FRICTION STIR WELDING

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Abstract: *Friction* Stir Welding (FSW) is a novel green solid state joining process. This joining technique is energy efficient, environment friendly, and versatile. The Principle advantages are fine microstructure, low distortion, absence of melt related defects and high joint strength. FSW parameters like tool rotational speed, welding speed and axial force play an important role. In this paper, literature on FSW has been reviewed, the gaps have been identified.

Index Terms - Friction stir welding, tool rotational speed, welding speed, axial force, microstructure, tensile strength.

I. INTRODUCTION

The friction stir welding (FSW) process was invented in 1991 by The Welding Institute (TWI) at Cambridge, in United Kingdom. It was further developed and was got patented by The Welding Institute (7). The first built and commercially availab le frict ion stir welding machines were produced by ESAB11. Welding and Cutting Products at their equipment manufacturing plant in La xa , Sweden. The development of this process was a significant change from the conventional rotary motion and linear reciprocating friction welding processes. It provided a great deal of flexibility within the friction welding process group.

Friction stir welding (FSW) is a solid state process for joining similar and dissimilar materials (21). The frict ion stir welding is very recent trends in the manufacturing technology of metal joining processes especially for aluminum alloys. Many various engineering industries will give importance for aluminum and aluminum based alloys. Friction stir welding was initially applied to aluminium alloys (3, 4, 5). 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 rigid ly o n a backing bar to prevent the abutting joint faces from being forced apart. The length of the pin is slightly less than the required welddepth (28). The plunging is stopped when the tool shoulder touches the surface of the job. The tool shoulder should be in int imate 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 (32). 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 th e pin can be quite complex [6]. 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 Fig. 1.1 [9].

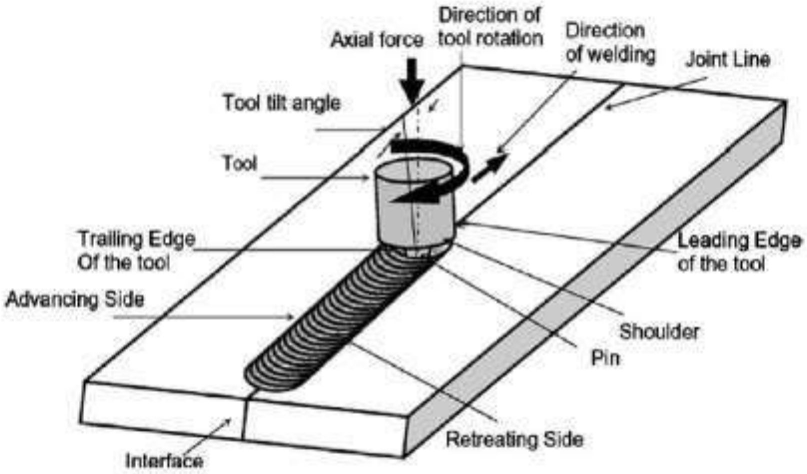

Figure 1.1 Schematic diagram of FSW

There are two different modes of material flow involved in friction stir welding called pin driven and shoulder d riven flow [10]. The material flow is layer wise in pin driven region, and it is bulk in shoulder riven region. When the material escapes out of the weld cavity due to insufficient a xia l pressure, it results in flash formation. Friction stir welding can b e applied to various types of joints like butt joints, lap joints, T butt joints, pipes and fillet jo ints with different thickness and different profile. These are pictured in Fig. 1.2 along with a T-joint [40].

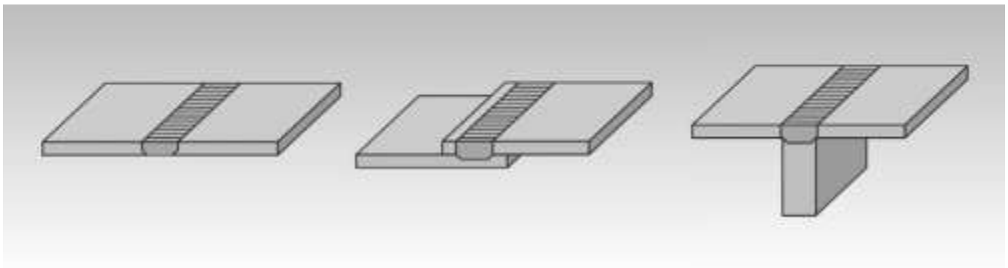

Figure 1.2 Common joint types: square butt, lap, and T-joint.

II. CLASSIFICATIO N OF LITERATURE

Literature review has been classified into five categories as given below.
History and development, advantages and applications of FSW, process parameters, performance parameters and future scope inFSW.

2.1 History and De vel opment

In 1993, NASA challenged Lockheed Martin Laboratories in Baltimore, Maryland, to develop a high -strength, low- density, lighter-weight replacement for aluminum alloy Al 2219 used on the original Space Shuttle External Tank (14). Lockheed Martin, Reynolds Today, the External Tank project uses the new alloy to build the Shuttle‘s Super Lightweight Tanks.

Since 1995 in Europe, Friction Stir Welding has been used in production applications. The first applications involved welding of extrusions to form panelling for marine applications. Since then, the process has been commercialized in many other applications. In 1997 the Institute of Materials Research of the German Aerospace Center (DLR), was the first non -industrial research institute in Germany working in the field of friction stir welding of aluminium alloys and one of the first TWI licensees in Ge rmany(13). The FSW is performed on a very stiff, numerically controlled bedplate milling machine.

Table 1: Chronology of production applications for FSW through (10)

Year	Applications	Company

1995	*Hollow heat exchangers	Marine Aluminium,Norway
1996	*Commercial shipbuilding	Marine Aluminium,Norway
1998	Delta rockets	Boeing, US
1999	*Commercial shipbuilding	Sapa, Swedan
2000	*Automotive components	Sapa, Swedan
2000	Laser system housing	General Tool, US
2001	*Motor Housings	Hudro Aluminium (formerly Marine Aluminium), Norway
2001	*Train bodies	Hitachi, Japan
2001	*Automotive components	Showa, Japan
2003	*Automotive components	Tower Automotive, US
2003	*Commercial shipbuilding	Advanced Joining Technology, US
2004	Space shuttle external tanks	Lockheed Martin, US
2004	Food trays	RIFTEC, Germany

*Denotes welding of extrusions

Friction stir welding is still considered to be the most significant development in joining of materials in last 20 years (4, 5, 7, 49, 50, 54). Many sophisticated welding methods for different alloys of variety applications are available now.

2.2 Advantages of FSW

FSW is recommended for the purpose of welding as it produces low distorted products with no fumes, porosity, spatter consumables etc. The advantages of FSW are shown in table no.2.

Table 2: Advantages of FSW

Sr.	Advantages	References
1	FSW is a green and environmentally friendly welding technology The welding process does not require filler wires or edge preparation and no gas emission. No porosity, no spatter, low shrinkage. The process is clean and does not produce any major safety hazards, such as welding fume or radiation.	3,4,6,16,19,28, 32,33,44,52,61 ,77.
2	Low distortion of workpiece, reduced residual stress. Good dimensional stability and repeatability. Fine microstructure, Absence of cracking and voids. Good corrosion resistance, formability and wedability. Eliminate grinding wastes. Decreased fuel consumption in light weight applications.	5,10,11,19,51, 68,73,99
3	High quality, high strength, Neither cooling water nor compressed air are required which allows for broad reductions in both equipment and running cost. No need for a large electrical current. Joining of dissimilar materials, similar metals.	21,43,76,104

2.3 Applications of FSW

There are wide applications of FSW process. Some of which are given below.

i) FSW is used in railway industries to build railway tankers and container bodies (2, 5, 6,11)

ii) Also used in shipping, marine and automotive industries, e.g. manufacturing of hulls, aluminum extrusions and offshore accommodations (9, 10, 12, 13).

iii) FSW can also be considered for electric motor housing, cooking equipments, kitchens, gas tanks, gas cylinders andconnection of aluminium or copper coils in rolling mills.

iv) All transport industries including pipe lines, storage tanks, shipbuilding, offshore, rail(high speed trains, carriages), automotive (chassis, wheel rims, space frames, truck bodies) and aerospace (civil and military aircraft) are using this technology (3, 10, 20, 21, 25, 32).

v) Widely used in making furniture, doors, and light structures (77), land transport, motorcycle and refrigeration industries (82).

2.4 Process Parameters

Finding the most effective parameters on properties of friction stir welds as well as realizing their influence on the weld properties has been major topics of interest for researchers. There are many factors or variables that can be affect the outp ut response. The primary variables are tool material, shape and size, tool rotational velocity, welding speed, tool tilt and plunge depth. All of these variables can affect weld properties significantly. The process parameter which influences the formation of weld joint are tool rotational speed, traverse speed, tool tilt angle, force e xerted by the tool and plunge depth also material used for join ing and its thickness. When compared to aluminium and its alloys, FSW process hs been used for alluminium alloys (1xxx, 2xxx, 3xxx, 5xxx, 6xxx, 7xxx). The most commonly used tool materials for FSW process are H13 and high speed steel. The tool material should have higher melting temperature than the work material. Defects can be minimized by properly selecting the process parameters.These parameters and material properties are responsible for the temperature profiles, cooling rate and torque exerted by the tool. When compared to conventional fusion welding process, the peak temperature and diffusion of heat source is signific antly low. With respect to axial pressure, when the rotating speed increases the peak temperature also rises in the weld zone. Many investigators used different process parameters in FSW as shown in the table 3.

III. GAPS IN LITERATURE

After a comprehensive study of the existing literature, gaps have been identified and presented below.

i) Most of the researchers have investigated the influence of a limited number of process parameters on the FSW of aluminium alloys.

ii) Literature lack some specific research that would focus on the impact of the FSW process parameters specifically on the tensile strength of the joint, quality of the weld (by concerning majorly on the defects formed in the weld joints), and heataffected zones.

iii) There is need to focus on the other parameters like tool material, pin profile, tilt angle and pin depth an d their effect on the mechanical properties of the joints and special focus on the dissimilar aluminum alloys.

iv) The researchers have carried out most of the work on varying one parameter at a time and no consideration has been given to interaction effect of two or more parameters.

v) There is less study on relative contribution of all the controllable process parameters on the weld qualities.

vi)) Selection of cost effective FSW tools and process parameters.

vii) Optimization of process parameters.

viii) Identify the significant process parameters of FSW.

Thus, keeping in view of the above research gaps , it is planned to investigate the effect of FSW process parameters on mechanical and metallurgical properties of friction stir welding of aluminium alloys using design of experiment technique.

IV. CONCLUSION

From the given literature review, the researchers reported that each process of parameter has its specific impact on the properties of the joints. Some of them are tool rotational speed, axial force, tool pin profile and tilt angle. This study helps in understanding the wide range of application of aluminum and its alloys in various sectors. Without the application of aluminium, alloys in industries are unimaginable. We find its importance in welding of aluminium alloy AA6061. The objectives taken by me from literature review studies the effect of FSW process parameters on tensile strength of weld, to study the effect of FSW p rocess parameters on weld quality and the study of FSW effect in process parameters on heat affected zone.

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