Friction Stir Welding Of AA2014& AA6082 Aluminium Alloy By Using Taguchi method

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Abstract - The welding processes most widely used for the welding process for aluminum alloys are incorporated with welding defects such as poor solidification and porosity in fusion zone. It is evident that the Friction stir welding is possible for defect free welding. In this present investigation AA6082 butt friction stir welded with AA2014 to get high weld metal properties and corrosion resistance. The optimization of the process parameters to get the better mechanical and micro structural properties of dissimilar joints AA2014 and AA6082 was done by friction stir welding using design of experiments in Taguchi`s method. The considered process parameters were welding speed, tool rotation speed, tilt angle. The process parameters were optimized and ranked based on the Signal to Noise Ratio values and means. The optimized welding parameters were the tool rotational speed of 600rpm, travel Speed of 60mm/min and Tilt angle of 1°. An attempt was made to join the dissimilar aluminium plate of 6 mm thickness with conical threaded tool profile. The quality of the joint was evaluated by means of tensile strength, impact test, micro hardness, macro, microstructure and salt spray test.

Keywords - Friction stir welding, tool rotational speed, travel speed, tilt angle, Taguchi method

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1. INTRODUCTION

The increasing demand for High strength weld in aerospace, automobile, and structural applications vast dissimilar applications are possible. These aluminum alloys are generally classified as non weldable because of the poor solidification microstructure and porosity in the fusion zone. Also the loss in mechanical properties as compared to the base material is significant. FSW has many notable advantages over fusion welding in order to get good strength.

As many parameters are important in the friction stir welding but in this experiment main two parameters are selected for analysis by using lathe machine; (1) Tool speed (2) Transvers speed

The proper choice of tool rotation and transverse speed will produce a good quality weld. The material use for base plate is Al alloy 2014 and AA6082 and the material use for the tool geometry is HSS.

It was observed all the pins preferred were broken due to high rotational speed and load applied. Pin profile has been changed to withstand the load. Design of Experiments is used to get a specific procedure for welding using the parameters used for welding.

Here Taguchi's method of design of experiments with 9 number of experiments and to get the results with good confidence limit. Taguchi's design of L9 orthogonal array was made for 3 levels and 3 factors. The factors selected are rotational speed, travel speed and tilt angle. The specimens were then prepared for FSW welding. Further which need to take the tensile test to do the optimization using Taguchi`s method and characterization studies Tensile test were carried out across the FSW welded samples.

This method (FSW) relies on the direct conversion of mechanical energy to thermal energy to create the weld with no application of heat from external sources. The rotational speed of the tools, welding speed, axial pressure, and the tool profile are the main principal variables that are to be controlled in order to provide the necessary combination of heat and pressure to form the weld.

These parameters are adjusted so that the interface of joining metals is heated into the plastic temperature range (plastic state) where welding can take place. The functional behavior of the welded joints was determined by the weld strength that is tensile strength, weld hardness and micro hardness. In this project an attempt will be made to determine and evaluate the influence of the process parameters of FSW on the welded joint.

Friction stir welding (FSW) is a developed solid state welding process to conquer the problems raised in fusion welding. This process uses a non-consumable tool. Rotational speed and frictional force generate heat. The welding parameters, such as tool pin profile, rotational speed, welding speed and axial force, play major role in determining the mechanical properties of welded joint.

The welding defects such as large distortion, solidification cracking, porosity, oxidation and other defects are not observed in FSW compared to many of the fusion welding processes that are generally used for joining structural alloys.

2. EXPERIMENTAL DETAILS

2.1 MATERIAL AND SAMPLEPREPARATION

From the given aluminum plate material was cut into the required dimension of 100X50X 6mm to get the required sample. As per the standards the chemical composition of AA2014 and AA6082 were given in Table 1 and Table 2.

Table -2.1: Chemical composition of AA2014 in weight%

Aluminium Alloy	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Al
Specified value	0.5-1.2	0.7 max	3.9-5	0.4-1.2	0.2-1.8	0.1	0.25	0.15 Max	Remainder
WT%	0.681	0.193	4.171	0.635	0.597	0.003	0.076	0.051	Remainder

Table -2.2: Chemical composition of AA6082 in weight%

Aluminium Alloy	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Al
Specified value	0.70-1.30	0.50 Max	0.10 Max	0.40-1.00	0.60-1.2	0.25 Max	0.20 max	0.10 Max	Remainder
WT%	1.160	0.169	0.035	0.540	0.831	0.005	0.002	0.017	Remainder

The Samples are welded by using HSS (High Speed Steel) then only we get required optimized sample from 9 samples.

Table -2.3: Process Parameters

FACTORS	LEVEL 1	LEVEL 2	LEVEL 3
Rotational Speed (rpm)	800	1000	1200
Travel Speed (mm/min)	70	80	90
Tilt Angle (0)	1	2	0

Experiments are performed to find the working levels of parameters. The levels are observed in experiments are shown inTable.3.It was chosen such a way that AA6082 in retreating side and AA2014 in advancing side so as to enhance corrosion behavior ofAA2014.

2.2 DESIGN OF EXPERIMENT

Taguchi`s designs aimed to allow greater understanding of variation than did many of the traditional designs. Taguchi contented that conventional sampling is in adequate here as there is no way of obtaining a random sample of future conditions. Taguchi proposed extending each experiment with an orthogonal array should simulate their and environment in which the experiment functions. ThedesignofexperimentisshowninTable.2.4

Table-2.4: Design of Experiment

Sample no	Tool Rotational speed (rpm)	Travel Speed (mm/min)	Tilt Angle (^{o})
1	600	60	1^{o}
2	600	80	2^{o}
3	600	100	3^{o}
4	900	60	2^{o}
5	900	80	3^{o}
6	900	100	1^{o}
7	1200	60	3^{o}
8	1200	80	1^{o}
9	1200	100	2^{o}

3. WELDED SAMPLES

Fig 3.1. Weld samples

3.1 ULTIMATE TENSILE STRENGTH

Then tensile testing has been done on UTM until fracture of specimen as per the standard ASTME8/E8M-09 and calculates the ultimate tensile strength and elongation for all specimens.

3.2 MICROSTRUCTURE

After that the FSW welded specimen was etched with freshly prepared Keller's reagent of solution containing 190ml of water, 5ml HNO_3, 3mm HCL and 2ml HF to reveal the microstructures.

3.3 MICRO HARDNESS

Micro hardness across the welded joint, have been carried out in polished and etched sections, as per the standard ASTM E 384-99. The hardness was carried out with Micro hardness tester using 0.5Kg weight for aluminium 6082-T6 and 2014-T6 with dwell time of 10s.

4.RESULTS AND DISCUSSION

4.1 ULTIMATE TENSILESTRENGTH

The table was showing the FSW AA 2014 and AA 6082 the value of ultimate tensile strength, percentage of elongation, yield strength ,and also fracture location was observed for all specimens. They high tensile values of 209Mpa in optimized parameters on tool rotation 600rpm, travel speed 60mm/min, and tilt angle are 1^{o}

Fig no 4.1:Tensile specimen fracture occur in AA 6082 weld side

They above the fig shown in tensile specimen for fracture location in AA 6082 weld side are appeared. Above the tensile test result on weld side fracture are also same in AA 6082 weld side are occurred.

Fig no 4.2: Tensile specimen fracture occur in AA 6082 HAZ

They above the fig shown in tensile specimen for fracture location in AA 6082 HAZ are appeared. Above the tensile test result on HAZ side fracture are also same in AA 6082 HAZ side are occurred.

Table -4.1: Tensile test results of dissimilar friction stir welded samples.

S.No	Yield Strength	UTS	% Elongation	Fracture location
1	170	209	9.30	Weld
2	155	185	14.75	HAZ
3	157	188	11.50	Weld
4	158	180	14.75	HAZ
5	146	171	8.5	Weld
6	159	192	13.50	Weld
7	147	170	9.50	Weld
8	181	207	11.25	HAZ
9	160	191	13.75	HAZ

Fig :4.3 tensile samples

4.2 TAGUCHI ANALYSIS:

They taguchi method are used optimization on parameter for friction stir welding are below mention the optimized parameter and plot graph on mean and SN/ratio shown.

Taguchi Analysis: UTS versus Tool rotational speed, Travel speed, Tilt angle

Table 4.2: Response Table for Signal to Noise Ratios

Larger is better

level	Tool rotational speed	Travel speed	Tilt angle
1	45.74	45.37	46.13
2	45.14	45.44	45.36
3	45.52	45.59	44.92

Delta	0.60	0.22	1.21
rank	2	3	1

Table 4.3: Response Table for Means

level	Tool rotational speed	Travel speed	Tilt angle
1	194.0	186.3	202.7
2	181.0	187.7	185.3
3	189.3	190.3	176.3
Delta	13.0	4.0	26.3
Rank	2	3	1

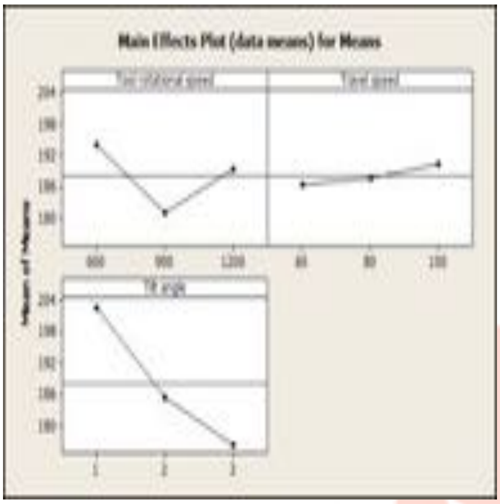


Fig :4.4 Main effects plot (data means)for means

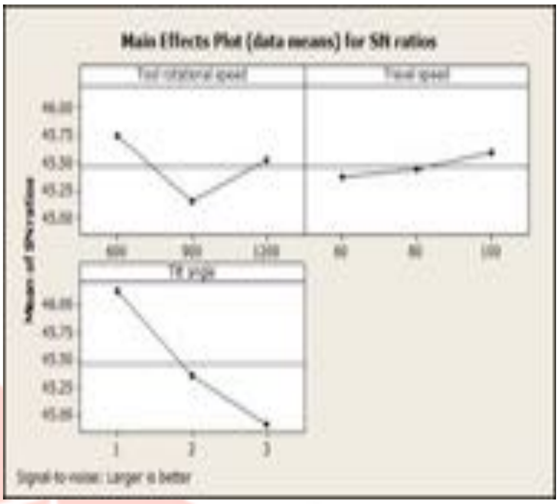


fig :4.5 Main effects plot(data means) for SN ratios

4.3. TILT ANGLE

The effect of tilt angle on the Tensile strength values are shown in fig.1 for taguchi method. So the optimum tilt angle is **1^{0}**.

4.4 ROTATIONAL SPEED

The effect of rotational speed on the tensile strength values are shown infig.1for taguchi method So the optimum rotational speed is 600rpm

4.5. TRAVEL SPEED

The effect of welding speed on the tensile strength valuesareshowninfig.1 for taguchi method .So the optimum travel speed is 90 mm/min

4.6 DISSCUSSION

Taguchi method shows the variation of response using signal to noise ratio, so it can be resulted as minimization of experiments using uncontrollable parameter. The ultimate tensile strength was considered as the quality characteristic with the concept of" the larger is better"

The S/N ratio for the larger-the-better is: $S/N=-10*\log(\sum(1/Y^2)/n)$

Where is the number of measurement signal trial, in this case n=1 and is the measured value in a run. The S/N ratio values are calculated by take into consideration equation with the help of software Minitab15.

Finally we got the optimum value of parameters of welding process for maximum tensile strength which is given in the Table6

Table 4.4 : Optimum Value of Parameter According to S/N Ratio

Tilt Angle	Tool rotational speed	Travel speed	UTS
1°	600	60	209

4.7 IMPACT TEST

Charpy impact test

They impact test was tested in specimens are high tensile, medium tensile, low tensile value on tensile test value to be tested in a high impact value for sample 1 specimen in 148 joules are shown below.

As per ASTM E-23 Standard Test Methods for **Notched Bar Impact Testing of Metallic Materials1**

Table 4.5: Impact test value

S.No	Sample(no)	Impact values(joules)
1	High level(1)	148
2	Medium level(7)	120
3	Low level(9)	116

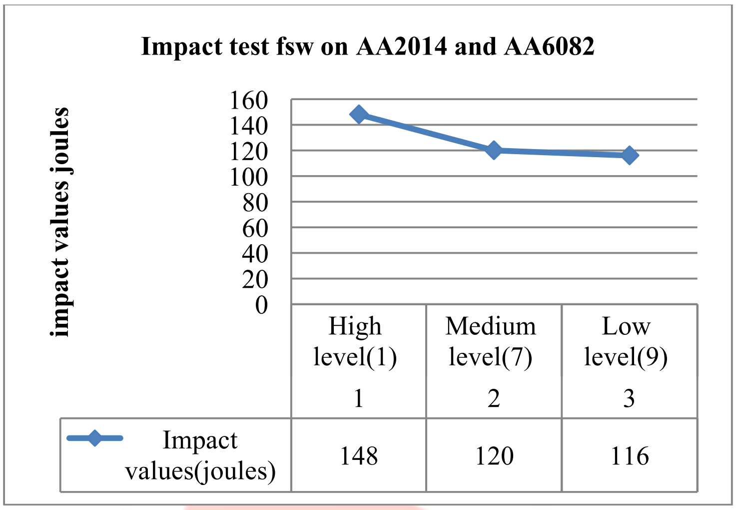


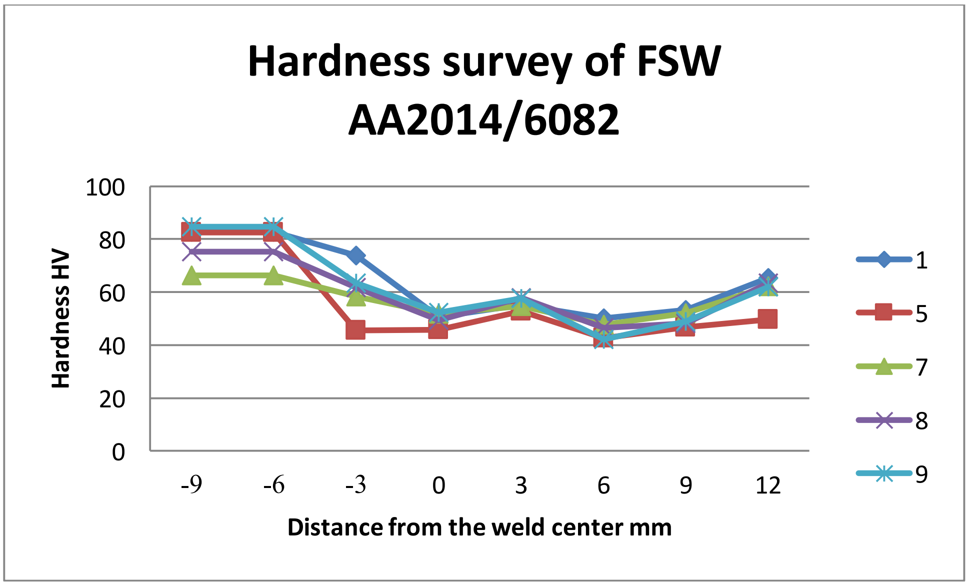
Fig :4.6 Impact specimen

4.8 MICRO HARDNESS

They below the table are shown micro hardness value for weld specimen with different zones are measured and they plot graph between hardness value vs distance from the weld centre.

Table : 4.6 micro hardness in (HV)

	1	5	7	8	9
-9	82.7	82.5	66.2	75.2	84.7
-6	82.7	82.5	66.2	75.2	84.7
-3	73.9	45.6	58.4	61.6	63.4
0	50.7	45.7	51.8	49.5	52.4
3	55.2	52.8	54.7	57.8	57.6
6	50.2	42.6	47.8	46.4	42.2
9	53.2	46.8	52.1	48.3	48.8
12	65.3	49.7	62.3	63.4	61.9



4.9 MACRO STRUCTURE

They below macro structure are evaluvated from AA2014 base metal, AA2014 HAZ, AA2014 TMAZ, weld metal, stir zone, AA6082 TMAZ, AA6082 HAZ and AA 6082 base metal. It will evaluvate in 10X magnification.

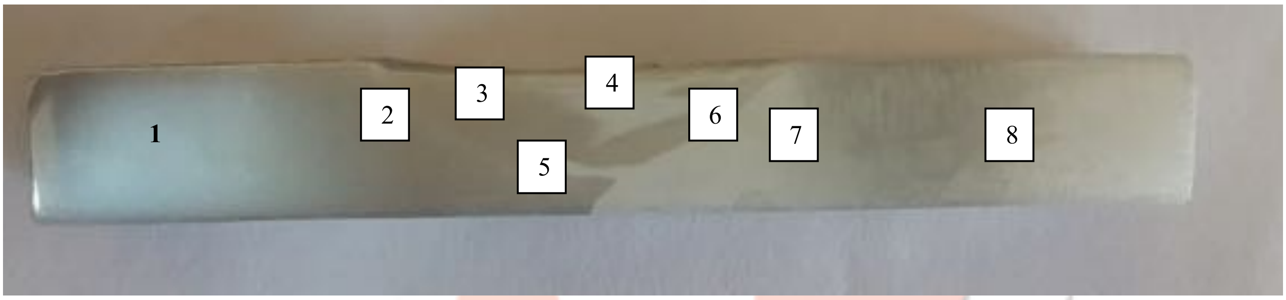


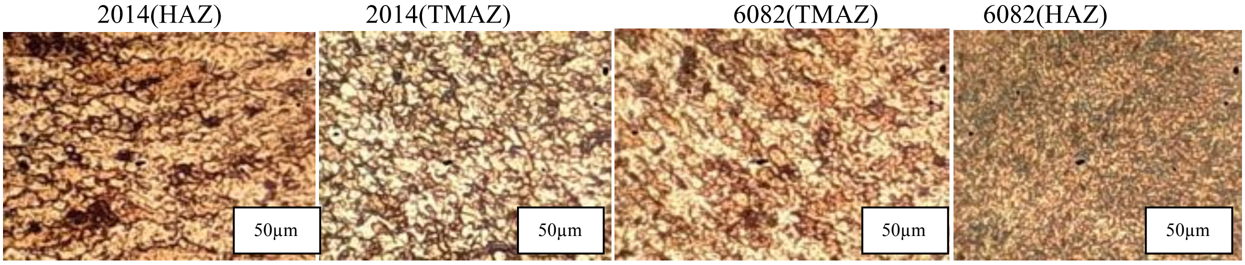
Fig no : 4.7 Macro structure for welded specimen

1. AA 2014 base metal
2. AA 2014 HAZ
3. AA 2014 TMAZ
4. Weld metal
5. Stir zone
6. AA 6082 TMAZ
7. AA6082 HAZ
8. AA 6082 base metal

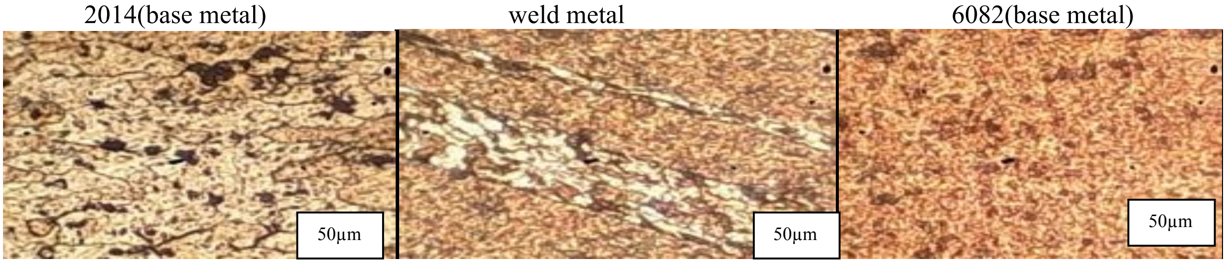
4.10 MICROSTRUCTURE ANALYSIS

- The micro structural analysis of the different zones in base metal and welded specimen is done which are base metal zone f AA6082 and AA2014and weld metal zone in 200X magnification.

2014(HAZ) 2014(TMAZ) 6082(TMAZ) 6082(HAZ)



2014(base metal) weld metal 6082(base metal)



We observe 2014 base metal, thermo mechanical heat affected zone, heat affected zone, weld metal,thermo mechanical heat affected zone, heat affected zone6082

4.10 SALT SPRAY TEST

The salt spray test is an accelerated corrosion test used to measure the comparative corrosion resistance of materials exposed to a salt spray or salt fog at high temperature. This corrosion test is intended to provide corrosion resistance information on metals and coated metals. With visual inspection following this test the suitability of coatings, paints and metals to resist corrosion or exposure to marine environments can be determined. The salt spray test is also known as ASTM B117 and fog testing.

Test parameters:

- chamber temperature:34.5 – 35.5°C
- pH Value: 6.65 – 6.85
- Volume of salt solution collected : 1.00 – 1.50 ml/hr
- Concentration of solution : 4.80 – 5.30% of Nacl
- Air pressure : 14-18 Psi
- Components loading in the Chamber Position : 30 Degree Angle

Observation:

- No White rust formation noticed up to 24 hrs .

Fig no 4.8: Salt spray test specimen

5. CONCLUSIONS

The study showed that dissimilar joints of Aluminium alloy 2014 and Aluminium alloy 6082 welded successfully by Friction Stir Welding Process to yield the required properties with out metallurgical difficulties. The following conclusions have been drawn from the study:

- The tensile strength of the dissimilar joints (AA2014&AA6082)was found. The higher tensile strength of 209MPa and it was observed that low rotational speed, lower travel speed, low tilt angle give more tensile strength.
- The optimum parameters are rotational speed of 600 rpm, welding speed of 60 mm/min and tilt angle 1degrees.
- They optimum parameters are high impact value and micro hardness values are obtained
- They salt spray test result are no white rust formation.

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