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A novel method for joining of Aluminium alloy AA6061 plates by friction stir welding using vertical milling machine

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Abstract - *Joining process of alloys & metals have short falls in aspects of continuity, thermal and mechanical properties of material post welding. This method recommends an innovative method of joining similar Nonferrous metal plates of Aluminum alloy AA6061. It's a method to join the alloys at their solid state. Tools used for Friction stir welding were manufactured from high speed tool steel H13. Experimentation were carried out using the vertical milling machine with additional attachment of indigenously fabricated work fixture for Aluminum plates. The milling cutter is replaced by friction stir pins. The aluminum plates are joined in butt configuration. The weldments produced were analyzed for their microstructure studies by SEM and mechanical strength by destructive testing method. The analysis discloses minimum HAZ and negligible loss in tensile strength and joint is reconfirmed of ductile in nature from its failure.*

Key Words: *Friction stir welding (FSW), Microstructure studies, HAZ.*

1. INTRODUCTION

Friction stir welding (FSW) is a relatively new and solid-state joining process. It involves plunging a portion of a specially shaped rotating tool between the abutting faces of the joint. The frictional heat due to relative motion creates a plasticized third-body region around the immersed portion of the tool. The shouldered region of the tool in contact with the work pieces generates frictional heat in addition to the tool tip. Thus the shoulder prevents plasticized material from being expelled from joint [1]. Advantages over fusion welding technique has drawn attention of various researchers around the world. Friction stir welding has numerous applications in potential areas like space shuttle fuel tanks, aluminum decking for car ferries, manufacturing of compound aluminum extrusions and automotive structural components. Most of the applications are on aluminum alloys. Still some experiments are reported on titanium alloys, steels [2] and metal matrix composites [3]. The optimization of input process parameters is required for this technology [4]. Being one of the emerging joining techniques due to its metallurgical and environmental benefits it is also energy efficient as only 2.5% of laser welding energy is needed for FSW.

2. Experimental setup

2.1 FSW Fixture design

FSW setup was prepared with specialized fixtures to hold on the plates and avoid distortion due to high torque and axial pressure developed due to traverse of rotating cylindrical pins. The fixture is made up of mild steel with components such as base plate, side support plate, top support plate and nuts bolts as shown in CATIA model figure 1. Base plate was made slotted holes to fix it on the vertical milling machine. Nut and bolts are attached to side supporting plates to restrict all translational and rotational degree of freedom. Base plate and side plates are welded to each other. However, the nuts are provided in side plate at lateral holes to hold the work piece. Actual fixture is shown in figure 2.

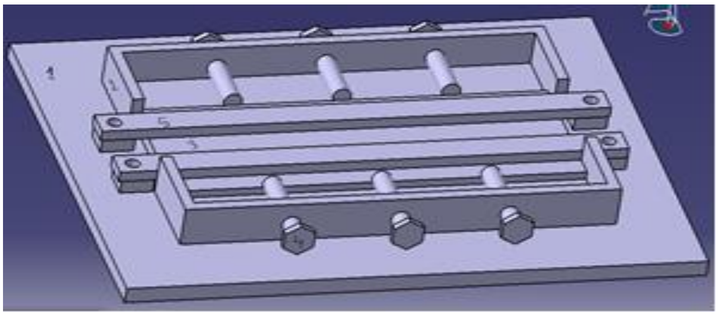

Fig- 1 Design in catiaV5. Parts of fixture (a) Base plate (b) side support plate (c) Aluminum plate (d) Bolt (e) Top support plate

Figure 2 FSW prepared fixture.

2.2 Friction stir welding pin design

The friction stir processing pins designed in CATIA V5.0 were manufactured by CNC lathe by importing to MASTERCAM software and converting to suitable G- codes and M- codes. The H-13 high speed tool steel was chosen for its high toughness, impact strength and excellent dimensional stability at high temperature [5][6]. FSP pins of taper profiles are prepared for their good weld bead characteristics in the joint [7]. The tool pin profile with tapper angle of 21.8 degree over a pin length of 5mm was manufactured. The Detail shape of the pin is and dimension of the pin is shown in figure 3.

Figure 3. H13 tool

2.3 FSW EQUIPMENT SETUP

The vertical milling machine of BFW (Bharat Fritz Werner. Ltd) make is used with special attachments for holding the pins in the collet and mounting of the fixture on to the bed of milling machine

Figure 4 Vertical milling machine.

The milling cutter is replaced with hardened tapered protruded pin with cylindrical shoulder. Vertical milling machine has the speed range from 1000 to 2000 rpm. The friction stir welding of AA6061-T6 aluminum alloy using a taper pin profile was done at speeds 1000, to 2000 rpm and with a feed rate 63 to 100 mm/min [8]. The vertical milling machine with table size 800*230mm equipped with a maximum spindle motor power of 5.5kw is used for experimentation.

2.4 PROCESS PARAMETERS

The process parameters used for effective and enhanced joining of AA6061-T6 alloy plates using FSW technique, are rotational speed, traverse speed [9]. Among the various combinations of these process parameters, the combination of following set of parameters with XXXXXXXXX gave the best suitable joint strength with least microstructural defects.

3.Exprimental Result

The FSW joint during the friction stir welding of AA6061-T6 aluminium alloy using taper pin profile H13 grade high speed steel tool with varying parameters as shown in fig 5.

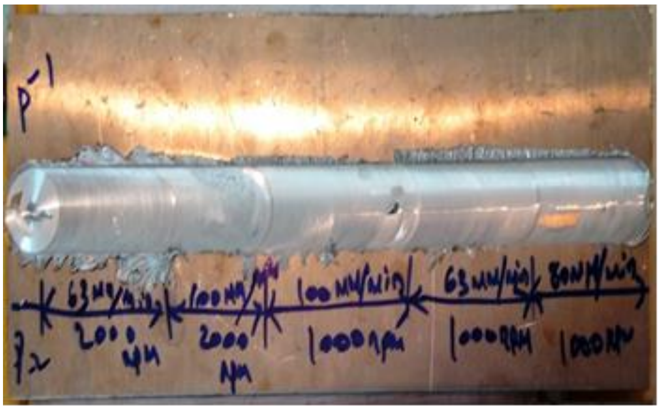

Figure 5 Weld bead

The top surface of the welded joint appears to be free from defects. However, the cross section of the specimen was examined and found to be carring some defect near the advancing or retracting side of the joint. The speciemen with rotational speed 200 rpm and 63 mm traverse speed parameters was found to be defect free at its cross section. Where as rest specimen were defect prone may be due to improper parameter combination during FSP.

Figure 6 welded and original specimen

The effect of the tool rotational speed and feed rate on the mechanical property of the joints for the specimen is determined by performing tensile test.

The joint fabricated under the combination of tool rotational speed of 2000 rpm and tranversing speed of 63mm/min is found to be free from welding defects, the tensile Speciemen was cut with ASTM B557 by wire EDM machine for welded and original aluminium speciemen. Sample no. 1 is of original aluminium speciem without welding and sample no. 2 is with friction stir welding as shown in above figure 6. Parent original speciemen no. 1 has a ultimate tensile strength of 156.30 Mpa and yeild strength of 115. 19 Mpa. Where as the FSW sample no.2 has a ultimate tensile strength of 133.44 Mpa and yeild strength of 111. 48 Mpa. Which shows appereciable strength achieved in welding in comparision with the original speciemen. The comparision of Tensile strength is between two speciemens is given in stressversus strain graph in below figure 7.

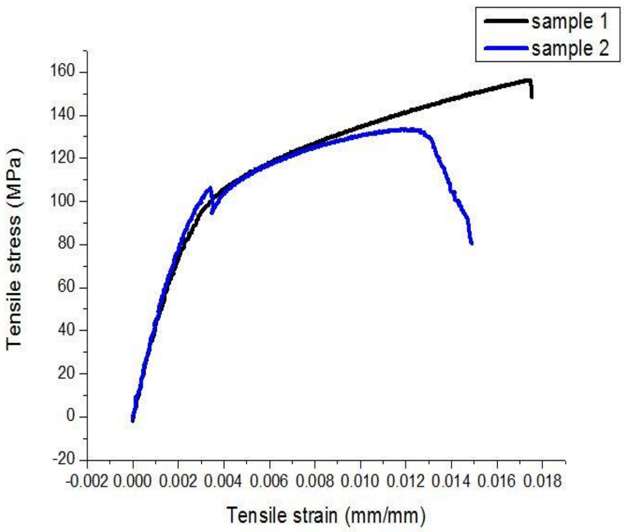

Figure 7 Tensile stress versus tensile strain

4. Microstructural investigation

The techniques used for revealing the topographic and surface morphology information of the materials are Scanning Electron Microscopy (SEM) and Optical microscope. The microstructural investigations of the welded joint specimen are carried out by JEOL SEM. The cross-sectional surface area of the welded region was taken from the middle of the length transverse section and etched before mounting on SEM as shown in figure 7 and figure 8. The microstructure of the weldment is shown in figure 7 with less defect and voids [10]. Which shows the greater and distinguishable grain size with boundaries at 20micron resolution. The figure 8 shows the distinguishable region between weld zone and parent material [11]. The heat affect zone is minimal with good grain structure [12].

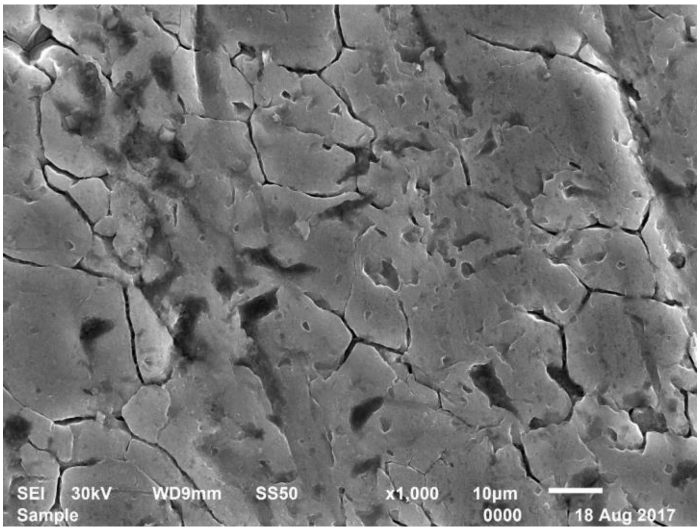

Figure 7 microstructure of weld bead

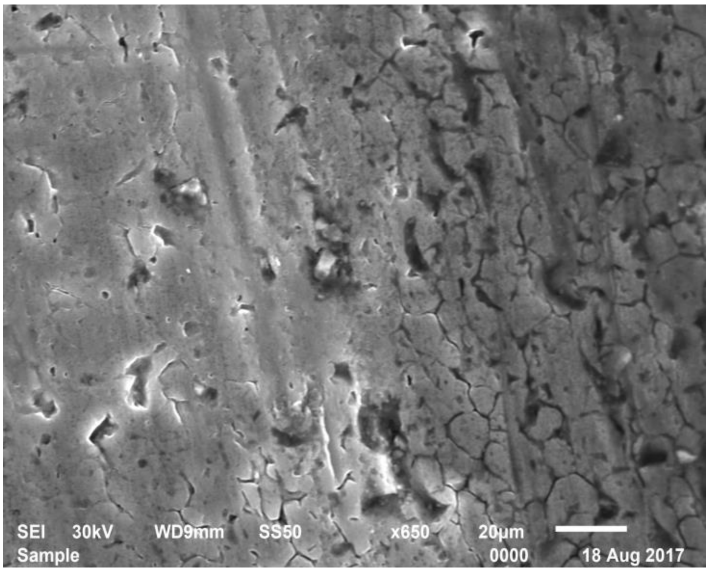

Figure 8 weld zone and HAZ

3. CONCLUSIONS

Friction stir welding of similar aluminum AA6061 plates is successfully carried out for Butt welding joints. This process is inconvenient for corner and T- joints but successful for butt joints. The experimental investigation revealed that welded joints are of ductile nature with less HAZ and with equivalent tensile strength properties at par with the parent material without welding.

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