EFFECT OF TOOL OFFSET ON FRICTION STIR WELDING OF AL ALLOY TO PURE COPPER

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ABSTRACT

In this research, effect of tool offset on tool erosion and metallurgical and mechanical properties of dissimilar friction stir welding of Al alloy to pure copper are investigated. As the tool erosion is one of the most important parameters on the defect-free friction stir welding, especially in butt joint of Al alloy to steel. In present work, different tool pin offset are used in friction stir welding at Al alloy to pure copper with a constant tool speed and feed rate named as 750 rpm and 100 mm/min respectively. The result of experimental observation is shown better performance by tungsten carbide (WC) tool material with 1 mm offset on Al alloy side.

Keywords: Friction Stir welding; dissimilar joints; copper; Aluminum

I. INTRODUCTION

Solid-state welding is the process in which coalescence is produced at a temperature below the melting point of the base metal without the use of filler metal. Various examples of solid-state welding processes include friction welding, Friction Stir Welding (FSW), ultrasonic welding, resistance welding, explosive welding and diffusion welding. There are fewer defects in solid-state welding because the metals do not reach their melting point temperatures during the welding process. However, the base metals being joined retain their original properties, and the Heat Affected Zone (HAZ) is small. Friction Stir Welding is a variant of friction welding that produces a weld between two or more work pieces by the heating and plastic material displacement caused by a rapidly rotating tool that traverses the weld joint (Thomas *et al.*, 1991).

Friction Stir Welding (FSW) is a solid–state joining technique invented and patented by TWI in 1991 for butt and lap welding of ferrous and nonferrous metals. FSW is a continuous process that involves plunging a portion of a specially shaped rotating tool between the butting faces of the joint. Schematic diagram of friction stir welding process is shown in **Fig.3**.The relative motion between the tool and the substrate generates frictional heat that creates a plasticized region around the immersed portion of the tool [1]. Friction stir welding process uses a non-consumable rotating tool consisting of a pin extending below a shoulder that is forced into the adjacent mating edges of the work pieces. Machine set up used for the friction stir welding is shown in the **Fig.1**.while tool used for the FS weld is shown in **Fig.2**.The rotation of the tool results in the stirring and mixing of material around the rotating pin during the welding process which in turn affect the evolving properties of the weld. There are fewer defects in solid state welding because the metals do not reach their melting temperatures during the welding process. The major advantage of FSW is that it follows local thermo mechanical metal working process without influencing properties of surrounding areas as observed in other welding process. Many emerging applications in power generation, petrochemical, nuclear, aerospace, transportation, and electronics industries lead to the joining of dissimilar materials tool between the butting faces of the joint.

Fig.1. FSW machine set up

Fig.2. Tool used in friction stirs welding

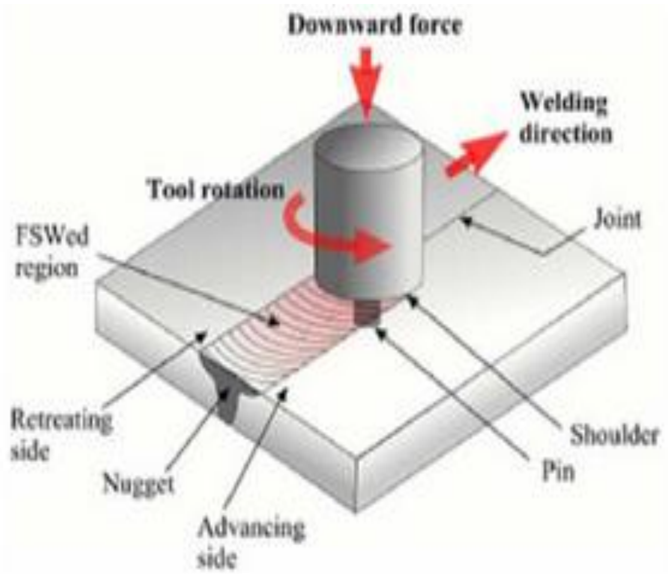


Fig.3. Schematic diagram of friction stir welding process

II. EXPERIMENT

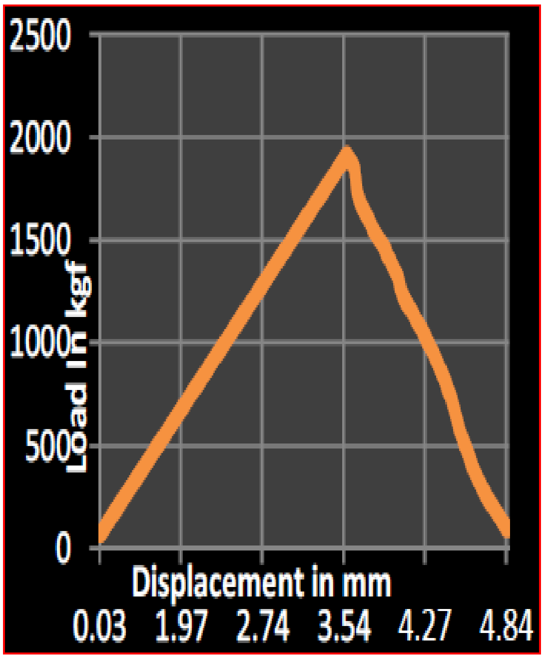
Al alloy 8011 of composition in weight(%): Al- 98.50; Cu- 0.103; Pb-0.019; Mg-0.086,Si-0.231,Fe-0.710,Ni-.0.120,Mn-0.132,Zn-0.160,Sn-0.004,Pb-0.012,Ti-0.019,Cr-0.021,V<0.01. Pure copper of composition in weight (%): Cu–99.65, Mn–0.001, Sn-0.235, Cr-0.012, V-.037 were cut into rectangular pieces of 180 mm X 45 mm X 3mm. Friction stir welding was carried out using a heavy-duty vertical milling machine adapted for FSW: Bharat Fritz Werner (BFW) with spindle motor capacity 11KW. The welding tool used in this study was made of tungsten carbide and had a shoulder 20 mm in diameter and a pin 6mm in diameter and 2.65 mm. Welds were made with a clock-wisely rotating pin at a rotation rate of 750 rpm and a constant traverse speed of 100 mm/min. Tool tilt angle of 2 degrees was used in the present study. The mechanical properties such as tensile strength and microstructure of the FSW joints were evaluated. The specimens for tensile testing were prepared according to standards ASTM E8M standard at room temperature at a crosshead speed of 3 mm/min. During the welding processes, several pin offsets from 0 mm to 1.5 mm were used. The tensile test specimens were prepared by Wire EDM and tested on the Tensometer. Parameters to be selected for three levels namely as Levels 1, Level 2 and Level 3.Tool Pin offset are 0.5 for level 1, 1.0 for level 2 and 1.5 for level 3. While the rotational speed to be taken as 550 rpm for level 1, 750 rpm for level 2 and 950 Rpm for level 3.

III. RESULTS AND DISCUSSIONS

Friction stir lap welding was successfully carried out at all the tool offsets and rotational speeds specified. In all the cases FSW joints were obtained. When the pin offset was larger towards the softer material, only a few Cu pieces with relatively small size were moved from the Cu bulk. The Cu pieces were harder than the Al matrix, therefore, the large Cu pieces were hard to deform and flow in the Al matrix, and the mixing between the large Cu pieces and the Al matrix would be very difficult. This led to the poor surface bonding and the formation of any voids in the weld bead. Moreover, when the pin offset was smaller, more Al because the more Cu pieces were stirred into the nugget zone. Thus, the Cu became poor due to the brittle nature of the IMCs.

IV. TENSILE TESTING

Fewer cracks were seen under a lower rotation rate of 600 rpm but at 950 rpm and 1200 rpm sound weld was not achieved. This might be due to the formation of inter-metallic compounds under the enhanced reaction between Al and Cu. Under the rotation speed of 1200 rpm many macro cracks were observed. When the rotation of the tool pin was high, large pieces of Cu would be detached from the bulk and get distributed in the bottom and the retreating side of the nugget zone. When the rotation speed was fixed to 750 rpm small pieces of Cu would be scratched off from the bulk and thus at a certain portion of the weld zone seem to have mixed properly. The increase in rotational speed from 750 to 1200 rpm resulted in a harsher material flow. When the pin offset was larger towards the softer material, only a few Cu pieces with relatively small size were moved from the Cu bulk. The Cu pieces were harder than the Al matrix, therefore, the large Cu pieces were hard to deform and flow in the Al matrix, and the mixing between the large Cu pieces and the Al matrix would be very difficult. This led to the poor surface bonding and the formation of many voids in the weld bead. Moreover, when the pin offset was smaller, more Al because the more Cu pieces were stirred into the nugget zone. Thus, the Cu became poor due to the brittle nature of the IMCs. Stress - strain curves of welded specimens welded with 750 rpm and 100 mm/min at a) 0.5 mm tool pin offset, (b) 1 mm tool pin offset Fig.4.



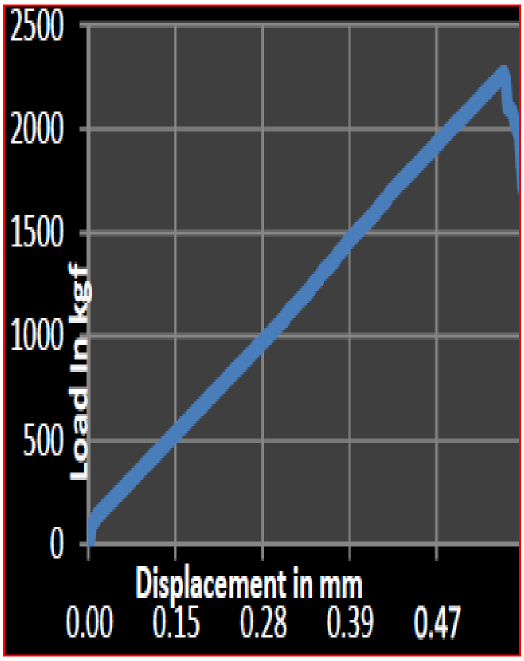


Fig.4. Stress - strain curves of welded specimens welded with 750 rpm and 100 mm/min at a) 0.5 mm tool pin offset, (b) 1 mm tool pin offset

IV. CONCLUSION

Friction stir lap welding of AA 8011 and pure copper were conducted and its mechanical properties studied. From this following conclusions were drawn:

• Friction stir welding is an appropriate method for joining aluminum AA 8011 and pure copper produce butt joints. At 750 rpm tool rotational speed, weld surfaces were good without any defects.

• The optimum tool feed which displayed good tensile strength during FSW was 100 mm/ min and tool rotational speed was 750 rpm.

• The FSW improves the flow of material and at a feed 100 mm/min; speed 750 rpm better results were achieved.

• Sound defect-free joint could be obtained only when the hard Cu plate was fixed at the advancing side.

• Sound defect-free joints were obtained under the pin offsets of 1mm to the Al matrix, and a good metallurgical bonding between the Cu bulk/pieces and Al matrix was achieved.

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