

# Influence of Tool Pin Profile on the Tensile Behaviour of Dissimilar Friction Stir Welded Joints of Aluminium Alloys

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**ABSTRACT:** AA6xxx aluminium alloy (Al–Mg–Si alloy) has gathered wide acceptance in the fabrication of light weight structures requiring a high strength-to weight ratio and good corrosion resistance. Compared to the fusion welding processes that are routinely used for joining structural aluminium alloys, 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. This process uses a non-consumable tool to generate frictional heat in the abutting surfaces. The welding parameters such as tool rotational speed, welding speed, axial force etc., and tool pin profile play a major role in deciding the joint strength. In the present investigation, Axxx and AA 6xxxx aluminum alloys were friction stir welded under tool rotational speed of 1000 rpm and traversing speed of 80mm/min, keeping other parameters same. In this project used three pin profiles like square, triangle, hexagon with same process parameter. To check weldment using tensile strength.

**KEYWORDS:** FSW, AA6xxx & A3xx Aluminium alloy.

## I. INTRODUCTION

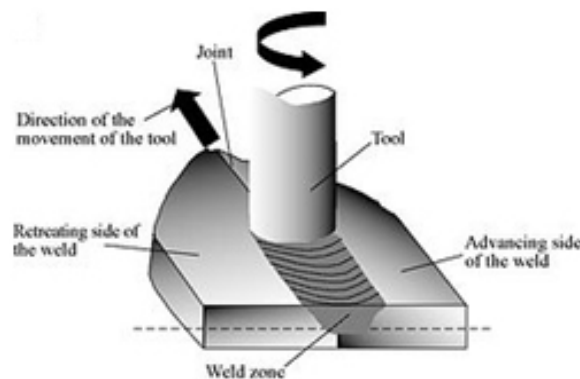
### 1.1 Friction stir welding

Friction-stir welding (FSW) is a solid-state joining process (meaning the metal is not melted) and is used for applications where the original metal characteristics must remain unchanged as far as possible. It works by mechanically intermixing the two pieces of metal at the place of the join, transforming them into a softened state that allows the metal to be fused using mechanical pressure, much like joining clay, dough, or plasticine. This process is primarily used on aluminium and most often on large pieces which cannot be easily heat treated post weld to recover temper characteristics.

### 1.2 Principle of operation



Fig 1: FSW Machine



**Fig 2: Cylindrical-Shouldered Tool**

(B) The progress of the tool through the joint, also showing the weld zone and the region affected by the tool shoulder. A constantly rotated cylindrical-shouldered tool with a profiled nib is transversely fed at a constant rate into a butt joint between two clamped pieces of butted material. The nib is slightly shorter than the weld depth required, with the tool shoulder riding atop the work surface. Frictional heat is generated between the wear-resistant welding components and the work pieces. This heat, along with that generated by the mechanical mixing process and the adiabatic heat within the material, cause the stirred materials to soften without melting. As the pin is moved forward a special profile on its leading face forces plasticised material to the rear where clamping force assists in a forged consolidation of the weld. This process of the tool traversing along the weld line in a plasticised tubular shaft of metal results in severe solid state deformation involving dynamic recrystallization of the base material.

### 1.3 Microstructural features

The solid-state nature of the FSW process, combined with its unusual tool and asymmetric nature, results in a highly characteristic microstructure. The microstructure can be broken up into the following zones:

The **stir zone** (also nugget, dynamically recrystallised zone) is a region of heavily deformed material that roughly corresponds to the location of the pin during welding. The grains within the stir zone are roughly equiaxed and often an order of magnitude smaller than the grains in the parent material. A unique feature of the stir zone is the common occurrence of several concentric rings which has been referred to as an "onion-ring" structure. The precise origin of these rings has not been firmly established, although variations in particle number density, grain size and texture have all been suggested.

The **flow arm zone** is on the upper surface of the weld and consists of material that is dragged by the shoulder from the retreating side of the weld, around the rear of the tool, and deposited on the advancing side. The **Thermo-mechanically affected zone (TMAZ)** occurs on either side of the stir zone. In this region the strain and temperature are lower and the effect of welding on the microstructure is correspondingly smaller. Unlike the stir zone the microstructure is recognizably that of the parent material, albeit significantly deformed and rotated. Although the term TMAZ technically refers to the entire deformed region it is often used to describe any region not already covered by the terms stir zone and flow arm.

The **heat-affected zone (HAZ)** is common to all welding processes. As indicated by the name, this region is subjected to a thermal cycle but is not deformed during welding. The temperatures are lower than those in the TMAZ but may still have a significant effect if the microstructure is thermally unstable. In fact, in age-hardened aluminium alloys this region commonly exhibits the poorest mechanical properties.

### 1.4 Advantages and limitations

The solid-state nature of FSW leads to several advantages over fusion welding methods as problems associated with cooling from the liquid phase are avoided. Issues such as porosity, solute redistribution, solidification cracking and liquation cracking do not arise during FSW. In general, FSW has been found to produce a low concentration of defects and is very tolerant of variations in parameters and materials.

Nevertheless, FSW is associated with a number of unique defects. Insufficient weld temperatures, due to low rotational speeds or high traverse speeds, for example, mean that the weld material is unable to accommodate the

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extensive deformation during welding. This may result in long, tunnel-like defects running along the weld which may occur on the surface or subsurface. Low temperatures may also limit the forging action of the tool and so reduce the continuity of the bond between the material from each side of the weld. The light contact between the material has given rise to the name "kissing-bond". This defect is particularly worrying since it is very difficult to detect using nondestructive methods such as X-ray or ultrasonic testing. If the pin is not long enough or the tool rises out of the plate then the interface at the bottom of the weld may not be disrupted and forged by the tool, resulting in a lack-of-penetration defect. This is essentially a notch in the material which can be a potent source of fatigue cracks.

A number of potential advantages of FSW over conventional fusion-welding processes have been identified:

- Good mechanical properties in the as-welded condition
  - Improved safety due to the absence of toxic fumes or the spatter of molten material.
  - No consumables — A threaded pin made of conventional tool steel, e.g., hardened H13, can weld over 1 km of aluminium, and no filler or gas shield is required for aluminium.
  - Easily automated on simple milling machines — lower setup costs and less training.
  - Can operate in all positions (horizontal, vertical, etc.), as there is no weld pool.
  - Generally good weld appearance and minimal thickness under/over-matching, thus reducing the need for expensive machining after welding.
  - Low environmental impact.
- However, some disadvantages of the process have been identified
- Exit hole left when tool is withdrawn.
  - Large down forces required with heavy-duty clamping necessary to hold the plates together.
  - Less flexible than manual and arc processes (difficulties with thickness variations and non-linear welds).
  - Often slower traverse rate than some fusion welding techniques, although this may be offset if fewer welding passes are required.

## ➤ 1.5. Important welding parameters

### 1.5.1 Tool rotation and traverse speeds

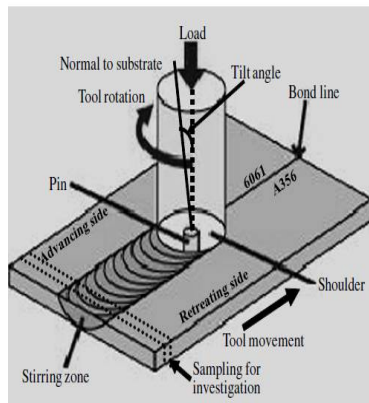
There are two tool speeds to be considered in friction-stir welding; how fast the tool rotates and how quickly it traverses the interface. These two parameters have considerable importance and must be chosen with care to ensure a successful and efficient welding cycle. The relationship between the welding speeds and the heat input during welding is complex but, in general, it can be said that increasing the rotation speed or decreasing the traverse speed will result in a hotter weld. In order to produce a successful weld it is necessary that the material surrounding the tool is hot enough to enable the extensive plastic flow required and minimise the forces acting on the tool. If the material is too cold then voids or other flaws may be present in the stir zone and in extreme cases the tool may break.

Excessively high heat input, on the other hand may be detrimental to the final properties of the weld. Theoretically, this could even result in defects due to the liquation of low-melting-point phases (similar to liquation cracking in fusion welds). These competing demands lead onto the concept of a "processing window": the range of processing parameters viz. tool rotation and traverse speed, that will produce a good quality weld. Within this window the resulting weld will have a sufficiently high heat input to ensure adequate material plasticity but not so high that the weld properties are excessively deteriorated.

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## 1.6 A3xxx ALUMINIUM ALLOY APPLICATION

Typical uses aircraft pump parts, automotive transmission cases, aircraft fittings and control parts, water-cooled cylinder blocks. Other applications where excellent castability and good weldability, pressure tightness, and good resistance to corrosion are required.

## 1.7 A6xxx ALUMINIUM ALLOYS APPLICATION

6061 is widely used for construction of aircraft structures, such as wings and fuselages, more commonly in homebuilt aircraft than commercial or military aircraft.

## 2. RAW MATERIAL PREPERATION

From my literature review we select AA6xxx & Axxx Aluminium Alloy for raw material. AA 6xxx plates cut by 100\*50 (length\*width) by using handsaw machine. A3xxx ingots cut by handsaw machine. after machining (turning, grinding) the A3xxx material. that machined material cut by same length and width using handsaw machine.

## CHEMICAL 3. COMPOSITION TEST;

After preparation the material to check this chemical composition. The composition details given below. Concentration of alloying elements in substrate (wt.%)

Elements	AA6061 T-6 Alloys	A356 Alloys
Si	0.70	6.85
Fe	0.25	0.17
Cu	0.19	0.04
Mn	0.12	0.031
Mg	0.86	0.42
Zn	0.10	0.03
Ti	0.052	0.09
Cr	0.063	0.008
Ni	0.01	0.008
Pb	0.013	0.035
Sn	0.007	0.003
P	0.003	0.006
Li	Nil	Nil
Al	97.5	92.16

Table 1: Alloying Elements

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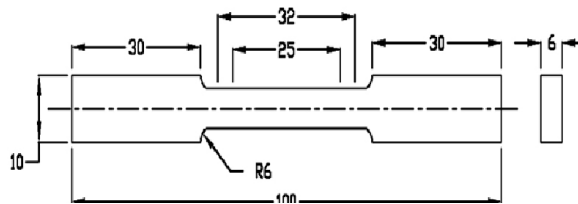
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## II. EXPERIMENTAL WORKS

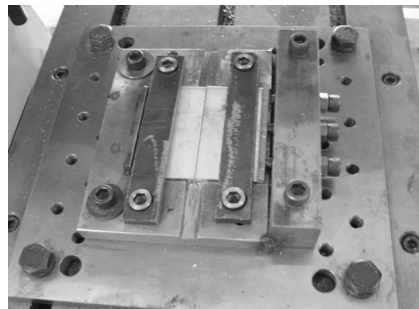
The substrate in the present investigation is wrought A3xx and 6xxx Aluminium alloys having dimensions 100 (l)×50 (w)×6(t) mm<sup>3</sup>. The analyzed chemical composition and obtained tensile properties of the base alloys are furnished in above.

The welding was carried out in load controlled friction stir welding equipment. Tool was made of high speed steel with shoulder diameter 15 mm, pin diameter 5 mm and cylindrical pin length 2.6 mm. Normal load (5 kN) and tool tilt angle (3°) were kept constant during processing. A3xx and 6xxx alloys were at retreating and advancing side respectively by clamping rigidly over the bed from four sides to avoid vibration or displacement during processing. single welding pass was carried out. tool pin height is 5.6mm .so its not touch bottom tables.

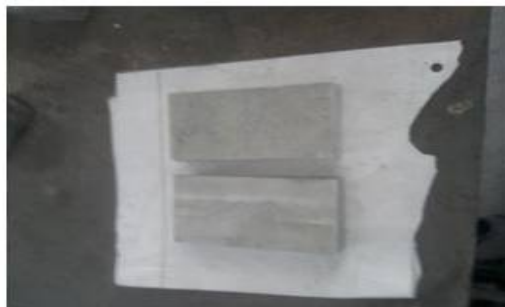
In this investigation we conduct six weldings. each tool proceeds two weldings. after welding the weldment it cut by ASTM E8M -04 Dimension. all tensile cutting done by wire cut edm machine.



**Fig 3: TENSILE SPECIMEN FOR ASTM E8M-044**



**Fig 4: WORK HOLDING DEVICE**



**Fig 5: RAW MATERIAL BEFORE WELDING**

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**Fig 6: RAW MATERIAL AFTER WELDING**

### III. RESULT&DISCSSION

Sample 1 conducted square pin profile with travelling speed 80mm/min, rotational speed 1000rpm. each pin profile used in two weldings. because one workpiece cut by tensile work purpose. another one cut by sem test. the welding conducted at room temperature. axial load is 5 kn. one side welding passes has done.

Sample 2 conducted triangle pin profile with travelling speed 80mm/min, rotational speed 1000rpm. Sample 3 conducted hexagon pin profile with travelling speed 80mm/min, rotational speed 1000rpm.

The tensile properties of the transition joints are collated in Table. Highest bond strength has been achieved for hexagonal pin profiles, where it is close to the tensile strength of 6061 alloy. because hexagonal profile is have six corners .so easy to run more stiring action. From the above results, it is evident, the tool pin profile also play major role of tensile strength and also hexagon profile achieved good result.

At the time of friction stir welding, as mentioned earlier in front of tool, material gets plasticized and transported from retreating to advancing side. At the back of the tool, the transported material cools down and consolidated by forging process. The material transport is evident from the re-distribution of Si rich particles within stirring zone. Voids within the weld nugget are generated owing to difference in material transport and degree of consolidation. Higher heat input needs higher interaction time between tool and work piece to obtain proper consolidation



**Fig 7: BEFORE TENSILE TEST**

S.NO	SAMPLE ID
1	AA6xxx&A3xx (SQUARE)
2	AA6xxx&A3xx (TRIANGLE)
3	AA6xxx&A3xx (HEXAGON)
4	AA6xxx(RAW MATERIAL)
5	A3xx(RAW MATERIAL)

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Sample id	Tensile strength( Mpa)	% of elongation
Sample 1	127.62	2.6
Sample 2	182.64	4.00
Sample 3	250.54	6.00
Sample 4	340.43	9.00
Sample 5	118.5	1.90

**Table 2: TENSILE SPECIMEN -I SECTION**

## IV. CONCLUSION

In the present study A3xxx and AA6xxx aluminum alloys were joined by friction stir welding under constant rotational speed and travelling speed with different pin profile. Hexagonal profile achieved good mechanical property. Because hexagonal six corners to participate the stir action .so A3xxx and AA6xxx dissimilar material exhibits superior mechanical properties with respect to the pin profiles.

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