A Study of Aluminium 6082 & Brass 319 Materials by Friction Stir Welding Process

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Abstract — *This paper contains the report of study of Aluminium-6082 to Aluminium-6082 and Brass-319 to Brass-319 welding joints weld by Friction stir welding process. The size of the work pieces used for the welding is (50mm x 35mm x 5mm) . Friction stir welding process allows achieving high quality joint when compared to conventional welding process. This paper mainly focuses on the welded joints of Aluminium and Brass.The main welding parameters which have a great influence on welding joints are Rotational speed, transverse speed and depth of cut. In this study the Rotational speed of the tool were varied from 710 to 1120 Rpm and tranverse speed were kept at 20 mm/min and depth of cut is maintained at 4.5mm throughout the experiment. The welded joints were then subjected to mechanical testing such as tensile testing,hardening test and microscopy of the welded joints.As per the reports of tensile testing,hardening test the welded joint of Aluminium is having high strength at the optimum speed of 900Rpm and the corresponding tensile strength is 173.19N/mm^2. For Brass the joint having high strength when the speed is 710 Rpm and the respective tensile strength is 231.360N/mm^2. Then the microscopy test is conducted as per the Standard of ASTME112 on the high tensile strength welded joints at 200x magnification and then brinells hardness test is conducted on the samples.*

Keywords — *Similar materials,tensile strength,Microstructure, Brinells hardness Mechanical Properties, and FSW.*

I. Introduction

FRICTION STIR WELDING (FSW) IS A SOLID STATE PROCESS FOR JOINING SIMILAR OR DISSIMILAR MATERIALS. IT WAS DEVELOPED BY THE WELDING INSTITUTE AND FIRST REPORTED BY W. THOMAS IN 1991. FSW IS INITIALLY USED TO WELD ALUMINIUM AND ITS ALLOYS BECAUSE THE DEFECTS LIKE POROSITY, ALLOY SEGREGATION, HOT CRACKING, HYDROGEN ENTRAPMENT ETC. ARE NOT ENCOUNTERED WITH THIS PROCESS THOSE ARE MAINLY APPEARED IN FUSION WELDING PROCESSES. FRICTION STIR WELDING IS A UNIQUE WELDING METHOD AND NEW INVENTION IN THE WELDING TECHNOLOGY WORLD. MOST OF THE RESEARCHERS CONTRIBUTED TOWARDS FINDING THE OPTIMUM RANGE OF DIFFERENT PROCESS PARAMETERS TO AVOID DEFECTS. IN THE FRICTION STIR WELDING THE WELDING PARAMETERS WERE THE IMPORTANT CRITERION WHICH DECIDES THE QUALITY OF THE WELD. A PROPER SELECTION OF WELDING PARAMETER ENSURES THE GOOD WELDING CONDITION AND THE FRICTION STIR WELDED PLATES OBVIOUSLY HAVE GOOD MECHANICAL PROPERTIES IRRESPECTIVE OF SELECTION OF MATERIALS.FSW WILL NOT CHANGE THE MICROSTRUCTURE OF THE METAL DIVERSE UNLIKE THE CONVENTIONAL WELDING. IT ALSO CAN REDUCE THE COST OF WELDING IF COMPARED TO THE CONVENTIONAL WELDING COST. IT INVOLVES THE JOINING OF METALS WITHOUT FUSION OR FILLER MATERIALS. IT IS USED ALREADY IN ROUTINE, AS WELL AS CRITICAL

APPLICATIONS, FOR THE JOINING OF STRUCTURAL COMPONENTS MADE OF ALUMINIUM, COPPER AND BRASS.

TABLE I

CHEMICAL COMPOSITION OF ALUMINIUM 6082.

Material	Silicon	Iron	Zinc	Copper	Aluminium
Aluminium 6082	0.70-1.30	0.5	0.15	0.10	Balance

TABLE II

CHEMICAL COMPOSITION OF BRASS 319

Material	Copper	Iron	Lead	zinc	Other Materials
Cuzn30	56-59	0.35(max)	2-3.5	Balance	0.7

In the previous studies High Speed Steel is used as tool material .In our study we are selecting High carbon High Chromium as tool material because it has more Rockwell hardness ,high melting point temperature and high density compare to High speed steel.

Since FSW is essentially solid-state, i.e. without melting high quality weld can generally be fabricated with absence of solidification ion cracking, porosity, oxidation and other defects typical to traditional fusion welding. Friction stir welding was used to control properties in structural metals including aluminium and the other nonferrous alloys. The pin may have a diameter one-third of the tapered tool shoulder. Aluminium and Brass metal are most widely used in industrial and engineering application.

A non-consumable rotating tool with a specially designed pin and shoulder is inserted into the abutting edges of sheets or plates (rectangular or circular) to be joined and traversed along the line of joint.

The tool serves two primary functions:

(a) Heating of work pieces (plates)

(b) Movement of material between two materials in a mushy state to produce a joint.

The fundamental difference between conventional fusion welding techniques and the solid-state friction stir welding technique is that no heat is added to the system in the later instead heat is generated internally by means of friction at the tool-material interface resulting in the plastic deformation of the material around the stir zone.

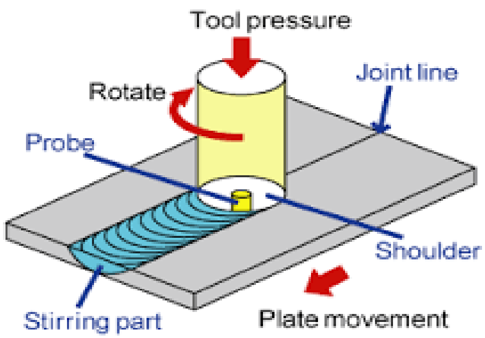


Fig.1. A Schematic of Friction Stir Welding.

II. EXPERIMENTAL PROCEDURE

A. *Work piece*

The plate size of work pieces Al-6082 and Brass-319 are having 50mm length, 35 mm width and 5mm thickness. Aluminium to Aluminium and Brass to brass with dimensions (50mm x 35mm x 5mm). The edges of the plates were prepared by machining. The plates were fixed in butt joint configuration to fabricate FSW joints. To perform the welding process a Universal milling machine was used.

TABLE III

PROPERTIES OF WORK PIECE MATERIAL.

Material	Tensile Strength (N/mm^2)	Thermal Conductivity (W/mK)	Melting Point Temp (^0C)	Density (g/cm^3)
Al 6082	140-330	180	555	2.70
Br 319	380	109	900	8.55

Images of work pieces Before Welding.

B. *Tool*

In the present work D2 or HCHC(High carbon high chromium) tool is used. The tool is having cylindrical Straight Shoulder and pin.

TABLE IV
PROPERTIES OF TOOL MATERIAL.

Material	Thermal conductivity (W/mK)	Hardness (HRC)	Density (g/cm^3)
D2 (or) High Carbon High Chromium	41.5	62	7.695

The tool is designed in Creo 2.2 as per Required.

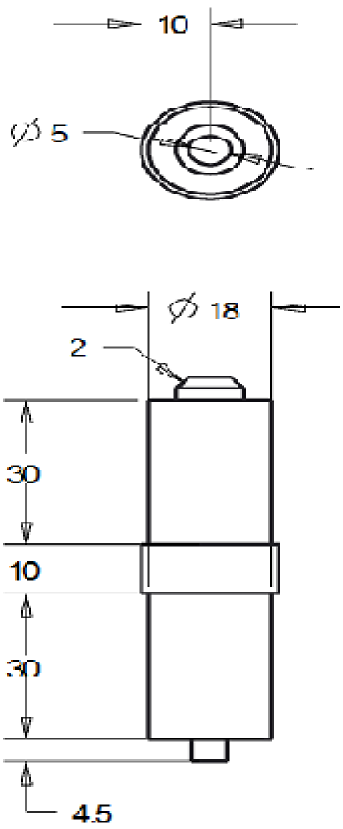


Fig.2. Design of Tool In Creo 2.2

TABLE V
DIMENSIONS OF TOOL

Parameter	Value
Shoulder Diameter (mm)	18
Shoulder Length (mm)	70
Pin Diameter (mm)	5
Pin Length (mm)	4.5
Collar Diameter (mm)	20
Collar length (mm)	10
Taper (mm)	2

Turning operation is carried on Turret lathe. The turret lathe having parameters as single phase,1.5 hp Induction motor which rotates at 1200 rpm.After turning the tool is send to foundry for tempering .Here the tool is heated to high temperature in the range of 900 to 1200^o C.The tool is hardened by application of oil.Then finishing operation is done on the tool by using grinding machine. After finishing the tool is ready for welding operation.

C. Welding

Vertical milling machine of 7kW is used to join the similar plates.Initally the tool is fixed in the chuck of milling machine and then required supports, fixtures are adjusted on the work bench of milling machine to fix the work samples.

TABLE VI
PARAMETERS OF WELDING

Parameters	Experiment-1 (Al-6082 to Al-6082)	Experiment-2 (Brass 319 to Brass 319)
Rotational Speed (Rpm)	710,900 & 1120	710,900 & 1120
Transverse Speed (mm/min)	20	20
Tilt angle (Degree)	1	1
Depth of Cut (mm)	4.5	4.5

D. Testing

After welding the specimens were prepared by using Wire EDM to cut the material and universal testing machine is used to test the mechanical properties such as ultimate tensile strength, yield strength, elongation % and Hardness. Tilt angle as 1 degree, offset were kept constant.

For micro structural evaluation Work piece Samples are prepared by Hyderabad Engineering Labs Balanagar and the Brinells micro hardness tests was also performed, by the load of 250 g on the cross section of joints and perpendicular to the welding direction. To make better estimation of the compositional region of the joint, micro hardness test was taken from multiple points. Specimens were prepared as per ASTME112 for microstructural investigation, microstructure are measured on Computerized Metallurgical Microscope

E. Input Data

TABLE VII
INPUT DATA OF EXPERIMENTS

Parameters	**Experiment-1 (Al-6082 to Al-6082)**	**Experiment-2 (Brass319 to Brass319)**
Thickness (mm)	5	5
Length (mm)	50	50
Width (mm)	35	35
Rotational Speed (Rpm)	710,900 & 1120	710,900 & 1120
Feed Rate (mm/min)	20	20
Tilt Angle (Degree)	1	1

III. RESULT & DISCUSSION:

The following results were obtained after conducting the mechanical tests on universal testing machine of joints (Al-6082 to Al-60820) and (Brass 319 to Brass 319).

Blow Images of Joints After Welding.

Images of work pieces After Welding.

A. Tensile Strength Evaluations

TABLE VIII

Output Data of Experiment -1
(Aluminium-6082 to Alluminium-6082)

Parameters	**Speed**		
	710 Rpm	**900 Rpm**	**1120 Rpm**
Ultimate Load (kN)	13.360	**13.440**	14.040
Ultimate Tensile Strength (N/mm^2)	154.326	**173.196**	166.924
Elongation (%)	9.900	**10.600**	10.520
Yield load (kN)	9.240	**11.040**	10.040
Yield Stress (N/mm^2)	106.734	**142.268**	119.367

TABLE IX

Output Data of Experiment- 2
(Brass 319 to Brass 319)

Parameters	**Speed**		
	710 Rpm	**900 Rpm**	**1120 Rpm**
Ultimate Load (kN)	**16.880**	14.120	15.440
Ultimate Tensile Strength (N/mm^2)	**231.360**	188.720	194.679
Elongation (%)	**4.500**	4.400	2.640
Yield load (kN)	**11.280**	9.560	8.520
Yield Stress (N/mm^2)	**154.605**	127.773	107.427

As seen above tables the tensile strength is maximum in joint of (Al-6082 to Al-6082) is at 900 Rpm which is equal to **173.196** (N/mm^2) where as in joint of (Brass to Brass) the maximum tensile strength is observed at 710 rpm which is equal to **231.360** (N/mm^2).

Now plot the graph between Load vs Displacement to show the variations in strength of welded joints.

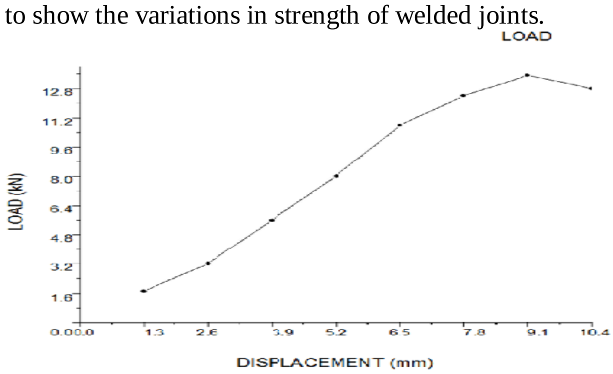


Fig 3. Graph of Aluminium 6082 to 6082 at 900 Rpm.

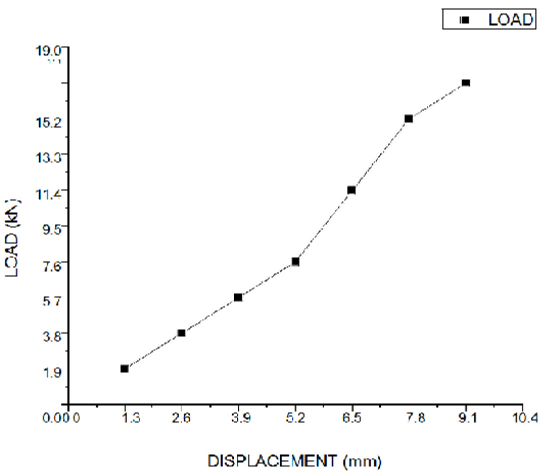
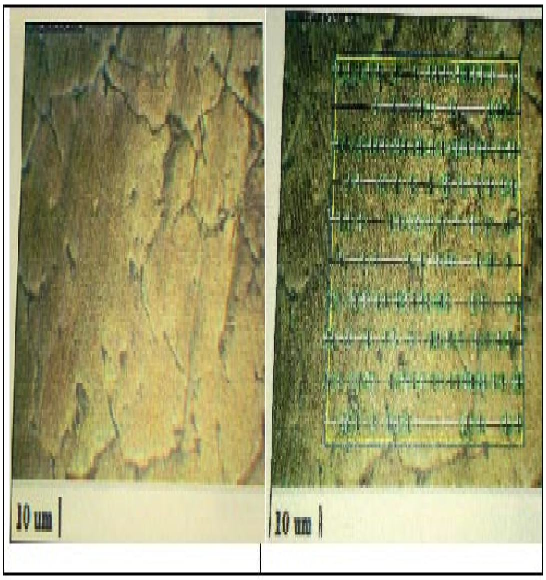


Fig 4. Graph of Brass 319 to Brass 319 at 710 Rpm.

B. Microstructure Analysis

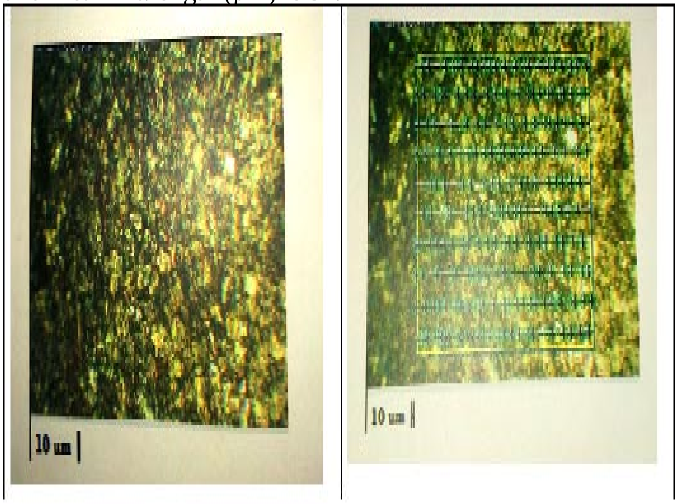
For Experiment 1
(Aluminium6082 to Aluminium6082)

The 200x magnification has been carried out at Center of weld At the Centre of weld Microstructure consists of uniformly Equi axed and Script Like Structure. Cracks and porosity are seen. Lack of fusion more a length of the root. Holes are also be seen in microstructure. And grain size according to ASTM E112 the number is 6 and intercept is 164 and mean Int.length (μm) is 43.2.



For Experiment 2
(Brass 319 to Brass 319)

The 200x magnification has been carried out at Center of weld dendrites of brass solid solutions with fine particles of grains are seen. The sample had microstructure of Equi Axed grains and Script like Structures and grain size according to ASTM E112 the number is 6.5 and intercept is 221 and mean Int.length (μm) is 32.



C. Microhardness

The Microhardness test is evaluated by Brinell hardness method shown below.

$$BHN = \frac{F}{\frac{\pi}{2}D.(D\sqrt{D^2 - d^2})}$$

Where

BHN = Brinells Hardness number.
D = Diameter of the Steel ball in (mm)
d = Diameter of Impression in (mm).
f = Load Applied in(kgf)

Diameter of Ball=5mm, Load=250kgf, F/D^2=10

Using Above values as references we find out the hardness of joint and Used Test Procedure is IS 1500:2005

TABLE X
Hardness of (Al-6082 to Al-6082) Joint at of Speed 900 Rpm

SI.No	Location	Observed value in BHN			
		1	2	3	**Avg**
1	Weld Zone	56.8	57.3	56.3	**56.80**
2	Base Metal	68.8	68.2	69.5	**68.83**

TABLE XI
Hardness of (Br 319 to Br 319) Joint at of Speed 710 Rpm

SI.No	Location	Observed value in BHN			
		1	2	3	Avg
1	Weld Zone	96.1	95.0	97.2	**96.10**
2	Base Metal	89.7	90.7	91.8	**90.73**

IV. CONCLUSIONS

Friction Stir Welding is performed to join 5mm thick plates of 6082 Aluminium to Aluminium And Brass to Brass (as per 319) with varied parameters (like, tool rotation speed (rpm), welding speed (mm/ min) and the joining conditions are characterized. All welds were defect free. Microstructure of weld and Micro hardness were shown at center of weld. Tensile strength was good. Brass to Brass has high strength rather than Aluminium to Aluminium.

As welding Speed Increases After 900 Rpm in Aluminium 6082 joint ,the Strength of the weld decreases. Where as in Brass 319 joint the strength of the weld decreases after 710 Rpm.

Finally we conclude that as welding speed increases the strength of the weld decreases.

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