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JOINING OF ALUMINIUM TO COPPER BY FRICTION STIR WELDING

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Abstract-The aim of present study was to analyze the influence of the microstructures and mechanical properties of friction stir welded joint of 6082 aluminium alloy and pure copper plates in 3 mm thickness with using Zinc, Tin, Silicon Carbide and Rare earth filler materials. With this aim, welds were produced using High molybdenum high speed steel, with a cylindrical pin tool having 3 mm and 14 mm diameter of pin and shoulder respectively. The microstructures of weld were studied by optical microscopy and grain size in TMAZ, HAZ and NZ were analyzed. Vicker's microhardness tests were done in transverse direction of weld to check the hardness distribution in HAZ, TMAZ and weld nugget. Transverse tensile test were performed to evaluate the weakest portion of weld joints.

Key words: Friction Stir Welding, Aluminium alloy, Pure Copper, Hardness, Tensile testing

I. INTRODUCTION

Friction stir welding (FSW) is a relatively new solid-state joining process. This joining technique is energy efficient, environment friendly and versatile [1]. In particular, it can be used to join high-strength aerospace aluminum alloys and other metallic alloys that are difficult to weld by conventional fusion welding [2]. FSW is considered to be the most significant development in metal joining in a decade and is a ''green'' technology [3]. Welding of dissimilar alloys is difficult due to variation in thermal and physical properties of parent metals. Joining of dissimilar alloys is possible by various fusion and solid state welding techniques. However, fusion welding techniques are not suitable due to melting related defects such as - porosity and formation of brittle intermetallics. Diffusion welding is time consuming process while there is limitation on parent metal thickness incase of ultrasonic welding. Therefore, friction stir welding is most suitable technique of joining dissimilar alloys among all techniques.

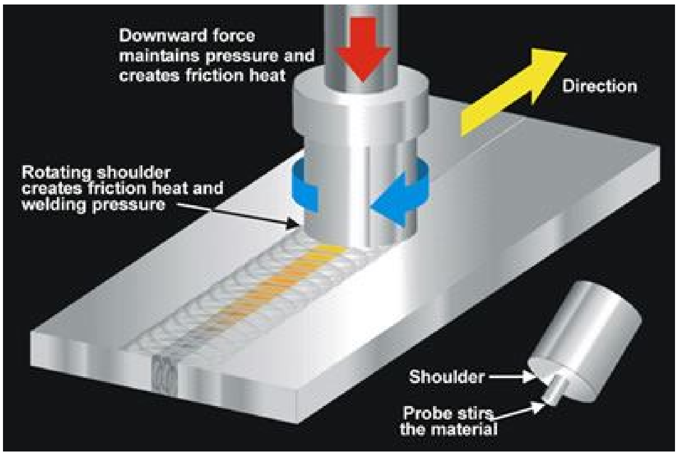


Figure: 1 Schematic diagram of FSW

In friction stir welding process a rotating pin emerging from a cylindrical shoulder is plunged between two edges of sheets to be joined and moved forward along the joint line. The material is heated by friction between the rotating shoulder and the work piece surface and simultaneously stirred by the profiled pin leaving a solid phase bond between the two pieces to be joined. Special preparations of the weld seam and filler wires are not required.

During friction stir welding, Advancing and retreating side orientations require knowledge of the tool rotation and travel directions. In schematic of Fig.1, the FSW tool rotates in the clockwise direction and travels into the page (or left to right).The advancing side is on the left, where the tool rotation direction is the same as the tool travel direction (opposite the direction of metal flow). The retreating side is on the right, where the tool rotation is opposite the tool travel direction (parallel to the direction of metal flow) [2].

The tool serves three primary functions: (1) heating of the work piece (2) movement of material to produce the joint, and (3) containment of the hot metal beneath the tool shoulder. Heat is generated within the work piece both by friction between the rotating tool pin and shoulder and by severe plastic deformation of the work piece. The localized heating softens material around the pin and, combined with the tool rotation and translation, leads to movement of material from the front to the back of the pin, thus filling the hole in the tool wake as the tool moves forward. The tool shoulder restricts metal flow to a level equivalent to the shoulder position, that is, approximately to the initial work piece top surface.

As a result of the tool action and influence on the work piece, a solid-state joint is produced. Because of various geometrical features on the tool, material movement around the pin can be complex, with gradients in strain, temperature, and strain rate. Accordingly, the resulting nugget zone microstructure reflects these different thermomechanical histories and is not homogeneous. In spite of the local microstructural inhomogeneity, one of the significant benefits of this solid-state welding technique is the fully recrystallized, equiaxed, fine grain microstructure created in the nugget by the intense plastic deformation at elevated temperature.

II. DIFFICULTIES IN WELDING OF ALUMINIUM TO COPPER

Aluminium and Copper are widely applied in engineering structure due to unique performances such as higher electric conductivity, heat conductivity, corrosion resistance and mechanical properties. However, the melting points of both materials have a significant difference. This may lead to a large difference in microstructure and performance of Al-Cu joints if copper and aluminium would be joined. Moreover, the Al was easily oxidized at an elevated temperature, and some welding cracks existed easily in a joint of brazed or fusion welding Cu.Therefore, a high quality weld joint of Al/Cu was difficult to obtain by means of conventional welding methods. During fusion welding or pressure welding (brazing, diffusion bonding, etc), the Cu-Al intermetallics, which resulted in decreased mechanical properties of joints, is very difficult to be avoided in Al/Cu dissimilar materials joint.

III. EXPERIMENTAL PROCEDURE

The plate size of aluminium and copper are same and having 150 mm length, 100 mm width and 3 mm thickness. The welding was carried out at constant rotation speed of 1000 rpm and constant feed rate of 28 mm/min. In the present work high molybdenum high speed steel tool is used. The tool was having concave shoulder. The tool shoulder diameter was kept 14 mm with 2.7 mm pin length and 3 mm pin diameter. The tool pin was cylindrical. For microstructural evaluation, samples prepared by the MEAT HEAT ENGINEERING, Vadodara and microstructure were measured on Metzer makes Optical Microscope. The micrographs were taken at 400X magnification. The Vickers microhardness was measured by using HARDWOOD HWMMT-X7 microhardness tester. The measurements were made along the cross-sections of the welds surface with a load of 200Kgf and a dwell time of 10 seconds. For tensile testing standard tensile specimens as per ASTM-E8-04 were cut in transverse direction to weld centerline.

IV. RESULT AND DISCUSSION

1. WELDS OBTAINED

Welds were obtained according to the experimental design with using filler materials and without filler materials. All welds were defect free. The intermixing of metals was also found in the welded samples. During the FSW process, the materials were transported from the advancing side to retreating side behind the pin where the weld was formed. Hardness of the copper was larger than the aluminium, and due to the pin stirring action the aluminium gets displaced in the weld.

2. Microstructural Characteristics

Microstructure of weld taken at NZ, TMAZ and HZ regions with or without filler materials. At the weld centre line mix region of Aluminium and copper were found. Small particles of aluminium and copper were distributed in opposite side by the stirring forces of tool. Small fine grain structure with porosity observed at joining of Al/Al with or without filler materials. At NZ Onion ring found at joining of Al/Cu with Zinc filler material due to movement of material with the tool pin and temperature generated in weld.

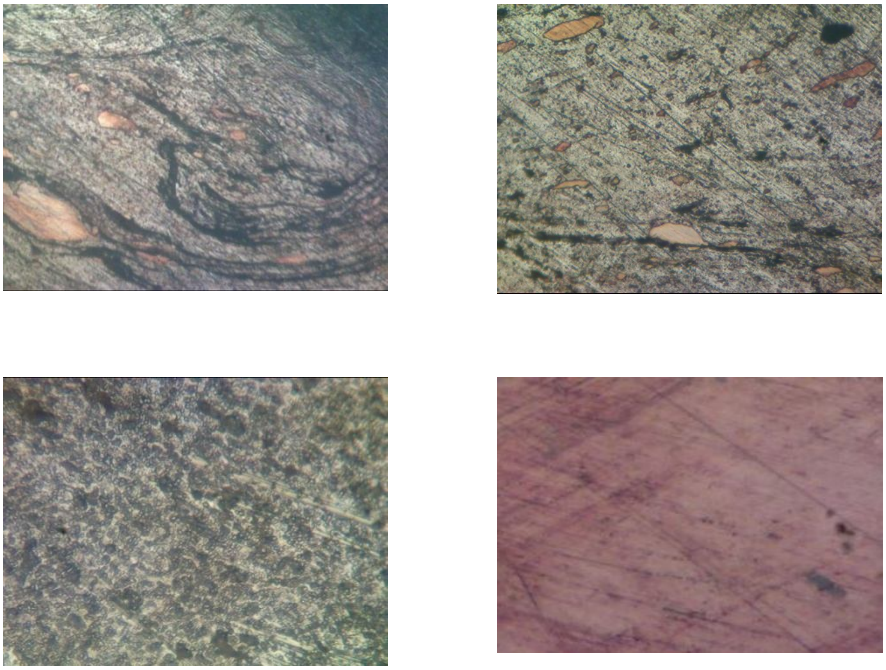


Figure: 2 Microstructure of NZ, TMAZ and HZ

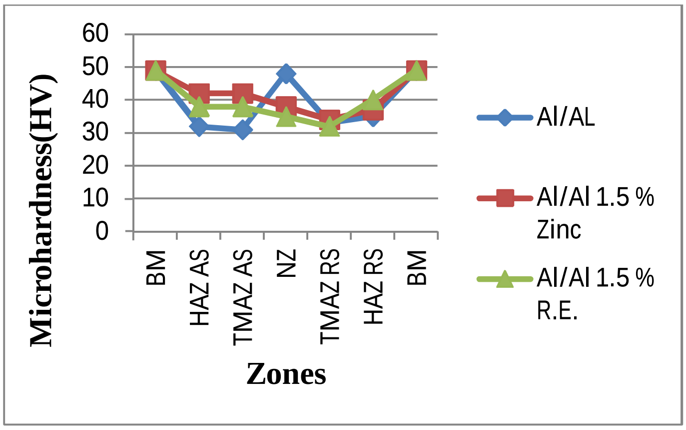
3. Tensile testing

Tensile properties of friction stir weld joints of Al/Cu are given in Table: 1. higher ultimate tensile strength was 218.90 MPa and higher yield strength was 135.43 MPa.

Samples	Yield strength	Ultimate strength
Al/Al Tin	132.55	192.39
Al/Al Zinc	*135.43*	218.90
Al/Al Rare earth	100	100
Al/Cu Tin	79.53	79.53
Al/Cu Zinc	108.14	108.14
Al/Cu SiC	132.55	182.15

4. Microhardness

Fig.3 shows the hardness profiles of the Al/Cu FSW welds. Microhardness values were found to be 163 for copper base metal & 49 for aluminium base metal. Higher microhardness was found at joining of Al/Cu with Tin Filler metal powder at Nugget zone.



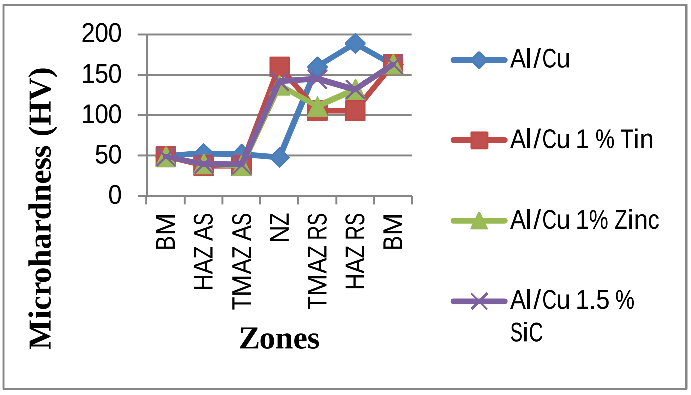


Figure:3 Microhardness values of Al/Al and Al/Cu

V. CONCLUSION

All welds were defect free. Microstructures of weld were shown different regions, like TMAZ and Nugget Zone. Microharness in NZ of Al/Al with Rare earth filler metal powder was lower than base metal. Tensile strength of Al/Cu with SiC and Al/Al with Zinc were good compares to others.

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