# Analysis and Fabrication of a Butt Joint Using Friction Stir Welding

[1]Maloth Prakash, [2]Munir Sharif, [3]Sardar Jaspal Singh, [4]Rega Rajender

[1 2 4]Department of Mechanical Engineering, University College of Engineering,
Osmania University, Hyderabad, Andhra Pradesh-INDIA,
Department of Mechanical Engineering, University College of Technology,
[3]Osmania University, Hyderabad, Andhra Pradesh-INDIA
Email: [1]malothprakash@gmail.com, [2]engrmunirsharif@gmail.com, [3]jaspal85@gmail.com

**Abstract— Aluminum alloy 6061 has gathered wide acceptance in the fabrication of light weight structures required a high strength to weight ratio. Compared to fusion welding processes that are routinely used for joining structural aluminum alloys, friction stir welding process is an emerging solid state joining process in which the material that is being welded does not melt and recast. This process uses non-consumable tool to generate frictional heat in the butting surfaces. The welding parameters tool pin profile plays a major role in deciding welding quality. An attempt is made to understand the effect of welding speed and tool pin profile on FSP zone formation in Aluminum alloy 6061 and 6082. Five different tool pin profiles are used to fabric the welding joints.**

**Index Terms— Friction Stir Processing, Microstructure, Hardness, Modeling, AA6061**

## I. INTRODUCTION

Friction stir welding (FSW) is a solid-state welding process that gained much attention in research areas as well as manufacturing industry since its introduction in 1991 (TWI) For almost 22years, FSW has been used in high technology applications such as aerospace to automotive till high precision application such as micro welding. The main feature of a solid-state welding process is the non-melting of the work material which allows a lower temperature and a lower heat input welding process relative to the melting point of materials being joined. This is advantageous over the conventional fusion welding where excessive high heat input is required to melt the work material. Much less heat input required for FSW translates into economic benefits, safer and less complicated welding procedures. The friction stir welding make it possible to join light weight materials such as aluminium alloy, magnesium alloy, copper and titanium alloys which are very difficult to weld by conventional welding. These clear advantages have greatly increased the usage of these materials in structural applications. In addition, FSW also makes possible to produce sound weldment in 5000 and 7000 series aluminium alloys that are not possible to be welded using conventional method. FSW does not produce sparks or flames.

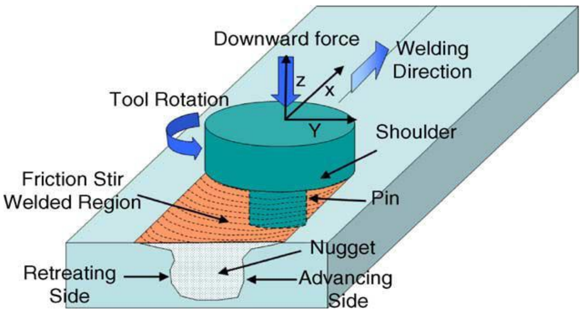



Figure 1: Schematic Drawing of FSW

Thus, safety, environmental and legislation issues are not of major concern. FSW process provides proven good quality and strong weldment with inexpensive and lesser number of equipment, eliminates the use of filler metal and improved weldability. Due to these factors FSW has successfully been employed in aerospace, automobile and ship building industries. The need to further understand and improve FSW process continues to propagate in many applications. Many researchers have looked into several methods including mathematical modeling of the process, aiming at understanding the physical-material interaction. However, there is lack of recorded work in the literature on a system or method to quantitatively measure the welding parameter such as force and torque in FSW process.

## II. PRINCIPLE OF OPERATION - FRICTION STIR WELDING

This welding technique involves the joining of metals without fusion or filler materials. It is used already in routine, as well as critical applications, for the joining of structural components made of aluminium and its alloys. Indeed, it has been convincingly demonstrated that the process results in strong and ductile joints, sometimes in systems which have proved difficult using conventional welding techniques. The process is most suitable for components which are flat and long (plates and sheets) but can be adapted for pipes, hollow sections and positional welding. The welds are created by the combined action of frictional heating and mechanical deformation due to a rotating tool. The maximum temperature reached is of the order of 0.8 of the melting temperature. The tool has a circular section except at the end where there is a threaded probe or more complicated flute; the junction between the cylindrical portion and the probe is known as the shoulder. The probe penetrates the work piece whereas the shoulder rubs with the top surface. The heat is generated primarily by friction between a rotating--translating tool, the shoulder of which rubs against the work piece. There is a volumetric contribution to heat generation from the adiabatic heating due to deformation near the pin. The welding parameters have to be adjusted so that the ratio of frictional to volumetric deformation-- induced heating decreases as the work piece becomes thicker. This is in order to ensure a sufficient heat input per unit length.

The micro structure of friction stir welding depends in detail on the tool design, the rotation and translation speeds, the applied pressure and the characteristics of the material being joined. There are a number of zones. The heat-affected zone (HAZ) is as in conventional welds. The central nugget region containing the onion-ring flow-pattern is the most severely deformed region, although it frequently seems to dynamically recrystallize, so that the detailed microstructure may consist of equated grains. The layered (onion- ring) structure is a consequence of the way in which a threaded tool deposits material from the front to the back of the weld. It seems that cylindrical sheets of material are extruded during each rotation of the tool, which on a weld cross-- section gives the characteristic onion-rings.

2.1 Friction Stir Welding Process Parameters

FSW involves complex material movement and plastic deformation. Welding parameters, tool geometry, and joint design exert significant effect on the material flow pattern and temperature distribution, thereby influencing the micro structural evolution of material. In this section, a few major factors affecting FSW/FSP process, such as tool geometry, welding parameters, joint design are addressed. The strength of Friction stir welding depends on the following three process parameters. They are

1. Spindle speed
2. Feed rate

2.1.1 Spindle Speed:

The spindle speed is the rotational frequency of the spindle of the machine, measured in revolutions per minute (RPM). The preferred speed is determined based on the material being cut.

- Weld strength and quality of the weldment required - Higher quality of weld and strength can be obtained at high speed operations.
- Material to be welded - Hard material requires high speed operation.
- Size of weld. Large welds require low speed operation.
- Thickness of the work piece to be welded.

2.1.2 Feed Rate

Feed rate is the velocity at which the cutter is fed, that is, advanced against the work piece. It is expressed in units of distance per revolution for turning and boring (typically inches per revolution (ipr) or millimeters per revolution). It can be expressed thus for milling also, but it is often expressed in units of distance per time for milling (typically inches per minute (ipm) or millimeters per minute).

3. Welding Parameters

For FSW, two parameters are very important: tool rotation rate (v, rpm) in clockwise or counter clockwise direction and tool traverse speed (n, mm/min) along the line of joint. The rotation of tool results in stirring and mixing of material around the rotating pin and the translation of tool moves the stirred material from the front to the back of the pin and finishes welding process. Higher tool rotation rates generate higher temperature because of higher friction heating and result in more intense stirring and mixing of material as will be discussed later. However, it should be noted that frictional coupling of tool surface with work piece is going to govern the heating. So, a monotonic increase in heating with increasing tool rotation rate is not expected as the coefficient of friction at interface will change with increasing tool rotation rate. The ratio of influence of tool speed and weld speed is 4: 3 which was found by experimental results.

PARAMETER OF FRICTION STIR WELDING

Table 1.1 parameter of friction stirs welding

| Properties/parameter | Values |
|---|---|
| Work material dimension, | 100×50×3 |
| Shoulder radius , mm | 20 |
| Pin radius, mm | 2.5 |
| Pin height ,mm | 3 |
| Pin conical angle ,◦ | 2 |
| Tool angle | 2 |
| Work piece material | 6061&608 |
| Tool material | H.S.S |

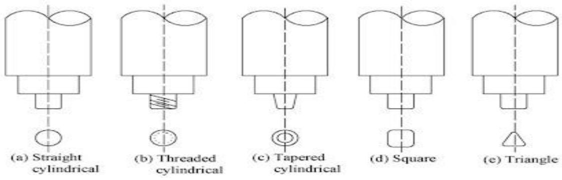



Figure 2: Tool used for FSW source

## III. EXPERIMENTAL PROCEDURE

ALUMINUM ALLOY AA6061& 6082:

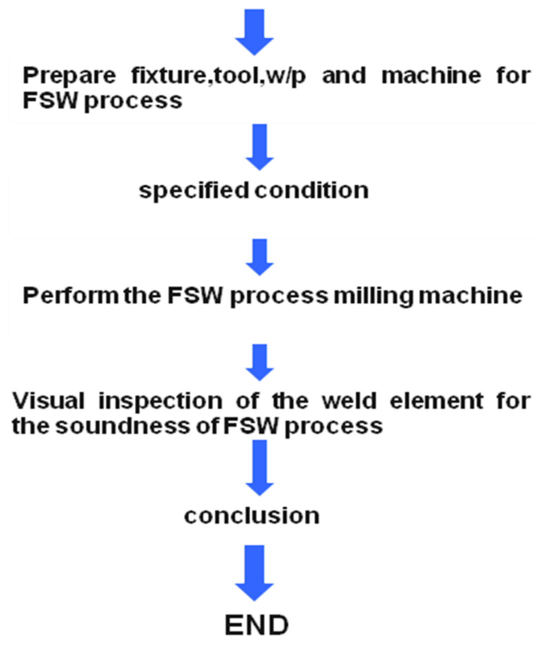
Aluminium alloy AA6061&6082 is a medium strength alloy with excellent corrosion resistance. It has the highest strength of the 64430 series alloys. Alloy AA6061&6082 is known as a structural alloy. In plate form, AA6061 is the alloy most common-ly used for machining. The addition of a large amount of manganese controls the Grain structure which in turn results in a stronger alloy. Alloy AA6061&6082 machines well and produce tight coil of swarf when chip breaker are used. Tool material: High speed steel

SAMPLE PREPARATION:

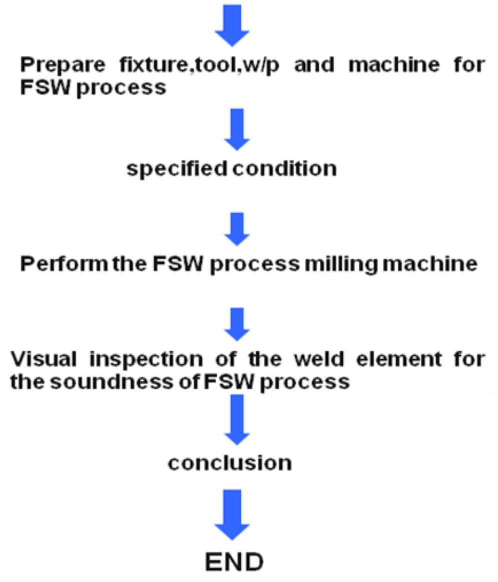
Rolled plates of 3mm in thickness were cut into the required size (100mm x 50 mm x 3 mm) by power hacksaw cutting and milling. The experiments were conducted on the aluminium alloy IS 64430. Before the friction welding, the weld surface of the base material was cleaned. . Plate edges to be weld were also prepared so that they are fully parallel to each other. This is to ensure that there is no uneven gap between the plates which may not result in sound welding. Secondly surface preparation was also done so that the surfaces of both the plates are of equal level and footing plates are of equal level and footing.

EXPERIMENT:

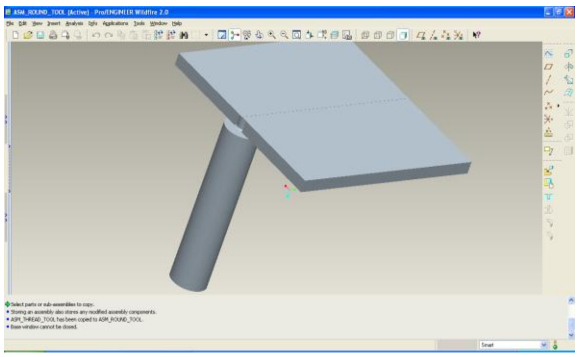
A semi automation milling machine was used for friction stir processing (FSW) of aluminum alloy. The machine was a maximum speed 6000 rpm and 10-horse power. test piece was clamped in the fixture tightly. Initially the rotating pin was inserted into a predrilled hole, which will facilitate the start up of welding .Tool tilt angle was 2 degree processing began at spindle speed of 1200 rpm and travel rate of 75mm/min. since tool plunge was to the extent of 3mm and plate thickness the same step was repeated for tool . The result was two side welded plates. The process was repeated for tool travel rate of 90 mm/min for the tool speeds of 1400rpm. The plates where then subjected to mechanical testing. In the present work the influence of speed, feed on the performance of FSW such as Hardness and tensile strength is evaluated at different experimental conditions.



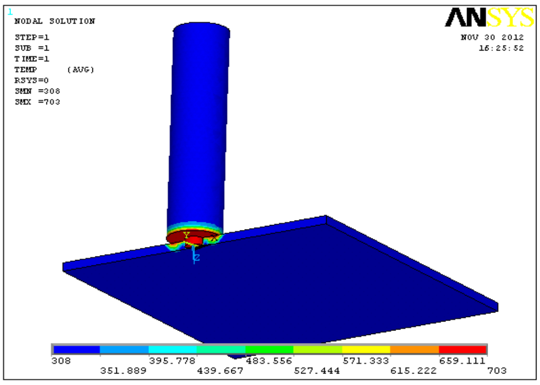

FLOW CHART OF EXPERIMENT




## IV. MODELS OF CUTTING TOOL



ANSYS MODEL OF EXPERIMENT




## V. UNIVERSAL TESTING MACHINE RESULTS

FOR 6061&6082

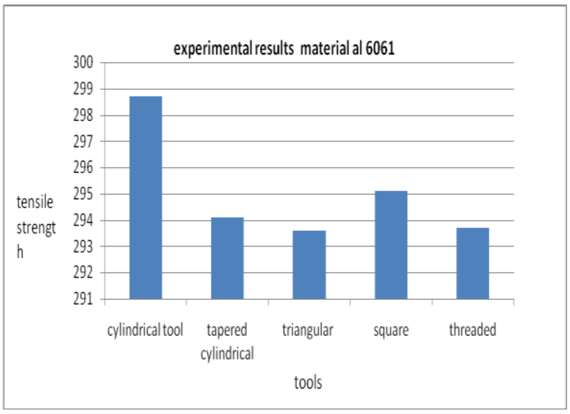
FOR AL 6061

| Tool geometry | Maximum load (N) | Tensile strength (mpa) |
|---|---|---|
| 1)Cylindrical tool | 11000 | 298.7 |
| 2) Tapered cylindrical | 10900 | 294.1 |
| 3)Triangular | 10950 | 293.6 |
| 4) square | 10750 | 295.1 |
| 5) threaded | 1070 | 293.7 |

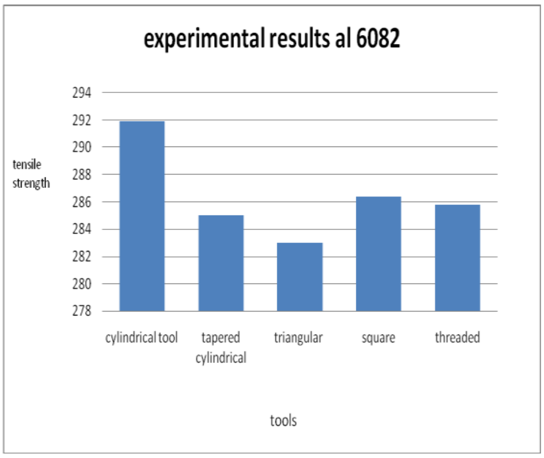
FOR AL 6082

| Tool geometry | Maximum load (N) | Tensile strength (mpa) |
|---|---|---|
| 1)Cylindrical tool | 10900 | 291.9 |
| 2) Tapered cylindrical | 10350 | 285.0 |
| 3)Triangular | 10200 | 283.5 |
| 4) square | 10650 | 286.4 |
| 5) threaded | 10700 | 285.8 |

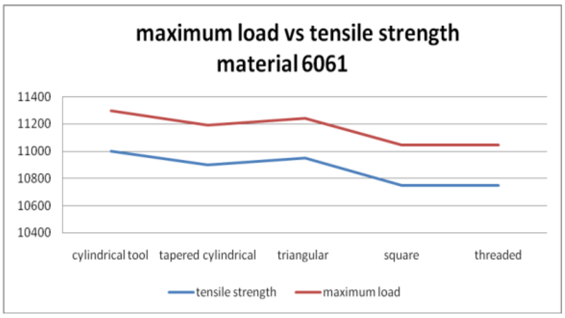
UNIVERSAL TESTING MACHINE RESULTS GRAPH



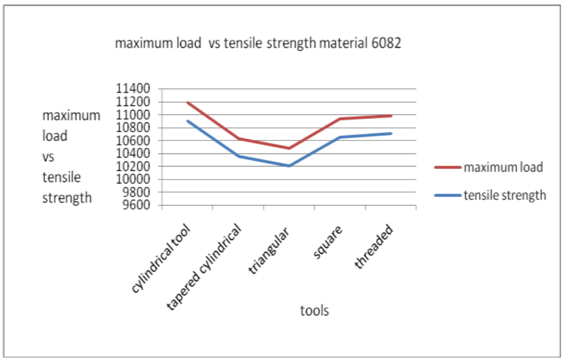

Graph 1: tensile strength of6061 vs tools



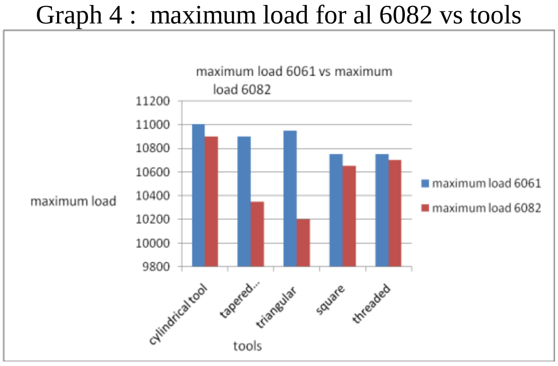

Graph 2: tensile strength 6082 vs tools




Graph 3: maximum load for al 6061 vs tools




Graph 4 : maximum load for al 6082 vs tools




Graph 5: results of 6061 & 6082

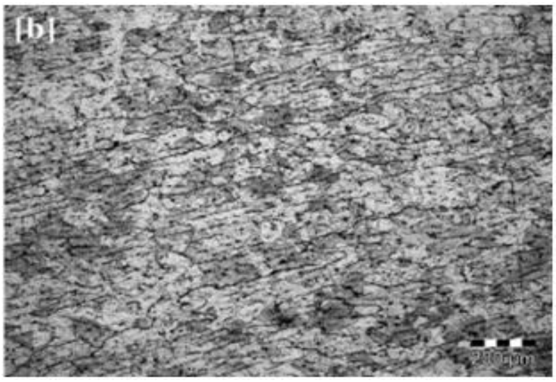
## VI. RADIOGRAPHY TEST RESULTS

The results of radiography test which were observed during the experiment were tabulated which shown in figure:

| S. No. | Test Parameter | Results |
|---|---|---|
| 1. | Radiography Test | No Significant Defects Indication are noticed hence acceptable |

BEFORE WELDING


AFTER WELDING




## VII. CONCLUSION

FSW process benefits solid state joining method that has great advantage on light weight material such as aluminium alloy due to its thermal properties which make it difficult to be joined using conventional methods. Similarly to the other welding method, heat generation and heat transfer play major role in determining the success of the joining process as well as predominantly establish the joint characteristics and properties. Though the detail of the process mechanism and the effect on the welding has been widely studied in lab scale, good understanding of the process mechanism provides a better view on choosing the best parameter for the process and finally to achieve the best result in practice. We have comparing two Al 6061&6082 material which is good for welding and designed 5 types of cutting tools cylindrical tool, round cylindrical tool, Square Triangle and Thread for doing Friction Stir Welding. Observing above analysis and experimental result for cylindrical tool is having more thermal flux and thermal gradient, then we will get good weld property while doing welding process. In material point of you 6061 are having good tensile strength properties compare to 6082.In structural analysis Triangle tool is having less displacement and yield stress. Also remaining tools is also within the limit. We are concluding that cylindrical tool is best suited tool for FSW.

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