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Mechanical Properties, Welding Joints of Similar & Disimilar Aluminium Alloys Aa6061

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Abstract: This paper focuses on the mechanical properties of the welded joints of similar and dissimilar pairs of Aluminum alloys. Three different pairs (AA6061-AA6061), (AA6061-AA6082) and (AA6082- AA6082) were considered in present study. Friction stir welding (FSW) was selected for the joining of lap and butt welded parts having 200 x 100 x 5mn thick sheets each. The welds were tested by NDT tests, Liquid penetration test and the ultrasonic test, which reveals acceptance. The samples were tested by ASTM standards of tensile test, bending test, charpy impact test. The characteristics (load at yield, yield stress, tensile strength and load at sample failure) of friction stir welded material are discussed. The present study shows that composite material has highest effect on mechanical properties of the specimens taken from welded zone (W) and non-welded zone (NW).
Keywords: (FSW) Friction Stir Welding Joints, similar and dissimilar pairs of Aluminum Alloys (AA6061-6061), (AA6061-6082) and (AA6082-6082). ASTM methods (W) Welded zone, (NW) Non welded zone.

I. INTRODUCTION

Friction Stir Welding (FSW) is a hot – shear joining process in which a non-consumable rotating tool plunges into rigidly clamped work piece and moves along the joint to be welded [1]. FSW is carried out below the melting temperatures of the metals. The schematic diagram of the FSW is shown in the Figure 1.

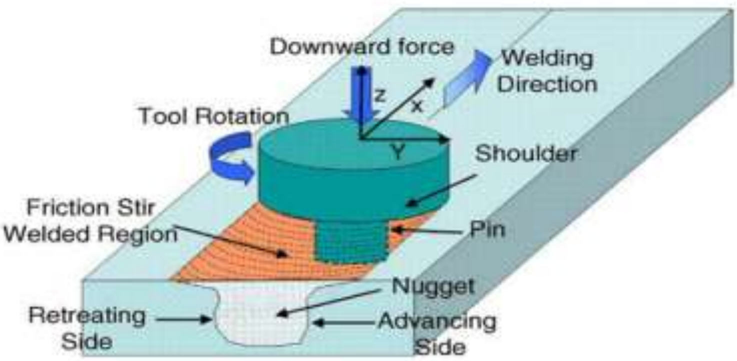

Figure 1 Schematic diagram of the Friction Stir welding process

1. Properties of Aluminum Alloys AA6061-T6 and AA6082-T6

N. Bhanodaya Kiran Babu et.al [2] discussed the chemical composition, physical properties and mechanical properties of aluminum alloys. The chemical composition of AA6061 and AA6082 are tabulated in table1, the physical properties were tabulated in table 2 and mechanical properties were tabulated in table3.

Table.1 Chemical composition of A6061-T6 & AA6082-T6

Elements	Mg	Mn	Fe	Si	Cu	Cr	zn	Al
Base Metal (6061-T6)	0.8-1.2	0.0-0.15	0.0-0.70	0.4-0.8	0.15-0.40	0.04-0.35	0.0-0.25	Balance
Base Metal (6082-T6)	0.6-1.2	0.4-1.0	0.0-0.5	0.7-1.3	0.0-0.1	0.0-0.25	0.0-0.1	0.0-0.2

Table 2 Physical Properties of AA6061-T6 & AA6082-T6

Physical property	Density (k/m^3)	Melting Point deg c	Modulus of Elasticity, Gpa	Poisson`s Ratio
Base Metal (6061-T6)	2700	660	69	0.33
Base Metal (6082-T6)	2700	555	70	0.33

Table.3 Mechanical Properties of AA6061-T6 & AA6082-T6

Mechanical Property	Yield Stress Mpa	Ultimate Tensile Strength, Mpa	Hardness Number VHN	Elongation %
Base Metal (6061-T6)	235	283	105	26.4%
Base Metal (6082-T6)	290	340	95	6 min%

II. NON-DESTRUCTIVE TESTING (NDT)

NDT is the way of testing without destroying the material the structural integrity, quality and reliability of components and plants can be ensuring [4]. NDT has extensive applications for condition monitoring, energy audit, Predictive maintenance etc.

A. Ultrasonic Testing- (UT): Ultra high frequency sound is introduced into the part being inspected and if the sound hits a material with different acoustic impedance some of the sounds will reflect back to the sending unit and can be presented on a visual display.

B. Penetrating Test: Liquid penetration testing is that when a very low viscosity liquid is applied to the surface of it will penetrate into fissures and voids open to the surface. Once the excess penetrate is removed the penetrate trapped in those voids will flow back out, creating an indication.

III. DESTRUCTIVE PHYSICAL ANALYSIS (DPA)

Tests are carried out to the specimen's failure in order to understand specimen's structural performance or material behavior under different loads.

A. Tensile Test: Test widely used to provide basic design information on the strength of materials and is an acceptance test for the specification of material. The major parameters that describe the stress – strain curve obtained during the tension test are tensile strength, yield strength, elastic modulus, resilience, toughness and Poisson's ratio [5].

B. Impact test: Notched bar Impact test of metals provide information of failure mode under high velocity leading sudden fracture where a sharp stress raiser (notch) is present. Impact test results are affected by lattice type of materials, testing temperature, thermo mechanical history, chemical composition of materials, degree of strain hardening etc.

C. Bending Test: Test will demonstrate both the quality of weld and over all ductility. Bend tests are designed so that the other outer surface of the specimen is stressed to a ductility level that approximates the minimum percent elongation in a tensile test.

IV. FSW PROCESS PARAMETERS

Many experiments are performed by taking spindle speed and feed as variable and other Parameters as Constant. Table shows details regarding FSW process parameter and tools.

Table 4 Process Parameters

Material / process parameters	AA 6061-AA6061	AA 6061-AA6082	AA 6082-AA6082
Rotational speed (RPM)	900	1120	1400

Welding Speed (mm/min)	50	50	50
Tool shoulder diameter D(mm)	18	18	18
Pin Diameter(mm)	6	6	6
Pin Length ,h(mm)	4.7	4.7	4.7
Shoulder Deepness Inserted Into The Surface Of Base Metal (mm)	0.15	0.15	0.15
Shoulder Length (mm)	40	40	40
Pitch And Included Angle Of Threaded pin	1 and 60	1 and 60	1 and 60

V. FSW PROCESS

The machine used for friction stir welding was a conventional vertical milling machine. The machine has a maximum speed of 1800 rpm and 7.4 horse power. The experiments were conducted on the Aluminum alloy 6061, Aluminum alloy 6082 of similar pair and Aluminum alloy 6061 & 6082 of dissimilar pair. Before the welding, the weld surface of base material is cleaned. Friction stir welding is done by holding the plates to be welded securely in the fixture designed so that the plates stay in place and do not fly away due to the welding forces. The rotational motion of the spindle is started and the tool is then got in contact with the surface of the plates and the pin is penetrated to a predetermined depth in between the faying surfaces of the plates to be welded. The tool is given some time as it rotates in contact with the surfaces to soften the material due to the frictional heat produced. This time is called as dwell time, and after the dwell time the forward motion is given to work -pieces which formed the weld. The tool is withdrawn after the weld is fabricated, the process leaves a hole and the design of the weld is done in such a way that the part with the hole in it is cut and not used for further processes with the welded plates. The welded joints were as shown from

Figure 2 AA 6061-AA 6061

Figure 3 AA 6082-AA 6082

Figure 4 AA 6061-AA 6082

VI. TESTING OF WELDED JOINTS

1.Tensile Test On Welded Joint: The tensile tests are done on the fabricated welds according to the standards given by the ASTM (American Society for Testing of Materials), the beginning and the end of the with holes are sheared and not used for the test purposes. The welded plates are marked for the right dimensions and sheared by using wire cut EDM. The specimens are marked for identification: the center of
the weld is identified and selected for the test specimen. The tensile test has been carried out in Universal Testing Machine (UTM). The specimen is loaded as per the standard. The specimen finally fails after necking and the ultimate tensile strength. Yield stress, and percentage of elongation have been evaluated. The tensile testing of welded joints is shown from figure 7 to figure 9.

Figure 7 AA 6061-6061 tensile tested specimen

Figure 8 AA 6082-6082 tensile tested specimen

Figure 9 AA 6061-6082 tensile tested specimen

2. Impact Test on Welded Joint: The Charpy impact test, also known as the Charpy V-notch test, is a standardized high strain-rate test which determines the amount of energy absorbed by a material during fracture. This absorbed energy is a measure of a given material's notch toughness and acts as a tool to study temperature-dependent ductile-brittle transition. The charpy impact test of welded joints is shown from figure 10 to figure 12.

Figure 10 wire cut impact test specimen

Figure.11 AA 6061-6082 impact tested specimen

Figure.12 AA 6082-6082 Impact tested specimen

3. Bend Test on Welded Joint: The mechanical resistance fall joint types and base material specimens was addressed using bending tests. These tests are very sensitive to defects near the surface of the welded, such as root flaws [6]. The bending test set up for welded joints is shown in figure 13.

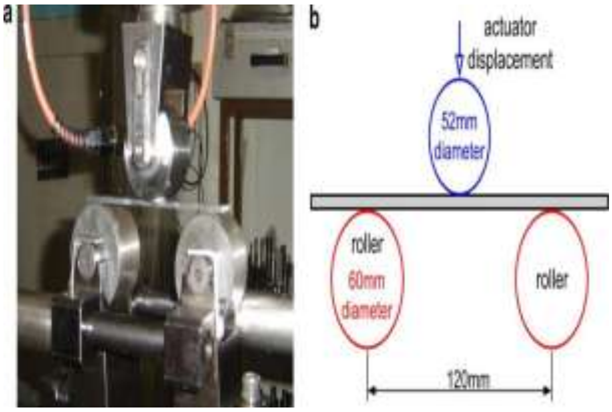

Figure 13 Testing rig :(a) bending device test assemblage; (b) Schematic representation and principal dimensions.

They were performed taking into consideration ASME code and NP EN 910 standard, using specimens with dimensions of 200mm*100mm*5mm. During the test a 1mm/min cross-head speed was used and two specimens for each type of weld and base materials were tested. The testing rig with its principal dimensions is presented in Fig. 13(b). No root flaws or other defects were detected in all joints. The load/displacement record was acquired during testing to identify the behavior of each specimen, as shown in Fig.13(a) Both base material specimens present a linear behavior until the load of approximately 420 N is reached. For loads higher than 420N, for the same displacement the AA6061-T6 presents higher mechanical resistance. The three welded joints present a linear behavior until a load of approximately 220N. The friction stir welded AA6061-T6 joint supports higher loads than the friction stir welded AA6082-T6. The dissimilar weld joint shows an intermediate behavior.

Figure 14 Bend tested specimen of AA 6061-AA6061

Figure 15 Bend tested specimen of AA 6082-AA6082

Figure 16 Bend tested specimen of AA 6061-AA6082

VII. RESULTS AND DISCUSSIONS

5.1. Results from the experimentation of FSW

After friction stir welding is carried out on the Aluminum 6061-6061 alloy, Aluminum 6082-6082 alloy and Aluminum 6061-6082 alloy samples, the work-pieces are tested for tensile strength, impact strength and bend strengths are shown from the table8 to table12.

Table 8 Friction Stir Welding Sample, Performing Tensile Test

S No	Output Data	AA6061-AA6061		AA6061-AA6082		AA6082-AA6082	
1	Load At Yield	8.94	KN	9.06	KN	9.39	KN
2	Elongation At Yield	5.330	mm	8.720	mm	8.770	mm
3	Yield Stress	137.759	N/mm2	143.525	N/mm2	159.038	N/mm 2
4	Load At Peak	11.640	KN	11.790	KN	11.760	KN
5	Cht At Peak	8.00	mm	11.410	mm	10.970	mm
6	Tensile Strength	179.364	N/mm2	186.772	N/mm2	199.179	N/mm 2
7	Load At Break	10.740	KN	10.350	KN	11.340	KN
8	Elongation At Break	9.070	mm	12.590	mm	11.580	mm
9	% Elongation	8.30%		9.52%		4.34%	

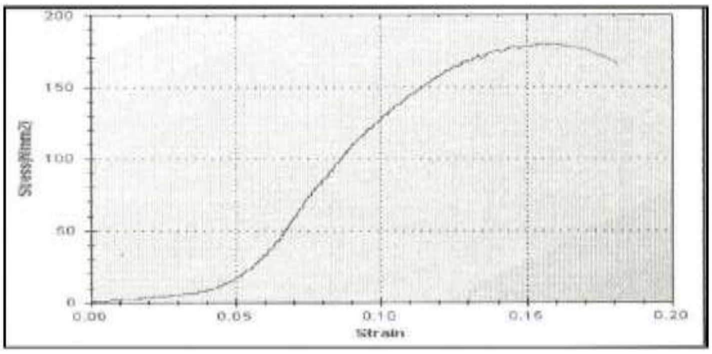

Figure 17 Tensile test graph AA6061-AA606

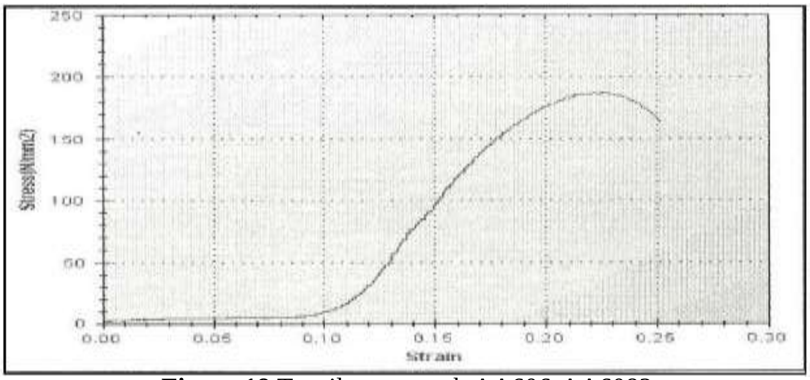

Figure 18 Tensile test graph AA606-AA6082

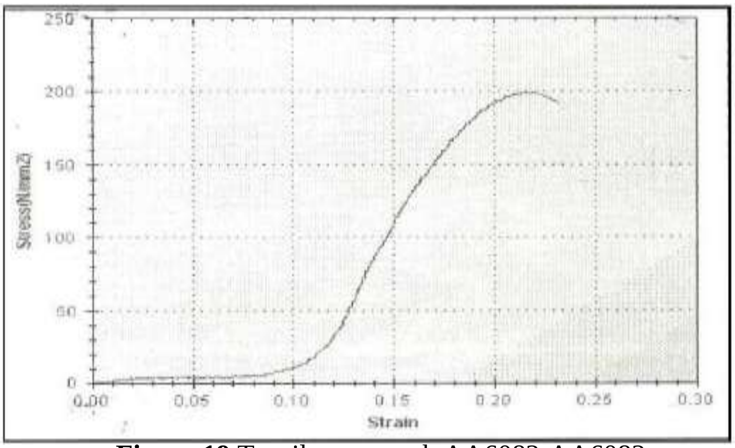

Figure 19 Tensile test graph AA6082-AA6082

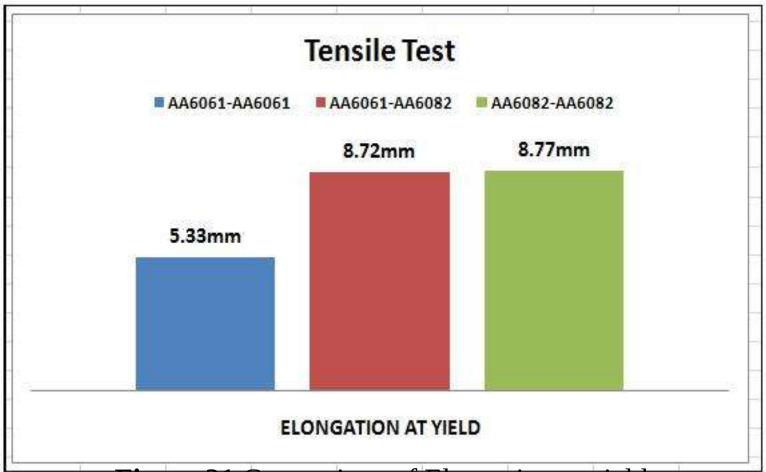

Figure 21 Comparison of Elongation at yield

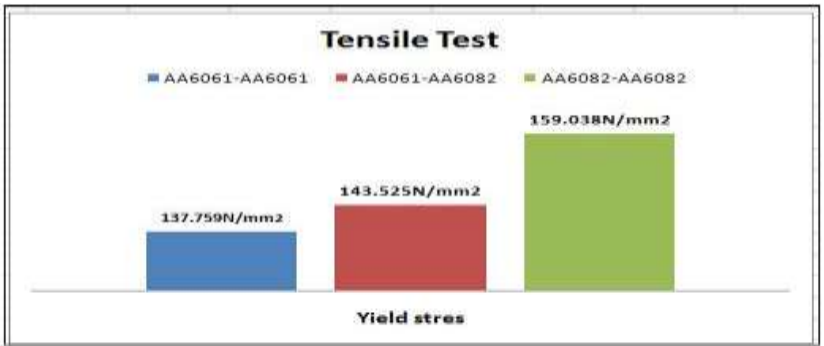

Figure 22 Comparison of Yield stress

Table 9 Friction Stir Welded Sample, Performing 3 Point Bend Test in Compression Mode

S.No	Input Data	AA6061-AA6061	AA6082-AA6082	AA6061-6082
1)	Specimen Width	19.92 mm	19.94 mm	19.90 mm
2)	Specimen Thickness	5.28 mm	4.9 mm	5.09 mm
3)	Pre Load Value	0 KN	0 KN	0 KN
4)	Max. Load	200 KN	200 KN	200 KN
5)	Max. Elongation	200 mm	200 mm	200 mm
6)	Specimen Cross Section Area	105.18 mm2	97.71 mm2	101.39 mm2

Table 10 Friction Stir Welding Sample, Performing 3 Point Bend Test In Compression Mode

S.No	Output Data	AA6061-AA6061	AA6082-AA6082	AA6061-6082
1)	Load At Peak	1.730 KN	2.130 KN	1.790 KN
2)	Cht At Peak	19.580 mm	23.970 mm	30.010 mm

Table 11 Friction Stir Welding Sample Performing Charpy Impact Test

Material	Impact Strength, Joules
AA6061-AA6061	24
AA6082-AA6082	18
AA6061-AA6082	24

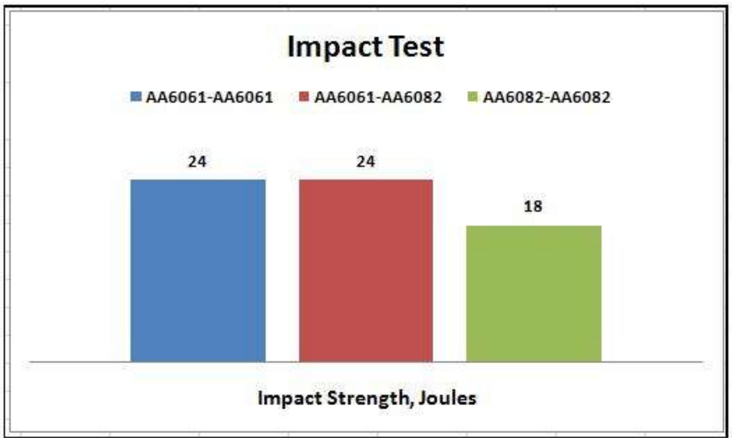

Figure 23 Comparison of impact strength

Table 12 Friction Stir Welding Sample, Performing Penetrate test

S. no	Item Description	Material	Method Used	Penetrant	Observation	Results
1	Weld plate200*100*5 mm	Al-Alloy 6061	Solvent Rermovalpenetrant	P-MET PD-130	Round indication was observed acceptable range	acceptable
	Weld	Al-Alloy	Solvent	P-MET	Round indication was	

2	plate200*100*5 mm	6082	Rermovalpenetrant	PD-130	observed acceptable range	acceptable
3	Weld plate200*100*5 mm	Al-Alloy 6061-6082	Solvent Rermovalpenetrant	P-MET PD-130	No significant indication was observed	acceptable

VIII. CONCLUSION

Mechanical Testing of Friction Stir Welded (FSW) butt joints of Aluminum Alloy 6061-T6 with 6082-T6 was carried out. For comparison, similar material and dissimilar material joints made from each one of the two alloys were used.

During tensile test the friction stir welded AA 6082-AA 6082 material has grater values of load at yield, elongation at yield, yield stress, tensile strength and load at break when compared to AA6061-AA6061 and AA6061-AA6082; Load at break, elongation at break & CHT at peak of friction stir welded AA 6061-AA 6082 has grater values when compared to AA6061-AA6061 and AA6082-AA6082 under T6 condition.

During bending test the friction stir welded AA6061-AA6082 has greater value of CHT at peak when compared to AA6061-AA6061 and AA6082-AA6082; load at peak of friction stir welded AA 6082-AA 6082 has grater values when compared to AA6061-AA6061 and AA6061-AA6082 under T6 condition.

For loads higher than 420N, for the same displacement the AA6061-T6 presents higher mechanical resistance. The three welded joints present a linear behavior until a load of approximately 220N. The friction stir welded AA6061-T6 joint supports higher loads than the friction stir welded AA6082-T6. The dissimilar weld joint shows an intermediate behavior.

During charpy impact test the impact strengths of AA6061-AA6061 & AA6061-6082 have similar values and AA6082-AA6082 has least value of strength.

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