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A Short Summary of Friction Stir Welding of 6xxx Aluminium Alloys

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ABSTRACT

In recent years, friction stir welding (FSW) has proven its capability as a commercial joining process for aluminum alloys. The AA 6xxx aluminium alloys are extensively used in marine frames, pipe lines, and storage tanks and aircraft applications. The literature review of friction stir welding process has been done in this paper to understand the effect of process parameters of friction stir welding on mechanical properties of selected substrate. On the basis of the literature reviewed it has been observed that still there is limited research studies on optimizing the process parameters of friction stir welding of AA6063.
Keywords: Friction Stir Welding, AA6xxx Aluminium alloys, Process parameters.

I. INTRODUCTION

Aluminum and aluminum alloys which are lighter weight and higher specific strength than ferrous material have found wide applications in recent years. These 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. The AA 6063 alloys are extensively used in marine frames, pipe lines, and storage tanks and aircraft applications.

Although these alloys are readily weldable by fusion welding, they suffer from severe softening in the heat affected zone (HAZ) due to reversion of Mg_2Si precipitates during the welding thermal cycle. Such mechanical impairment presents a major problem in engineering design.

In recent years, friction stir welding (FSW) has proven its capability as a commercial joining process for aluminum alloys. For example, in the aerospace industry, large tank for launch vehicles is being produced by FSW from high-strength aluminum alloys. In shipbuilding and rolling stock industries, the FSW process is exploited for the production of large prefabricated aluminum panels, which are made from aluminum extrusion.

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.

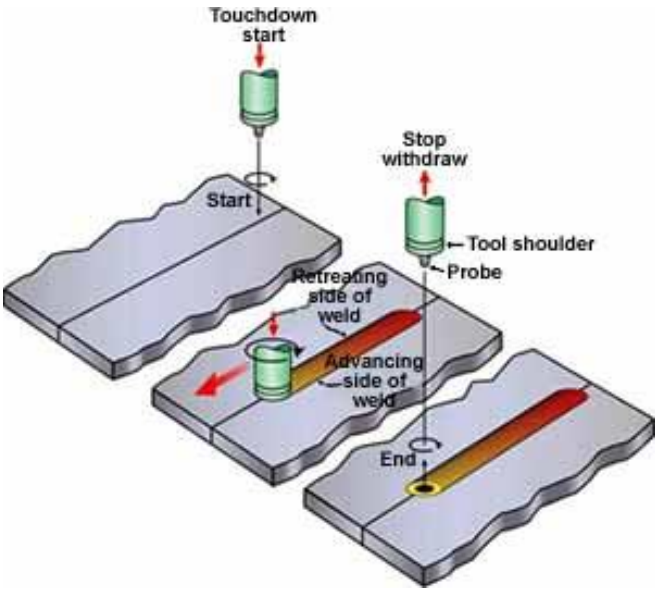

Figure 1. Friction Stir Welding

II. LITERATURE REVIEW

Thomas (1997) focuses on this study the relatively new joining technology, friction stir welding (FSW). Friction stir welding can be used to join most aluminum alloys and surface oxide presents no difficulty to the process. On the basis of this study it was recommend that number of lightweight materials suitable for the automotive, rail, marine and aerospace transportation industries can be fabricated by FSW.

Huijie liu et al (2003) investigated the tensile properties and fracture locations in FSW of AA6060-T6 alloy of dimensions 30 mm X 80 mm X 5 mm. An HSS tool with diameter of shoulder and pin as 15, 6 mm respectively with pin length of 4.7mm and 3° tilt angle. Rotation speed, weld speed and revolutionary pitch were taken as weld parameters in ranges 1000-1500 rpm, 100-1000 mm/min, 0.07-1.00 mm/r respectively. They concluded that for 0.53 mm/r of pitch, 1500 rpm, welding speed of 800 mm/min, the maximum UTS of joint is about 77% of base metal.

Minton and Mynors (2006) demonstrated conventional milling machine has been capable of performing FSW and producing reasonable welds using a relatively stout tool to join 6.3 mm thick 6082-T6 aluminium. Lesser quality welds were produced when joining 4.6 mm thick 6082-T6 aluminium. Further work is required to establish if the welds in the 4.6 mm can be improved, by enhancing the tool design, while ensuring the tool is sufficiently robust to survive the process. The methodology is tested by producing same thickness welds of 6.3 mm and 4.6 mm 6082-T6 aluminium sheets. The results from micro-hardness profiles across the tool shoulder diameter are presented in conjunction with tensile test results.

Cavaliere et al (2006) studied the effect of processing parameters on mechanical and microstructural properties of AA 6056 joints produced by Friction Stir Welding. Different samples were obtained by employing rotating speeds of 500 rpm, 800 rpm and 1000 rpm and welding speeds of 40 mm/min, 56 mm/min and 80 mm/min. The mechanical properties of the joints were evaluated by means of micro hardness (HV) and tensile tests at room temperature.

Cabibbo et al., (2007) investigated the microstructure and mechanical properties of a friction stir welded 6056-T6 aluminum alloy plates. The microstructure revealed different grain morphologies in the thermo-mechanically affected zones, in proximity of the weld nugget. The advancing side had fairly elongated, bent grains, whilst the broader retreating side had more elongated, narrower grains. Tensile tests showed yield and ultimate strength slightly lower across the weld as compared to the parent material.

Scialpi et al (2007) studied the influence of shoulder geometry on microstructure and mechanical properties of friction stir welded 6082 aluminium alloy. In this work, they considered three shoulder geometries and AA 6082 T6 1.5 mm thick sheets for investigation. The welding process was carried out rotating the tool at 1810 rpm and at a feed rate of 460 mm/min. By visual inspection the crown and root quality has been evaluated. The tools with dissimilar shoulders produce very different crown quality.

Moreira et al (2008) studied Fatigue crack growth in friction stir welds of 6082-T6 and 6061-T6 aluminium alloys. In this work, a comparative study between fatigue crack growth behavior of friction stir welds of 6082-T6 and 6061-T6 aluminium alloys was carried out. Fatigue crack growth curves were determined for cracks growing in different locations of the weldments, including the base material, the heat affected zone and the welded material. Generally, friction stir material exhibited lower strength and ductility properties than the base material. However, an enhanced crack propagation resistance was observed in the welded material. The 6082-T6 and 6061-T6 base materials exhibited very similar crack propagation behavior. On the other hand the friction stir 6061-T6 material showed lower crack propagation rates than corresponding 6082-T6 friction stir material.

Elangovan et al (2008) had been made investigation to understand the effect of axial force and tool pin profiles on FSP zone formation in AA6061 aluminium alloy. Five different tool pin profiles (straight cylindrical, tapered cylindrical, threaded cylindrical, triangular and square) have been used to fabricate the joints at three different axial force levels. It is found that the square tool pin profile produces mechanically sound and metallurgically defect free welds compared to other tool pin profiles.

Elangovan et al (2009) developed a mathematical model to predict tensile strength of the friction stir welded AA6061 aluminium alloy by incorporating FSW process parameters. Four factors, five levels central composite design has been used to minimize number of experimental conditions. Response surface method (RSM) has been used to develop the model. The joints fabricated using square pin profiled tool with a rotational speed of 1200 rpm, welding speed of 1.25 mm/s and axial force of 7 kN exhibited superior tensile properties compared to other joints.

Rajakumar et al (2011) developed empirical relationships to estimate the grain size and hardness of weld nugget of friction stir welded AA 6061-T6 aluminium alloy joints incorporating FSW tool and process parameters. A linear regression equation was established between grain size and hardness of the weld nugget of friction stir welded AA6061-T6 aluminium alloy joints. The developed relationships can be effectively used to predict the grain size and hardness of friction stir welded AA6061-T6 aluminium alloy joints within the range of parameters.

L. Karthikeyan et al (2011) conducted a study on relationship between process parameters and mechanical properties of friction stir processed AA6063-T6 aluminum alloy with 200 mm X 50 mm X 10 mm as work piece dimensions. The tool used was HSS with cylindrical shoulder and right hand threaded pin. Shoulder and pin diameter were 18 mm and 6 mm respectively with 5.7 mm pin length, rotational speed of 800, 1000, 1400, 1600 rpm is taken for each of 22.2, 40.2 and 75 mm/min tool feed for each of 8, 10 and 12 kN of axial force were weld parameters. They concluded that the weld had refined and homogenized grain structure in microstructure. The great mechanical properties can be got with feed of 40.2 mm/min, rotational speed in range of 1200-1400 rpm and axial force of 10 kN. Defect free welds with good microstructure was obtained by these properties. The maximum increase in UTS is 46.5%, ductility is 133%, microhardness is 33.4% of the parent metal. Specimens in which welding is done at 8 kN feed rate yielded process defects.

Fu et al. (2015) performed FSW over dissimilar 6061-T6aluminum alloy to AZ31B magnesium alloy using 800 rpm & 50 mm/min by H13 Quenched & Tempered to 50 HRC tool. The placing of Mg on the advancing side lead to removal of defects and more homogeneous mixing. A small cavity was observed when the tool offset is zero in Mg-Al configuration. In Mg-Al configuration when the tool was given offset towards Al the area defects increased. When the tool speed was varied (with tool offset +0.3mm) from 600 to 800 rpm & traverse speed was in the range 30 to 60 mm/min, sound weld with no defect is obtained. The Energy dispersive X-ray analysis of IMCs of specimen obtained at 700 rpm, 60 mm/min with Mg on AS and offset +0.3 mm revealed the presence of the Al, Mg content, the variation of contents suggested that layers of $Al_{12}Mg_{17}$ & Al_3Mg_2 were present. Welding condition was affected by two factors heat input and level of heat input to materials. The heat input was varied from rotation rate and welding speed.

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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