16 and C1 (Tilt Angle) =10

4.1 Effect of Speed, feed and tilt angle on Ultimate Tensile Strength of FSW

In response factors, the larger-the-better of UTS S/N Ratio value was considered to determine the tensile properties of dissimilar metals. Tensile tests were performed to determine the tensile properties of the Aluminium 6351 with dissimilar combination of pure copper. In fig 4.1 shows that the effect of rotational speed of the tool on tensile properties of friction stir welded Aluminium 6351 with pure copper. It seen from this figure that lower rotation speed of the tool (900 rpm). As rotational speed increases, tensile strength of welded joint has decreased. The optimum values were observed at rotation speed of 900 rpm, feed rate of 16mm/rev, Tilt angle of 10 were observed.

For given feed rate from 16 mm/rev to 25 mm/rev, the weldability observed to be improved. the maximum weldability was observed at 16mm rev/min. if the feed rate is increased from 16 to 20 mm/rev, the welded joint has decreased and again from 20 to 25 mm/rev, the tensile properties of the welded joint has slightly increased.
For the tilt angle, the tilt angle from 00 to 10 the tensile strength of the welded joint has increased and further decreased.

Table 4.1 ANOVA Table for Ultimate Tensile Strength (UTS)

Source	DF	Adj SS	Adj MS	F-Value	P-Value	% contribution
SPEED	2	364.2	182.1	0.22	0.821	7.0155
FEED	2	2349.5	1174.8	1.41	0.415	46.158
TILT ANGLE	2	708.2	354.1	0.42	0.702	13.913
Error	2	1668.2	834.1			32.773
Total	8	5090.1				100

4.2 Analysis of variance for UTS

ANOVA is carried out in Minitab software 18. The main analysis is to estimate the F-Test, percentage of the individual contribution of the welding parameter values for the process parameters and their specific performance characteristics can be obtained. From ANOVA table 4.1 shows that the first significant parameter was feed for UTS, second significant parameter was tilt angle, third was speed and their percentage of contribution was 46%, 13% and 7%.

In UTS, Feed rate is the velocity at which the cutter is fed, advanced against the workpiece is more significant for the tensile strength and it given high strength followed by tilt angle and speed. The ultimate tensile strength was found to be 81.86 $N/mm^{2.}$ But actual parent metal strength was 269.447 N/mm^2.

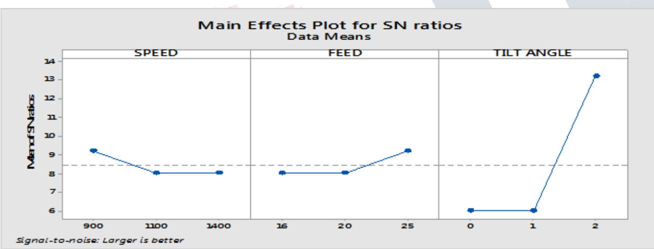

Figure 4.2 Effect of FSW process parameters on Impact Test

A1 (Speed) = 900Rpm, B1 (Feed Rate) = 25 mm/rev and C1 (Tilt Angle) = 20

4.3 Effect of speed, feed and tilt angle on Impact Test of FSW

In response graphs from fig 4.2, the larger-the-better S/N Ratio of impact test values were considered to determine the high impact properties of weldability of dissimilar metal. In fig 4.2 shows the effect of rotational speed of the tool versus impact test values were considered for high value of impact strength of the friction stir welded of aluminum 6351 with pure copper. It seen from this figures, higher impact properties of the FSW welded joint were observed at 900 rpm followed by the feed 25mm/rev and tilt angle at 20. If the rotational speed is more than 900rpm, the impact strength of the weld was weak. The optimum values are observed at rotation speed of 900 rpm, feed rate was 16mm/rev and 20 Tilt angle were observed.

For given feed rate from 16 mm/rev to 25 mm/rev, the higher weldability was observed at 25 mm/rev and the feed rate were constant at 16 to 20 mm/rev. From 20 to 25 mm/rev, the impact strength of the welded joint has increased.

For the tilt angle, the tilt angles from 0 to 10 constant. From 10 to 20 the impact strength property of the welded joint has increased. The impact strength values were observed 6Joule. But parent metals of impact test were 82Joule. So the impact test of the weldability was purely failed.

Table 4.2: ANOVA for Impact Test

Source	DF	Adj SS	Adj MS	F-Value	P-Value	% contribution
Speed	2	0.8889	0.4444	1.00	0.500	5.263
Feed	2	0.8889	0.4444	1.00	0.500	5.263
Tilt Angle	2	14.2222	7.1111	16.00	0.059	84.210
Error	2	0.8889	0.4444			5.263
Total	8	16.8889				100

4.4 Analysis of variance for impact test

ANOVA is carried out in Minitab software 18. The main analysis is to estimate the F-Test, percentage of the individual contribution of the welding parameter values for the process parameters and their specific performance characteristics can be obtained. From ANOVA table 4.1

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ISSN (Online) 2456-1290

International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)
Vol 2, Issue 10, October 2017

shows that the first significant parameter was tilt angle, second significant parameter Was feed and speed and their percentage of contribution was 84%, 5% and 5%.

For impact test, the tilt angle is most significant parameter. With the tool tilt angle the material is pushed and stirred along the path of travel direction, but without the tool tilt angle only the normal stirring action takes place. Inclination of the tool thus helps to provide a good plastic deformation at the weld zone; better material flow can be achieved. The combination of process parameters of 900 rpm tool rotation speed, 20 tool tilt angle and 25mm/rev feed has been predicted under the impact strength of 6 Joule.

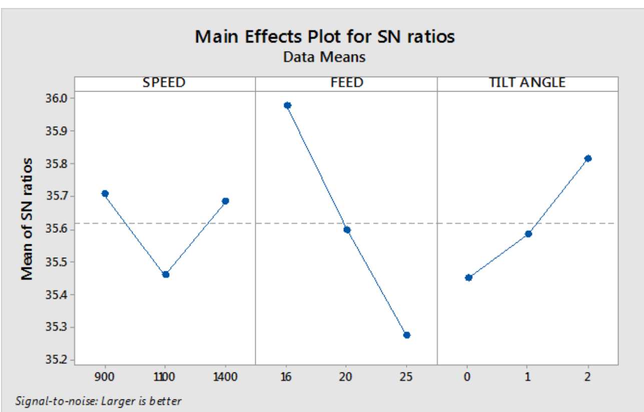

Fig 4.3 effect of FSW process parameters on HV

A1 (Speed) =900Rpm, B1 (Feed Rate) =16 and C1 (Tilt Angle) = 20

4.5 Effect of speed, feed and tilt angle on hardness Test of FSW

In response graphs from fig 4.3, the larger-the-better S/N Ratio of hardness test values were considered to determine the high hardness properties of dissimilar weld joint metal. In fig 4.3 shows the effect of rotational speed of the tool versus hardness test values were considered for high value of hardness of the friction stir welded of Aluminum 6351 with pure carbon. It seen from this figures, higher hardness properties of the FSW welded joint were observed at 900 rpm followed by the feed 16mm/rev and tilt angle at 2^{0}. The rotational speed is 900rpm, 1400rpm is sufficient to the hardness. Hardness strength was weak at 1100rpm and reduced the hardness strength. The optimum values are observed at rotation speed of 900rpm, 1400rpm feed rate of 16mm/rev, Tilt angle of 2^{0} were observed. Rotational speed produces the frictional heat required to plasticize the material. The weld produces at low speed have fine mechanical properties than weld produced at higher speed. The mechanical property increases with the rotational speed and welding speed but up to a certain level then they starts declining.

For given feed rate from 16 mm/rev to 25 mm/rev, the higher hardness was observed at 16 mm/rev.

For the tilt angle, the tilt angle from 0 to 2^{0}. From 0^{0} to 20 the hardness strength property of the welded joint has increased.

Table 4.3 ANOVA FOR HV

Source	DF	Adj SS	Adj MS	F-Value	P-Value	% contribution
speed	2	6.466	3.233	0.04	0.964	2.789
feed	2	38.952	19.476	0.22	0.818	16.807
Tilt angle	2	11.054	5.527	0.06	0.941	4.769
Error	2	175.286	87.643			75.633
Total	8	231.757				100

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4.5 Analysis of variance for impact test

ANOVA is carried out in Minitab software 18. The main analysis is to estimate the F-Test, percentage of the individual contribution of the welding parameter values for the process parameters and their specific performance characteristics can be obtained. From ANOVA table 4.3 shows that the first significant parameter was feed followed by tilt angle and speed and their percentage of contribution was 16%, 4% and 2%. For hardness, the feed is most significant parameter.

5. CONCLUSIONS

To find the optimum process parameters by using tagchi method has been concluded in this present investigation. The concluding remarks can be made from the present study:

- The ANOVA for the tensile result concludes that the feed rate is most significant parameter with percentage of 46.15% followed by tilt angle of 13.91% and rotation speed of 7.01%
- The optimum combination of parameter obtained from the main effect plot for the S/N ratio and means is 900 rpm rotation speed, 16mm/rev feed, tilt angle was 10and tensile strength has been predicted as 81.86Mpa. The confirmation test performed with the optimum process parameter is found to have an average tensile strength of 88Mpa, and hence optimization is useful.
- The ANOVA for the impact test result concludes that the tilt angle 20 was most significant parameter with percentage of 84.21% followed by rotation speed of 5.26% and feed rate of 5.26%
- The pin or probe tilt angle helps the material movement towards the travel path and also the combining of the plasticized material flow in the weld zone, hence good mechanical and metallurgical properties of the weldmements.
- The optimum process parameters for hardness test were 900rpm, feed rate 16mm/rev and tilt angle 20. But most significant parameter is feed rate followed by tilt angle and speed.
- From the ANOVA test on impact, the most significant parameter is feed rate and its contribution was 16.8%, tilt angle 4.76% and speed of rotation were 2.78%. and the maximum impact value of weld joint were 6 joule
- The ANOVA shows that for the hardness, feed were most significant parameter for weldability followed by tilt angle and speed, and their contribution orderly 16.8%, 4,7% and 2.7%.
- Compare with parent metal, the weld of dissimilar metal (6351 and pure copper) of the strength of ultimate tensile strength , Impact and hardness test were very poor

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