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Parametric Effects in Friction Stir Welding Process: A Literature Survey

Manish Vadiya, Prabhdeep Singh Bajwa

Department of Mechanical Engineering, LRIET, Solan, Himachal Pradesh, India

ABSTRACT

Friction Stir Welding (FSW) was invented by Wayne Thomas at TWI (The Welding Institute), and the first patent applications were filed in the UK in December 1991. Friction stir welding (FSW) is the latest technology in the area of metal joining and is perhaps the most promising of all the welding processes. Friction Stir Welding (FSW) has become a major joining process in the railway, aerospace, auto industries and ship building industries especially in the fabrication of aluminium alloys. This paper looks at the review, on friction stir welding process, various welding variables like tool rotation, welding speed, tool tilt angle, plunge depth and tool pin geometry, for the welding of aluminium alloys.
Keywords: - Friction Stir Welding, Aluminium Alloys, Process Parameters.

I. INTRODUCTION

Aluminum and its alloys have wide range of applications especially in the fabrication industries, aircraft manufacturing, automobile body building, shipbuilding and other structural applications, due to their high strength to weight ratio, higher ductility and good corrosive resistance.

Welding and joining are integral parts of any manufacturing process. Research and Development in welding and joining processes, have continuously grown over the years. This has aided the advancement and growth of the manufacturing industry. Welding processes range from simple gas welding to laser welding, and have been broadly classified as fusion welding and solid state welding. Fusion welding processes involve chemical bonding of the metal in the molten stage and usually require filler materials. Formation of inert atmosphere is necessary to avoid oxidation of the molten metal in fusion welding processes. This is achieved by a flux material or an inert gas shield in the weld zone. Heating the metal to its melting point and letting it to solidify deteriorates its mechanical properties.

Solid state welding is the process where coalescence is produced at temperatures below the melting temperatures of the base metal without any need for the filler material or any inert ambience. Friction stir welding, friction welding, explosion welding, forge welding and ultrasonic welding are examples of solid state joining processes. As the metals are not melted, micro structural defects mentioned above are minimized. Absence of melting and narrow heat affected zone (HAZ) help in retaining the material properties of the metal. Joining of dissimilar metals is also feasible.

Friction Stir Welding (FSW) was developed by The Welding Institute (TWI), Cambridge, in 1991. The process takes place in the solid state and appears to offer a number of advantages over conventional fusion welding techniques, such as no need for expensive consumables such as filler wire and gas shields, ease of automation on simple milling machinery, good mechanical properties of the resultant joint, and low distortion. In addition, since welding occurs by the deformation of material at temperatures below the melting temperature it is possible to avoid problems commonly associated with the joining of dissimilar aluminum alloys.

A non-consumable rotating tool with a specially designed pin and shoulder is inserted into the abutting edges of sheets or plates to be joined and traversed along the line of joint. The parts have to be suitably clamped rigidly on a backing bar to prevent the abutting joint faces from being forced apart. The length of the pin is slightly less than the required weld depth. The plunging is stopped when the tool shoulder touches the surface of the job. The tool shoulder should be in intimate contact with the work surface. The function of tool is heating of work-piece, and movement of material to produce the joint. The heating is accomplished by friction between the tool and the work-piece and plastic deformation of work-piece. The localized heating softens the material around the pin and combination of tool rotation and translation leads to movement of material from the front of the pin to the back of the pin Here a substantial forging force is applied by the tool to consolidate the plasticized metal behind the tool. The welding of the material is facilitated by severe plastic deformation in the solid state involving dynamic recrystallization of the base material. As the tool is moved along the seam the desired joint is created.

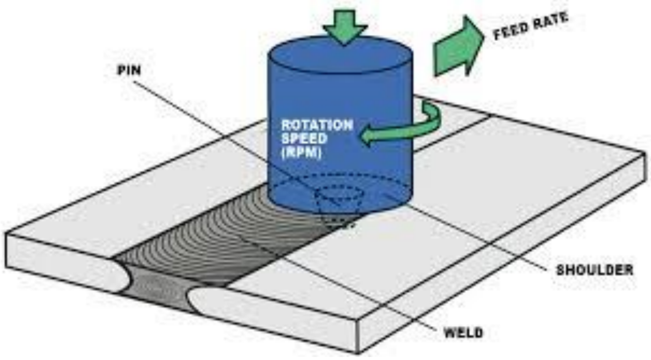

Figure 1. Friction Stir Welding

FSW involves complex material movement and plastic deformation. Welding parameters, Tool geometry and joint design exert significant effect on the material flow pattern and temperature distribution, thereby influencing the micro structural evolution of material **(Mishra R.S. et al., 2005).** Therefore, tool rotational speed, welding speed, tool tilt angle, tool material and the tool design are the main independent variables that are used to control the FSW process.

Tool The rotating device between the machine spindle and the work piece is referred to as the tool. The part which creates stirring action is referred to as the pin. The part of the tool, which is pressed on to the surface of the work piece during welding is referred to as shoulder. Pin geometry plays a crucial role in material flow.

Tool Rotational Speed is the speed at which the friction stir welding tool rotates. Rotation speed determines the heat input and temperature as well as the shear experienced by the FSW welds. Consequently, it influences the microstructure and mechanical properties of the FSW welds. The motion of the tool generates frictional heat within the work pieces, extruding the softened plasticized material around it and forging the same in place so as to form a solid-state seamless joint.

Welding or traverse speed is referred to travelling speed, which is the rate of travel of tool along line of joint. During traversing, softened material from the leading edge moves to the trailing edge due to the tool rotation and the traverse movement of the tool, and this transferred material, are consolidated in the trailing edge of the tool by the application of an axial force. Another important process parameters is tool tilt with respect to the work piece surface and plunge depth. Tool tilt angle is the angle between the tool axis and the normal to the surface of the sheets being welded. A suitable tilt of the spindle towards trailing direction ensures that the shoulder of the tool holds the stirred material by threaded pin and move material efficiently from the front to the back of the pin.

II LITERATURE REVIEW

Olga Valero Flores et al (1998), he had conducted experiments at low spindle speeds at given traverse speed and the joints showed low tensile strengths with increase in spindle speed. The strength and elongation increased with the increase in welding speed and the strained region width decreased.

Liu et al (2003) studied the relation between welding parameters and tensile properties of 2017-T351 aluminum alloy. They reported a weld tensile strength equivalent to 82% of base material at a tool rotation speed of 1500 rpm and welding speed of 100 mm/min.

Peel et al., (2003) used AA 5083 aluminium alloy for friction stir welding by varying the welding conditions like tool design, rotation speed and translation speed. The effect of different welding speeds on the weld properties remains an area of uncertainty. The results of microstructural, mechanical property and residual stress investigations of four aluminium AA5083 friction stir welds produced under varying conditions were reported. It was found that the weld properties were dominated by the thermal input rather than the mechanical deformation by the tool.

The influence of pin geometry on bonding and mechanical properties of friction stir welded 2014 aluminum alloy was studied by **Zhao et al (2005).** It is concluded that the pin profile affects the flow of the plastic material and the best quality weld was acquired using the taper tool with screw thread.

Yan et al., (2005) used, four different stir pins, two of them were column pin and taper pin and the other two were the same size but with screw thread, for FSW of 2014 aluminum alloy. Microscopic examination of the weld zone and the mechanical property tests results showed that the best bonding was obtained with screw pitched taper stir pin. The appearance of the weld is well and no obvious defect is found using this tool.

Hidetoshi Fujii (2006) investigated the effect of the tool shape on the mechanical properties and microstructures of 5-mm thick welded aluminium plates. The simplest shape (column without threads), the ordinary shape (column with threads) and the triangular prism shape probes were used to weld three types of aluminium alloys. It has been found for 1050-H24 whose deformation resistance is very low, a columnar tool without threads produces weld with the best mechanical properties.

Cavaliere P. (2006) studied the effect of processing parameters on mechanical and microstructural properties of AA6056 joints produced by Friction Stir Welding. Different samples were obtained by employing rotating speeds of 500, 800 and 1000 rpm and welding speeds of 40, 56 and 80 mm/min. The mechanical properties of the joints were evaluated by means of micro hardness (HV) and tensile tests at room temperature.

Lombard et al., (2008) presented a systematic approach to optimizing FSW process parameters (tool rotational speed and feed rate). Eleven experiments were conducted by varying the tool rotational speed and welding speed. The tensile strength of the joint was increased from 289 to 313 MPa by varying the tool rotational speed from 400 rpm to 200 rpm at the constant welding speed of 85 mm/min. The tensile strength of the joint increased from 254 MPa to 315 MPa by varying the tool rotational speed from 635 rpm to 254 rpm at the constant welding speed 135 mm/min. The work indicates that the tool rotational speed is the key parameter governing the tensile strength.

Rajakumar et al., (2011) explored the influence of process and tool parameters on tensile strength properties of AA7075-T6 joints produced by friction stir welding. Tensile strength of the joints were evaluated and correlated with the microstructure, micro hardness of weld nugget. From this investigation it is found that the joint fabricated at a tool rotational speed of 1400 rpm, welding speed of 60 mm/min, axial force of 8 kN, using the tool with 15 mm shoulder diameter, 5 mm pin diameter, 45 HRC tool hardness yielded higher strength properties compared to other joints.

R. Hariharan, R.J. Golden and Renjith Nimal, (2013) investigated the development of friction stir welded joint of dissimilar aluminum alloys (6061 and 7075) by using Computerized Numerical Control Machine and compared the effect of tapered pin and cylindrical pin type tools on tensile strength of aluminum alloys (6061 and 7075).The main process parameters considered are rotation speed (1600 and 1250rpm), traverse speed (120mm/min) and tool tilt angle 2^0. The results demonstrated that the tensile strength of tapered pin sample was around 30% and 15% higher than cylindrical one at 1250rpm and 1600rpm respectively. The maximum tensile strength value (485Mpa) is obtained at rotation speed of 1250 rpm, welding speed of 120 mm/min and tool angle 2 degree tilt.

III CONCLUSION

Friction Stir Welding has many benefits when applied to welding of aluminum alloys and dissimilar materials which were difficult to weld. In order to prevent defective welded joints, utmost care should be taken into account of all the pertinent variables. From the Literature survey is found that tool pin geometry, taper of the pin, Pin depth and taper angle are the important parameters in addition to the tool rotational speed (TRS), weld speed (traverse speed/WS) and the axial force (F).

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