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Special Issue

EFFECT OF VARIOUS PROCESS PARAMETERS ON FRICTION STIR WELDING: A REVIEW

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ABSTRACT

Friction stir welding (FSW) is a new solid state connection process for soft materials such as aluminium and magnesium alloys because it avoids many of the common problems associated with fusion welding.In this process, a cylindrical-shouldered tool with a profiled probe is turned at a constant speed and fed at a constant traverse rate into the joint line between two pieces of plate material, which are butted together. The weld quality and cost is mainly dominated by selection of appropriate process parameters in friction stir welding technique.FSW has many welding parameters such as tool rotation speed, welding speed, tool tilt angle, tool material, pin profile and shoulder diameter. Here we review and critically examine several important aspects of process parameters on friction stir welding of magnesium alloy.

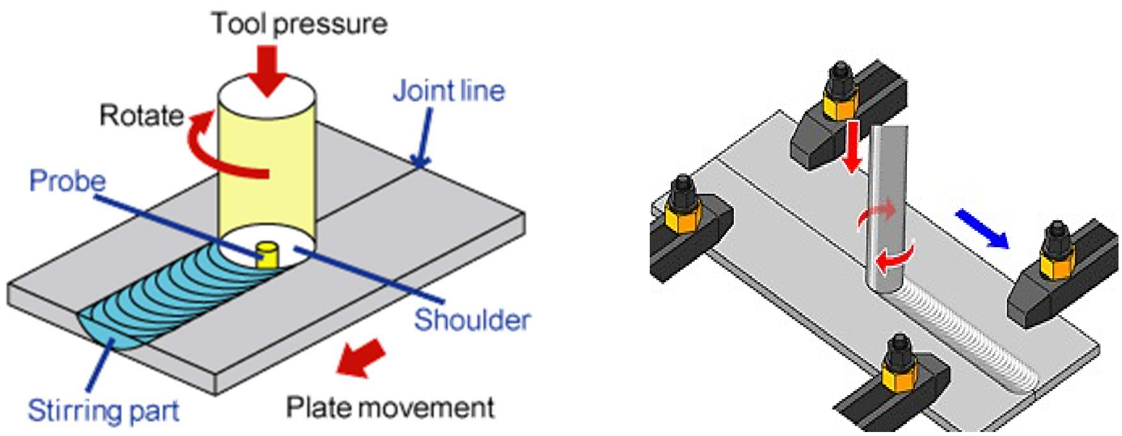
Key words: Friction stir welding. Magnesium alloy, Tool Rotation Speed, Axial Force, Welding Speed.

INTRODUCTION:

Friction stir welding, a process invented at TWI, Cambridge, involves the joining of metals without fusion or filler materials; in other words, it connects materials by using frictional heat. This joining technique is energy efficient, environment friendly, and versatile. It is already used in routine, as well as critical applications, for the joining of structural components made of aluminium, magnesium and its alloys. Friction Stir Welding (FSW) is a solid-state process, which means that the objects are joined below the melting point. This opens up whole new areas in welding technology. Friction stir welding (FSW) technique (1) appears to be a very promising joining method for increasing the industrial application of magnesium alloys. (2). The feasibility of friction stir welding of Magnesium alloy was demonstrated by Richard Johnson (TWI-2003) and they reported that more systematic study of the FSW process parameters is required.

PRINCIPLE OF FRICTION STIR WELDING:

In FSW, a cylindrical shouldered tool with a profiled probe is rotated and plunged into the joint area between two pieces of sheet or plate material. The parts have to be securely clamped to prevent the joint faces from being forced apart. Frictional heat between the wear resistant welding tool and thework pieces causes the latter to soften without reaching melting point, allowing the tool to traverse along the weld line. The plasticized material, transferred to the trailing edge of the tool pin, is forged through intimate contact with the tool shoulder and pin profile.



WELDING PARAMETERS:

Friction stir welding requires to create a certain amount of frictional heat which helps the material flow and plastic deformation at a suitable heat level and to generate a pressure along the joint line so that the sound welds can be obtained. The heat input in the weld area is affected by the welding parameters, tool geometry and joint design. Therefore, welding speed, tool rotational speed, tilt angle of the tool, tool material and tool design are the main important factors that are used to control the FSW process.

TOOL ROTATION SPEED:

In FSW the formation of friction stir zone is mainly depends upon the tool rotation speed. 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 (3).When the tool rotation speed is too low, causes lower heat input due to lack of stirring which results in defects observed in the weld region. When the tool rotation speed is high which causes the high heat input due to excess stirring.

WELDING SPEED:

The material flow pattern is greatly depends on the welding speed that there two main material flows in the nugget, one is form the advancing side and another one is forms the retreating side. The material floe on the advancing side determines the whether the weld is defect free or not (4). Due to the linear movement of the tool, softened material from the advancing side moves to the retreating side and this transferred material are consolidated in the trailing edge of the tool.

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AXIAL FORCE:

In FSW, the axial force is directly responsible for the plunge depth of the tool pin in to the work piece and load characteristics around with linear friction stir welding. When the axial force is relatively low there is a possibility of insufficient stirring at the bottom, while the higher the axial force the sound welds with full penetration.

TOOL DESIGN:

The friction stirring tool consists of a pin, or probe, and a shoulder. Tool design influences heat generation, plastic flow, the power required, and the uniformity of the welded joint. The important factor of the tool design that the material flow has adequate direction and quantity during welding. Generally, the greater volume of material to stir better weld quality is obtained, but it has strong correlation with other technological parameters (rotational speed, welding speed). Tool shoulders are designed to produce heat to the surface and subsurface regions of the work piece. The tool shoulder produces a majority of the deformational and frictional heating in thin sheet, while the pin produces a majority of the heating in thick work pieces. So one of the most important parameter of the shoulder is the diameter because it has significant effect to the amount of frictional heat.The tool shoulder diameter is having directly proportional relationship with the heat generation due to friction . If the shoulder diameter is larger, then heat generation due to friction will be higher due to large contact area and vice versa. An attempt was made to select proper tool pin profile, tool shoulder diameter and tool material to friction stir weld AZ31B magnesium alloy Padmanaban et al (5).

Fig : 1 Few tools developed and used for friction stir welding processes

PARAMETRIC STUDY OF FSW:

Many investigators have performed friction stir welding to study the effect of various parameters on quality of friction stir welded joint.

MAGNESIUM ALLOYS:

The ever increasing the fuel costs and automobile emissions have triggered a special interest in the automobile fuel economy and the climate changes. Now a days the technologies geared towards to substitution of light weight material for improving the fuel economy and reduction of emissions. In order to achieve the weight optimization and energy saving, replace the steel and iron parts with magnesium light weight components. A lighter weight translates into a increased fuel efficiency and come with good deformation properties, giving good parts with good dent and impact resistance, as well as fatigue resistance.Magnesium alloys are 35% lighter than aluminium and possess good machining and casting characteristics. Magnesium alloys are welded by using conventional welding like GTAW or TIG and gas tungsten arc welding with considerable welding speeds. The joints obtained having the problems of high welding residual stresses and changes in metallurgical structure due to melting and solidification and also high shielding gas is needed to prevent the weld contamination. The other methods of electron beam welding and laser beam welding of magnesium alloys is possible but it requires high focused energy for melting and joining of Mg alloys (6).

Razal rose et al. Studied the Effect of axial force on microstructure and tensile properties of friction stir weld AZ61A Mg alloy. They reported that axial force has significant influence on the formation of defects, grain size and hardness is the stir zone. The joints fabricated under an axial force of 5KN, rotational speed of 1200 rpm and welding speed of 90mm/min shows a maximum tensile strength compared to other joints and also the higher hardness (7).

Harikrishna et al Investigated Friction stir welding of magnesium alloy ZM21.they also reported that the grain size is the weld nugget and heat affected zone was found to increase with the base material. They also reported failures were occurred in the advancing side at the weld nugget/HAZ interface in both tensile and bend tests. The defect free, full penetration welds were obtained after careful process parameter optimization (8).

Commin et al Investigated the relationship between the processing parameters during friction stir welding , the heat and plastic deformation produced and the resulting microstructure and mechanical properties, weld quality was improved with increase in load applied ,weld speed and rotation rate. The temperature distribution is uniform along the weld length. Frictions stir welding induced lower tensile mechanical properties of this alloy (9).

Zengrongchang et al Evaluated Microstructure and tensile properties of friction-stir-welded AM50 magnesium alloy. They reported that the Friction Stir Welded AM50 Mg alloy has recrystallized microstructure with smaller equalized grains and is characterized by α-Mg matrix and β phase. The hardness of the weld nugget is improved because of the finer grains. Tensile strength and yield strength reduced compare to base metal (10).

Xie et al Studied the Effect of micro structure on mechanical properties of friction stir welded ZK60 alloy. They obtained the defect free welds under a rotation rate of 800rpm and traverse speed of 100mm/min. They also reported that fine and equalized recrystallized grains formed and $MgZn_2$ particles were broken and dispersed (11).

Wang xunhong et al Studied the microstructure and properties of friction stir butt welded AZ31 magnesium alloy. They fabricated excellent joint and no distortion friction stir welded (AZ31) Mg alloy with proper process parameters. Magnesium grains greatly retired due to dynamic recrystallization. The micro hardness is higher than the base material in the FSZ. The intermetallic compounds present in the alloy played important role in dynamic recrystallization (12).

CONCLUSIONS

From the above review it is observed that:

1. Tool rotation speed, traverse speed, axial force and tool design are the most significant process parameters in friction stir welding.
2. The tensile strength, hardness and microstructure of the friction stir welded Mg alloy is depends on the above process parameters.

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