Effect of Friction Stir Welding Parameters on the Mechanical and Microstructure Properties of Dissimilar Metals

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Abstract— Friction Stir Welding (FSW) is a solid-state welding process used for welding similar and dissimilar materials. FSW is especially suitable to join sheet Al alloys and this technique allows different materials couples to be welded continuously. In this study, 6061 Al alloys and commercially pure Cu and Al alloy 6061 to Brass were produced at four different tool rotation speeds (710, 900, 1000, 1120 rpm) and different tool traverse speeds (10-60 mm/min) Copper and aluminium are important metals for the electrical industry due to their good electrical and thermal conductivity as well as high corrosion resistance and mechanical properties. Brass materials are widely used as engineering materials in industry because of their high electrical and thermal conductivity, high strength, and high corrosion resistance. The aim of present study was analogy of the microstructures and mechanical properties of friction stir welded joint of Aluminium to Copper and Aluminium to Brass plates in 4mm thickness.

Key words: Aluminium 6061, Pure Copper, Brass (CuZn30), Materials, Microstructure, Micro Hardness and Mechanical Properties, FSW

I. INTRODUCTION

Friction Stir Welding (FSW) is a unique welding method and new invention for the welding technology world. FSW will not change the microstructure of the metal diverse unlike the conventional welding. It also can reduce the cost 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. Since FSW is essentially solid-state, i.e. without melting high quality weld can generally be fabricated with absence of solidification 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.

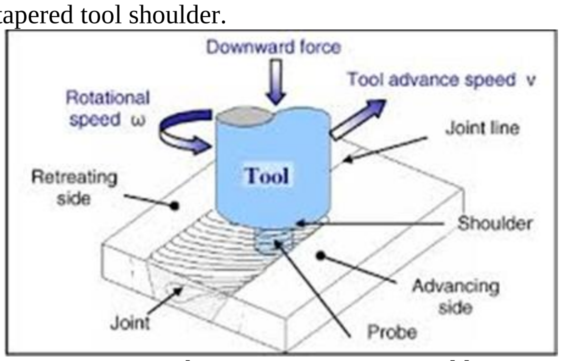

Fig. 1: A Schematic Friction Stir Welding

In friction stir welding process a non-consumable rotating tool with tapered pin and shoulder is inserted into abutting edges of plates. A non-consumable spinning tool bit is inserted into a work piece. The rotation of the tool creates friction that heats the material to a plastic state. As the tool traverses the weld joint, it extrudes material in a distinctive flow pattern and forges the material in its wake. The resulting solid phase bond joins the two pieces into one.

II. EXPERIMENTAL PROCEDURE

Vertical milling machine of 7Kw is used to join the dissimilar plates. The plate size of Al6061 and pure copper are having 100mm length, 70mm width and 4mm thickness. Aluminium to Brass with dimensions (100mm x 70mm x 4mm) .In the present work H13 tool is used. The tool is having tapered shoulder and pin. For micro structural evaluation samples prepared by Raghavendra Spectro Metallrgical Laboratory, Hyd and microstructure were measured on Optical Metallurgical Microscope (Met Scope-1).The micrographs were taken at 100x magnification. The Vickers micro hardness was measured by using Hardwood HWMMT-X7 micro hardness tester.

Shoulder Diameter (SD)	Pin Diameter (PD)	Pin Length (PL)
25mm	6mm	3.6mm

Table 1: H13 tool dimensions

6061 Al	Si 0.80, Fe 0.70, Cu 0.40, Mn 0.15, Mg1.2, Cr 0.35, Zn 0.25, Ti 0.15, Al balance
Brass	Zn 30, Cu rest
Copper	Bi 0.001, O 0.04, Pb0.0005, Cu rest

Table 2: Chemical composition of 6061 Aluminium, Pure Copper and Brass (ZnCu30)

Properties	Alumunium (Al)	Copper (Cu)	Brass
Tensile Strength(Mpa)	111.20	231.38	350.46
Elongation (%)	14.98	41.03	53.42
Hardness (HV)	41	88	75

Table 3: Mechanical Properties of Al, Cu and Brass

	Unit	Experiment 1	Experiment 2
Rotation Speed	Rpm	710, 900, 1000,1120	710,900,1000, 1120
Transverse Speed	mm/ min	10-60	10-60
Offset	Mm	1	1
Plunge depth	Mm	3	3

Table 4: Process parameters

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

A. Input Data
- Material: Dissimilar
- Thickness: 4mm
- Length: 100mm
- Width: 70mm
- Rotational Speed: 710,900, 1000 and 1120 rpm
- Feed: 10-60 mm/min
- Experiment 1: Aluminium to Copper
- Experiment 2: Aluminium to Brass

III. RESULTS AND DISCUSSIONS

The following results were obtained after conducting the mechanical tests on FSW of Aluminium - Copper and Aluminium – Brass metals.

A. Output Data for Experiment 1 (710, 900, 1000 & 1120 rpm)

1) For 710 rpm
- Ultimate Tensile strength: 37.69 N/mm²
- Yield Strength: 29.808 N/mm²
- % Elongation: 0.42%

2) For 900 rpm
- Ultimate Tensile strength: 55.89 N/mm²
- Yield Strength: 40.5 N/mm²
- % Elongation: 0.62%

3) For 1000 rpm
- Ultimate Tensile strength: 62.78 N/mm²
- Yield Strength: 49.8 N/mm²
- % Elongation: 0.72 %

4) For 1120 rpm
- Ultimate Tensile strength: 76.80 N/mm²
- Yield Strength: 60.6 N/mm²
- % Elongation: 0.81%

B. Output Data for Experiment 2 (710, 900, 1000 & 1120 rpm)

1) For 710 rpm
- Ultimate Tensile strength: 73.15 N/mm²
- Yield Strength: 55.118 N/mm²
- % Elongation: 0.64%

2) For 900 rpm
- Ultimate Tensile strength: 90.19 N/mm²
- Yield Strength: 72.9 N/mm²
- % Elongation: 0.82%

3) For 1000 rpm
- Ultimate Tensile strength: 98.20 N/mm²
- Yield Strength: 82.7 N/mm²
- % Elongation: 0.90 %

4) For 1120 rpm
- Ultimate Tensile strength: 108.56 N/mm²
- Yield Strength: 89.9 N/mm²
- % Elongation: 0.98%

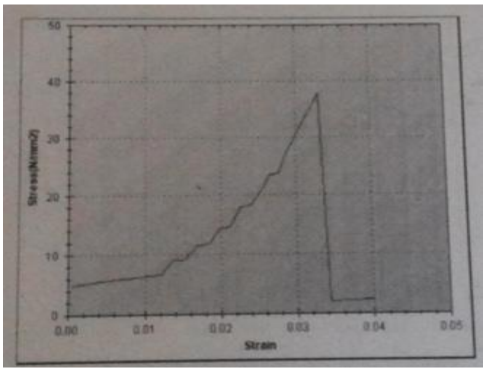

Fig. 2: Graph for Al-Cu at 710rpm

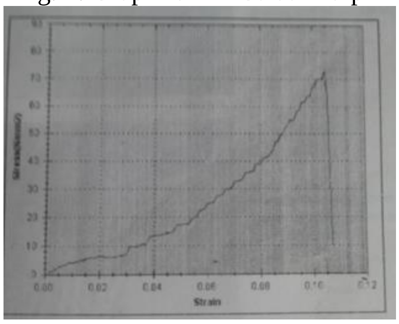

Fig. 3: Graph for Al-Brass at 710 rpm

C. Microstructure Analysis

FSW is being targeted by the industry for structurally demanding applications to provide high performance benefits.

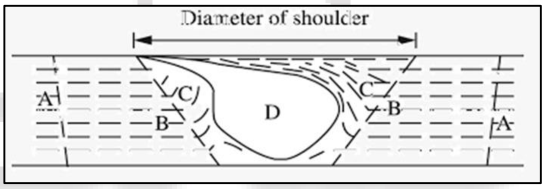

Fig. 4: Typical weld cross-sections with four different zones in FSW

- A: Unaffected zone
- B: HAZ (Heat affected zone)
- C: TMAZ (Thermo-mechanically affected zone)
- D: Weld nugget

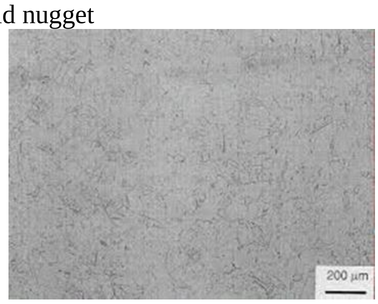

Fig. 5: Microstructure of BM of Al 6061

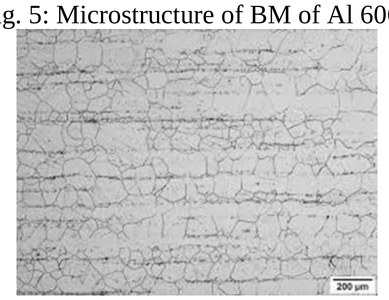

Fig. 6: Microstructure of BM of Pure Copper

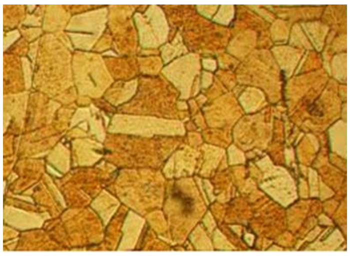

Fig. 7: Microstructure of BM of Brass

1) For Experiment 1

Microstructure of weld taken at centre of weld with or without filler materials. At the centre of weld a line mix region of aluminium and copper were found. Microstructure consists of uniformly distributed fine intermetallic particles in a matrix of aluminium solid solution. Cracks and porosity are seen. Lack of fusion more a length of the root.

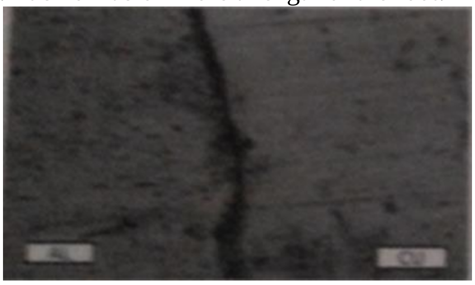

Fig. 8: Microstructure Distribution at centre of Weld at 100x for 710rpm

2) For Experiment 2

The 100x magnification has been carried out at Center of weld dendrites of brass solid solutions with fine particles of grains are seen. Blow holes and cracks are observed.

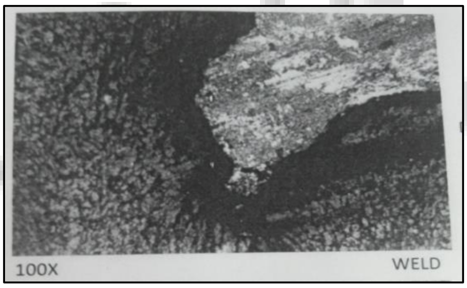

Fig. 9: Microstructure Distribution at Center of Weld at 100x for 710 rpm

D. Microhardness

Vicker's hardness of the final polished samples were measured by indentation test, with square base diamond base indenter which under the application of 5kg load with a dwell time of 10 sec. Then the diagonals of the indent formed on the material surface (Dissimilar metals) were measured.

The Microhardness test is evaluated by Vickers shown below.

1) For Experiment 1:

- For 710 rpm: 370HV
- For 900 rpm: 410HV
- For 1000 rpm: 420 HV
- For 1120 rpm: 440HV

2) For Experiment 2:

- For 710 rpm: 400HV
- For 900 rpm: 440HV
- For 1000 rpm: 490 HV
- For 1120 rpm: 510HV

IV. Conclusion

Friction Stir Welding is performed to join 4mm thick plates of 6061 Aluminium to Pure Copper and Aluminium to brass (CuZn30) 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 centre of weld. Tensile strength was good. Aluminium to Brass has high strength comparative to Aluminium to copper.

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