# Design of Friction Stir Welding Operation on Dissimilar Materials using Aluminium, Copper and Magnus

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**Abstract-** Friction stir welding (FSW) is one solid state welding method that is frequently used to combine materials like Al, Cu, Mg, and their alloys. These materials are utilized often in the transportation industry and other sectors where lightweight materials with high mechanical features are required due to low weight. The mechanical properties of the welds are decreased if any fusion welding procedures are used to combine these materials. For the past 20 years, FSW has been proved to be a specific and significant improvement in welding technology. Selected parameters such as shoulder diameter, shoulder profile, pin length, pin diameter, tool angle, rotating speed, feed rate, and weld speed which affects the weld strength, quality, heat production, and material mixing. It has been concluded that the key parameters, including welding speed, "rotational speed", "plunge depth", "spindle torque", "shoulder design", "base material", "pin profile" and "tool type", significantly affect the weldability of the aluminum joint through the FSW method. Also, the selection of these parameters is important and fundamental as they directly affect the joint. It is recommended that future work focuses on FSW for aluminum. Among these, the most essential is the application of artificial intelligence (AI) techniques to select the optimum FSW parameters for aluminum welding.

***Keywords*-** Friction stir welding, process variables and dissimilar materials

## 1. INTRODUCTION

Friction stir welding (FSW) is a solid-state welding to attach two surfaces in contact plates or components without burning the materials. Copper, titanium and their alloys are the materials utilized for welding in this procedure. This method is likewise quite effective, does not release gases, but does not require additives to be used. The mechanical characteristics of the joints can be enhanced using this technique. It has become a sustainable compare to fusion welding techniques [1-3]. This technique, which joins surfaces of different metals by inserting a spinning pin tools into the metal pieces, is beneficial. Several studies have been conducted to enhance the tensile properties and other material performance of joint elements. Heat and friction are created by tool movement. To supply the necessary heat and pressure for the creation of the weld, we had to manage the welding speed (WS), shoulder diameter (SD), tilt angle (TA), axial load (AL), rotating speed (RS), tool profile (TP), and axial pressure (AP). There are four elements or zones which are HAZ, TMZ, and weld nugget (WN) that make up the connection microstructure in the process. SW is applied in many fields including offshore, aircraft, automotive, railroads, manufacturing, robotics, and personal computers. When the welding path is similar to the tool rotating direction, the position of the weld is called as the advancing direction, and when it is the reverse of the tool rotating direction, it is known as the retreating path [4].The FSW process is primarily influenced by three factors: (i) Tool Arrangement,(ii) Welding variables, (iii) Joint character. These parameters have a massive effect on the temperature variation and flow of material pattern. [5-7].This technique is strongly influenced by tool geometry. Earlier reviews claimed that the tool configuration has a significant role in the flow of raw materials and controls the traverse speed of the FSW process [8].The design of the tool is essential since a good tool will improve both the weld feature and the fastest achievable welding speed. How rapidly the tool turns and how fast it moves over the interface are the two tool speeds that need to be considered carefully. Although the link between RS, WS and heat input while weld is complicated, it is generally true that hotter welding would come from either increasing rotational speed or reducing traversing speed. It has been discovered that a key parameter for ensuring weld quality is the depths of the fall, also called as the depth under the weld plate surface at the shoulder bottom point.

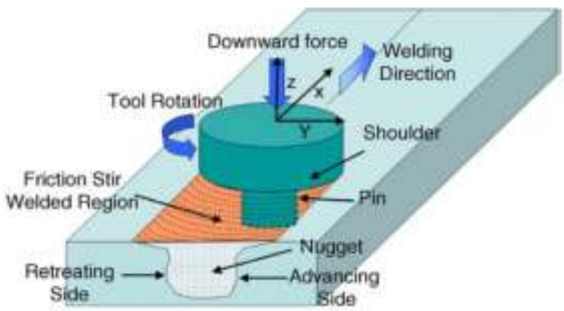


**Figure 1.** The schematic view of the FSW process

## 2. FSW PROCEDURE

To perform welding operations, a specific attachment for a machine tool is preferred. On both sheets, grooves are made at the ends before operation begins. A cylindrical tool with a probe is spun and gradually inserted between two sheets or plates of material that will be joined by welding. The components must be secured to a back bar by clamping them in a way that prevents the faces of the abutting joints from being wrenched apart or moved in any other way. The spinning tool is used to gradually penetrate the specimens till the shoulder is 0.5 mm through into sample. In order to provide the necessary heat for the operation, the indicated position is remained for 50 to 90 seconds [9]. The tool moves past the moving direction mechanically. The material which enters a plastic stage as a result of the heat generated at the weld area and the stirring created by tool movement, allowing the joining of the two metals [30-32]. The machine setting is removed from the location when the weld is performed. Welding operations will be carried out in accordance with tool input parameters.

**Table 1: Important terms in FSW tool**

| Items | Description |
|---|---|
| Tool material | H13 tool steel |
| Tool Geometry | Cylindrical truncated cone, square, triangle and threaded cylindrical pin, |
| Weld velocity | 0-300mm/min and above |
| Tool Rotational rate | Upto 3000 rpm. It may be increased depends on material selection |
| Shoulder Diameter | Up to 20mm |
| Pin Diameter | Range (1 to 8mm) |
| Pin length | Till 8mm |
| Tilt angle of tool | Depends on operation and application |

**Figure 2: FSW setup**

**Figure 3: Plates joint process in FSW**

## 3. MECHANICAL TESTING

### Tensile testing

It is a destructive technique of measuring that reveals details about the metallic material's tensile strength, yield resilience, and ductile [10,11]. It assesses the amount of stretch or elongation that a composites or plastic object must undergo to reach its breaking point.

**Hardness test**

This examination is frequently used to assess a material's characteristics and suitability for a certain task. A specially formed indenter like ball shaped is used in all test specimens [12]. With a given quantity of force, the 1/16 ball indentor is pressed against the specimen top. The hardness value is calculated by measuring the width and depth of the impression

**Fracture toughness test**

The purpose of that test is to gauge a material's resistance to the existence of a fault in terms of the load necessary to extend a fatigue pre fracture into a brittle or ductile cracked in a standard specimen.

**Creep test**

Using a continuous tensile or compressive stress at a constant temperature, this test measures the amount of material deformation that occurs over time.

**Nondestructive testing**

It is a practice of observing for faults or differences in a material and assembly without destructive the part's capacity to purpose routinely [13]. For example, optical testing, liquid penetrant testing [14], electromagnetic testing, magnetic particle testing, and radiographic testing are types of NDT.

**FSW Joint Design**

Numerous joint designs are commonly used in the FSW process. It shows these joint designs. A backing plate is usually used to avoid any separation of both plates (work pieces). However, the thickness of both plates must be the same. Also, fixation becomes extremely important during the first “tool dive” course, as it tests the higher amount of force exerted on it. In the case of the lap joint, two “backing plate” plates in the coil setup are welded to each other by putting plunge FSW perpendicularly into the bottom plate via the top plate and going through it along the direction of the weld [12,29]. Additionally, the tool shape and welding parameters have a considerable influence on the material deformation and material flow in FSW to get a successful weld joint. The tool shape and welding parameters, as well as joint design, heavily influence the material flow. Thus, it is critical to effectively study and research the material flow in order to obtain optimal tool geometry and welds that are free of defects [31].

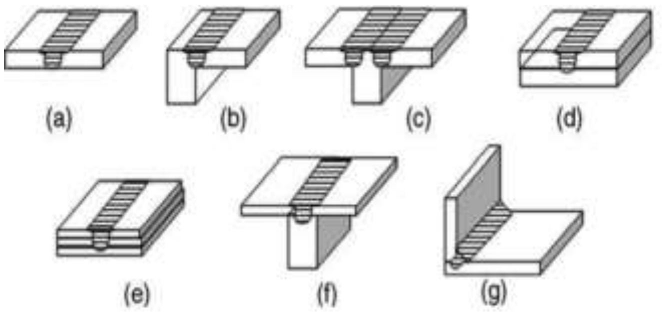


**Figure 4: Various FSW joint configurations (a) Butt welding (b) Angle T-welding (c) Double T-welding (d) Double lap welding (e) Triple lap welding (f) T-welding (g) Angle welding**

**4. LITERATURE SURVEYS**

Various studies have been conducted to determine how to use friction stir welding to increase the UTS [15] and other properties of joint metals. In this part, a few literature reviews are discussed. In order to connect Al 6061 with 7075 alloys, Ravikumar et al. discussed the impact of chosen factors on FSW. The usage of three types of pin tools in various forms, including cylinder, square, and taper square [16].Using various weld rates and distance adjustments between the sheets, Al alloy (2A70) was joined. When the weld speed was maintained at roughly 185 mm/min, the tensile strength increased up to 400Mpa [17].The use of an ultrasonic type shoulder as a tool for creating connections led to the development of optimum WS of 60 mm/min, RS of 915rpm and ultrasonic power around 1500 W parameters that increased UTS of 158MPa [18].In D. Maneiah study on FSW 6061-T6 Al alloys, he used three variables to determine the best UTS. The results displayed that the highest elongation 10 % and TS - 190Mpa were achieved at a tool's rotating speed of 1400 rev / min, a 0 degree tilt angle, and a feed rate of 110 mm/min [19].Al6061/SiC/Alumina was created by Devaraju Aruri research by using FSW, and it demonstrated excellent hardness when especially in comparison to base metal 6061. Additionally, SiC and Al2o3 particles increased avoidance distance of displacement through deformation as well as decreased elongation [20].It has been discovered that the variation of weld and tool speeds reduces BHN in the stir-zone of junction between AA7075-O with AA2024-T4 by increasing rotating speed and reducing welding speed [21].the relationship between shoulder and pin diameters to achieve superior mechanical characteristics. The shoulder pin dimension strongly impacts the heat generated during the FSW [22-24]. Rajkumar et al explained that the joint with shoulder diameter 15mm), rotating speed (900 rpm), and welding speed (100mm/min) provided the higher tensile strength in AA1100 joints [25]. The primary factors of heat creation are the tool rotating speed, tilt angle, and weld speed, therefore the amount of heat produced and the way the materials mix throughout the weld process generally determine the strength and quality of the weld. Y. Zhang et.al examined at the connections between the microstructure, the welding conditions, and the mechanical characteristics. The joints were created by friction stir welding, and they were examined at rotating speeds ranging from 300 to 600 rpm. In this project, the plate is 3 mm thickness, the travel speed of 1 mm/s, and the depth of the welding tool's plunger of 2 mm [26]. Emel investigated the properties of the weld area for steel and aluminum elements. They performed experiments on tensile, micro-hardness, and bend and tensile test which revealed that the strength is 170 MPa for mild upset pressure and 250 MPa for severe upset pressure [27].FSW done using on stainless steel and other materials was studied by Kumar et al. They verified that the composite carbides, which contain reinforced particles, may be employed as a tool material. They discovered that this tool material has to have excellent wear resistance and functional hardness [28].For friction stir welding, LI Xia et al. combined 3 mm thick Al /Cu sheets. They noticed that the majority of the pin diameter is on the aluminum side when rotating at 1000 rpm and moving at 80 mm per minute [29]

## 5. CONCLUSION

It may be concluded from sources of literature reviews of publications about the friction stir welding process that the joint characteristics were considerably influenced by pin diameter, tool shape and profiles. The primary cause of heat created in FSW is abrasion between the plate and tool shoulder. Depending on the melting temperature of the work items to be welded, several types of tools are employed .Material flow patterns are greatly affected by tool pin geometry, the force flowing stress of material, and welding temperature. FSW is the ideal procedure to utilize if a high-quality weld is required to unite different alloys of aluminum that are lengthy in length. The FSW factors and conditions have a major effect on the mechanical characteristic of the composites after welding.

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