

Review Paper on Analysis of Friction Stir Welding of Aluminium Alloy (Al 6061)

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ABSTRACT

With ever increasing demand for both high production rates and high precision, fully mechanized or automated welding processes have taken a prominent place in the welding field. To make effective use of the automated systems it is essential that a high degree of confidence be achieved in predicting the weld parameters to attain the desired mechanical strength in welded joints. There are many types of welding techniques used to join metals. The welding processes differ in the way temperature and pressure are combined and achieved. The welding process is divided into two major categories: Plastic Welding or Pressure Welding and Fusion Welding or Non-Pressure Welding. Unlike the conventional fusion welding process, where the material to be joined is melted and re-solidified, FSW works on the principle of severe material deformation. This avoids the melting of the material to be joined which is the source of the welding defects. In this review paper we will discuss about all type of welding techniques, their process, advantages and disadvantage.

Keywords: Welding Process, Welding Techniques, Friction Stir Welding (FSW)

1. INTRODUCTION

Aluminum is non-ferromagnetic, a property important in the electrical and electronics industries. Some of the aluminium alloys exceeds structural steel in strength. However pure aluminium and few aluminium alloys are noted for extremely low strength and hardness [1]. Various properties of aluminium that makes this metal and its alloys the most economical and efficient for a wide variety of uses are mainly its appearance, light weight, fabric ability, physical properties, mechanical properties, and corrosion resistance. Aluminium has a density of 2.7 g/cm³, approximately one-third of steel (7.83 g/cm³), copper (8.93 g/cm³), or brass (8.53 g/cm³). Aluminium display excellent corrosion resistance in most of environments including atmosphere, water (including salt water), petrochemicals, and many chemical systems [2]. It typically displays excellent electrical and thermal conductivity. Various Al alloys have been designed with high degrees of electrical resistivity and conductivity. These alloys are very useful in high-torque electric motor. Welding is the process of joining together two pieces of metal so that bonding takes place at their original boundary surfaces. When two parts to be joined are melted together, heat or pressure or both is applied and with or without added metal for formation of metallic bond.

Various welding process can also be classified as follows:

Name	Types
1. Gas Welding	Oxy Acetylene Welding, Oxy Hydrogen Welding, Pressure Gas Welding
2. Arc Welding	Carbon Arc Welding, Shield Metal Arc Welding, Submerged Arc Welding, Metal Inert Gas Welding, Tungsten Inert Gas Welding, Electro Slag Welding, Plasma Arc Welding
3. Resistance Welding	Spot Welding, Flash Welding, Resistance Butt Welding, Seam Welding
4. Solid State Welding	Forge Welding, Cold Welding, Friction Stir Welding, Explosive Welding, Diffusion Welding, Ultrasonic Welding

5. Thermo-Chemical Welding	Thermit Welding, Atomic H ₂ Welding
6. Radiant Energy Welding	Electron Beam Welding, Laser Welding

Apart from above mentioned techniques of welding, Friction stir welding (FSW) was invented at The Welding Institute (TWI) of UK in 1991 as a solid-state joining technique, and it was initially applied to aluminum alloys [Thomas et al. 1991].

2. LITERATURE SURVEY

MIDDLE AGES: During the Middle Ages, the art of blacksmithing was developed and many items of iron were produced which were welded by hammering. The earliest examples come from the Bronze Age. Small gold circular boxes were made by pressure welding lap joints together. It is estimated that these boxes were made more than 2000 years ago.

IN THE YEAR 1800: During the late 1800s, gas welding and cutting was developed. Arc welding with the carbon arc and metal arc was developed and resistance welding became a practical joining process. Edmund Davy of England is credited with the discovery of acetylene in 1836. The production of an arc between two carbon electrodes using a battery is credited to Sir Humphry Davy in 1800.

1900: Strohmenger introduced a coated metal electrode in Great Britain. There was a thin coating of clay or lime, but it provided a more stable arc. Oscar Kjellberg of Sweden invented a covered or coated electrode during the period of 1907 to 1914. Stick electrodes were produced by dipping short lengths of bare iron wire in thick mixtures of carbonates and silicates and allowing the coating to dry. Elihu Thompson originated resistance welding. His patents were dated 1885-1900. In 1903, a German named Goldschmidt invented thermite welding that was first used to weld railroad rails.

1920: Automatic welding was introduced. It utilized bare electrode wire operated on direct current and utilized arc voltage as the basis of regulating the feed rate. Automatic welding was invented by P.O. Nobel of the General Electric Company. It was used to build up worn motor shafts and worn crane wheels. It was also used by the automobile industry to produce rear axle housings.

1930: Stud welding was developed in 1930 at the New York Navy Yard, specifically for attaching wood decking over a metal surface. Stud welding became popular in the shipbuilding and construction industries. The automatic process that became popular was the submerged arc welding process.

1940: Gas tungsten arc welding (GTAW) had its beginnings from an idea by C.L. Coffin to weld in a nonoxidizing gas atmosphere, which he patented in 1890. The concept was further refined in the late 1920s by H.M. Hobart, who used helium for shielding, and P.K. Devers, who used argon. This process was ideal for welding magnesium and for welding stainless and aluminum.

1957: Gage invented plasma arc welding. This process uses a constricted arc or an arc through an orifice, which creates an arc plasma that has a higher temperature than the tungsten arc. It is also used for metal spraying and for cutting.

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. Based on 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 [3].

Colligan (1999) studied the material flow behavior during Friction Stir Welding of aluminum. A threaded tool pin was used in the experiment. Steel balls of 0.38 mm were used as tracer material to find the path of the material flow. He found that not all material influenced by the pin is stirred in the welding process. The material that is stirred originates from the upper portion of the path of the welding tool pin. The stirred material is forced down in the weld by the threads on the pin and is deposited in the weld nugget. Other material in the weld zone is extruded around the retreating side of the welding tool pin [4].

Peel et al., (2003) used AA 5083 aluminum 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. It was found that the weld properties were dominated by the thermal input rather than the mechanical deformation by the tool [5].

Cavaliere et al (2006) studied the effect of welding parameters on mechanical and micro structural properties of AA6056 joints produced by Friction Stir Welding. Fatigue test was carried out on the welds using a resonant electro-

mechanical testing machine. By using higher rotating and welding speeds, the hardness of the material reaches higher values in all the conditions and the profiles become less uniform across the weld center[6].

Elangovan et al (2008) developed an empirical relationship to predict the tensile strength of Friction Stir Welded AA2219 aluminum alloy. It was found that the welding parameters such as tool rotational speed, welding speed, axial force and tool pin profile play a major role in deciding the strength of the joint. They used straight cylindrical, taper cylindrical, square, threaded and triangular pin profiles for the study [7].

Moreira et al (2009) investigated the mechanical and metallurgical characterization of friction stir welded butt joints of aluminum alloy 6061-T6 with 6082-T6. For comparison, similar material joints made from each one of the two alloys were used. The work included microstructure examination, micro-hardness, tensile and bending tests of all joints. An approximate finite element model joint, considering the spatial dependence of the tensile strength properties, was made, modeling a bending test of the weldments [8].

Lee Xu et al (2013) investigated the influence of welding parameters and tool pin profile on microstructure and mechanical properties along the thickness in friction stir welded 2219 aluminum alloy. They used two tool pin profiles. The first profile is the threaded and tapered tool profile with three spiral flutes and the second profile is the threaded and tapered profile with triangle [9].

3. FRICTION STIR WELDING

In FSW, 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 must 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. Because of various geometrical features of the tool, the material movement around the pin can be quite complex [Boz and Kurt, 2004]. 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. The schematic view of the operation is shown in Figure 1.[10].

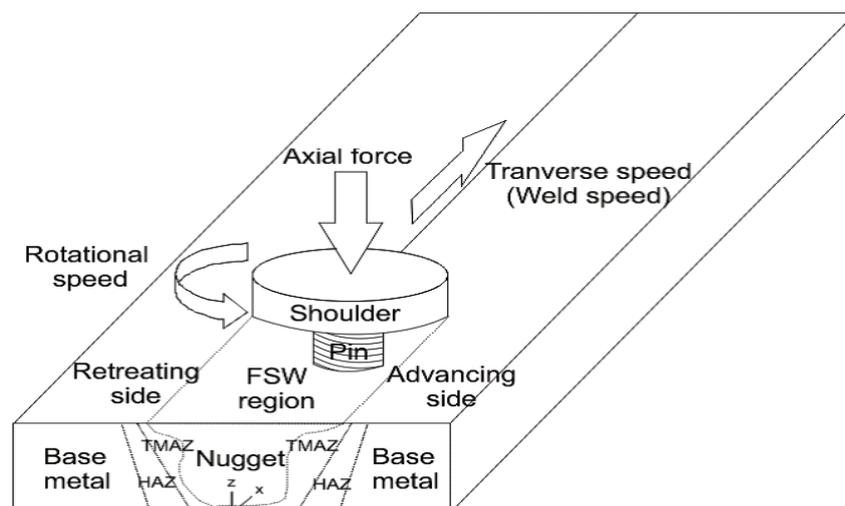


Figure 1.

There are two different modes of material flow involved in friction stir welding called pin driven and shoulder driven flow[11]. These two driven material merges together at the rear side of the pin to form a defect free weld. The pin driven material flow occurs during the interaction of base metal with tool pin in the weld cavity. The shape of the cavity depends on the outer most pin profile. The material transfer in the pin driven region takes place layer by layer. When the tool is traversed, the material at the leading-edge flows through retreating side to trailing edge. This material periodically fills the space created in the trailing edge. The shoulder deflects the pin driven material from retreating side

to advancing side. This occurs by the sliding action of the tool shoulder surface on the pin driven material. As the shoulder interaction increases, material is deflected back to the weld cavity. Thus, the material flow is layer wise in pin driven region, and it is bulk in shoulder driven region. When the material escapes out of the weld cavity due to insufficient axial pressure, it results in flash formation [12].

The FSW process can be thought to consist of three phases: the plunge phase, where the weld is initiated; the main phase, where the weld is made; and the termination phase, where the welding tool is withdrawn from the workpiece. The plunge phase consists of inserting the rotating welding tool into the joint, typically accomplished by commanding the welding system to drive the total pin axially into the work-piece at a specific rate. Frictional heating and pressure, at the end of the pin, induce work-piece material to displace, forming a ring of expelled, plastically deformed material around the pin as the pin enters the work-pieces. As the tool is plunged into the joint, heat is generated into the surrounding material. Once the welding tool is plunged into the work-piece, it rotates at several hundred rpm and heat is generated between welding tool and work-piece to reach a higher temperature [13].

Once the welding tool begins to travel along the joint, friction and plastic work produce heat to maintain sufficient softening in the work-piece to permit material flow around the pin. Heat from the welding process conducts within the work-piece, serving to precondition the material in front of the tool, producing softening from recovery of work hardening and averaging in materials such as aluminium.

Many of the advances made in friction stir welding have been enabled by the development of new welding tools. The welding tool design, including both its geometry and the material from which it is made, is critical to the successful use of the process. Welding tool geometry development led to the first sound welds made in aluminium alloys, and this field of study has led to higher weld production speeds, higher workpiece thickness, improved joint property, new materials and new welding equipment. Welding tool material development has enabled welding of high melting point materials, such as titanium, steel, and copper, and has improved productivity in aluminium welding.

New welding tool features have been developed with, for the goal of reducing process forces, increasing the robustness of the process, or simplifying welding control. Different features are used by different practitioners of FSW, depending on the materials being welded and the process performance goals required. FSW practitioners needing to weld at higher travel speeds or with deeper weld penetration may adopt variations to the original tool design[14][15].

4. CONCLUSION & FUTURE SURVEY

Friction Stir Welding (FSW) process is an emerging solid state joining process in which the material that is being welded does not melt and recast. FSW creates the weld joint without bulk melting. In addition, the extensive thermomechanical deformation induces dynamic recrystallization and recovery that refine the microstructure of the stir region. Therefore, welds made by FSW are shown to have much improved mechanical properties such as the tensile strength and the fatigue life than the corresponding fusion welds. This metallurgical alteration may be slight, such as in when welds are made at very high travel speed, or it may dramatically soften the work-piece. Simultaneously, this material is pulled around the welding tool and deposited behind it in a way that prevents the formation of voids as the welding tool arrives at the end of the joint, forward motion of the tool is typically stopped and the tool is withdrawn from the work-piece, leaving a keyhole at the end of the weld. The end of the weld is generally not usable and must be trimmed away.

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