Effect of Tool pin Profile on Aluminum alloy using FSW for optimum results by finding optimum Parameters

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***Abstract*— the research generally lies on characteristics of FSW tool pin's profile on FSW joint. Previous researches proven that square, tapper cylindrical profile shaped tool pin gives optimum results. In present work will be carried out using different tool pin profile like tapper cylindrical, square, tapper hexagonal, and threaded cylindrical. Test specimen will be prepared from obtain results and various tests (tensile and bending test) will be carried out to prove its optimum joints. On the basis of these results and parameters used during experiment the effect of tool pin profile will be understood.**

***Keywords*—Friction Stir Welding, Pin Profile, Threaded tool pin, Shoulder geometry**

I. INTRODUCTION

Welding and joining technology is fundamental to engineering and manufacturing. Without the ability to make strong and durable connections between materials it would not possible to produce the many different items upon which we all rely in our everyday lives, from the very large (building, pipelines, trains and bridges) to the very small (medical implants and electronic devices) The unique combination of light weight and relatively high strength makes aluminum the second most popular metal that is welded. Aluminium is the most widely used non-ferrous metal in the modern world. The welding of aluminium and its alloys has always represented a great challenge for designers and technologists

Conventional welding are proven and well established techniques for joining the 5xxx and 6xxx series aluminium alloys that are generally used for fabricating structures in rail road and marine transport and for bridges, off-shore oil-platform and buildings. Nevertheless, the production of sound welds when using these techniques requires special care in terms of joint edge preparation, the removal of surface oxide immediately prior to welding, the application of weld pool shielding gas, the selection of the correct filler wire, plus the implementation of the process control and operation parameters.

Therefore, as a joining technique for thin sheets of those alloys, Friction stir welding (FSW) was invented by The Welding Institute (TWI) U.K. in 1991.[1] It is energy efficient, environmental friendly and versatile.

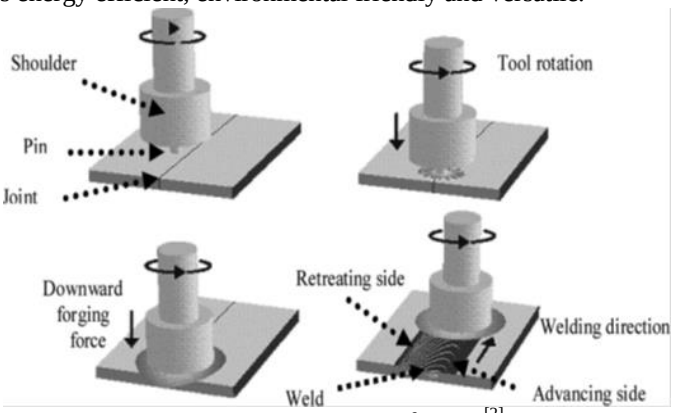

Fig.1 Basic Process of FSW [2]

Friction stir welding is a relatively new solid state joining process.

FSW process is divided in two famous processes defined as lap joints and butt joints. In above Fig 1. Basic process is shown. There are two work pieces are fixture (clamped) on a rigid back plate. The fixturing prevents the work pieces from spreading apart or lifting during welding. The welding tool, consisting of a shank, shoulder and pin, is then rotated to a prescribed speed and tilted with respect to the workpiece normal. The tool is slowly plunged into the workpiece material at the butt line, until the shoulder of the tool forcibly contacts the upper surface of the material and the pin is a short distance from the back plate. A downward force is applied to maintain the contact and a short dwell time is observed to allow for the development of the thermal fields for preheating and softening the material along the joint line. At this point, a lateral force is applied in the direction of welding (travel direction) and the tool is forcibly traversed along the butt line, until it reaches the end of the weld; Upon reaching the end of the weld, the tool is withdrawn, while it is still being rotated.[2]

II. EFFECT OF FSW TOOL PIN PROFILE

Generally tool pin profile acts major role to obtain better joint, hence many researchers have don researches on different tool pin profile and obtained optimum results. **Bahemmat P**[3] has studied on the influence of the pin geometry on the weld shape and mechanical properties and effect of different rotational speed. AA 2024 alloy was bonded using FSW process. And four-flute and taper screw thread tool pin used.to show the different tool geometry used in this paper in table 2.1:

Table 2.1 Different tool geometry

No	Description of the pin	Big diameter of the pin	Small diameter of the pin
1	Four-flute pin	6 mm	6 mm
2	Taper screw thread pin	6 mm	4 mm

Table 2.2 The welding parameter and tool dimension

Rotational speed (rpm)	400, 600, 800, 1000
Welding speed (mm/min)	50
Pin length (mm)	4.7
Tool shoulder diameter (mm)	18
Axial force (kN)	10
Attack angle	2^0

The joint fabricated using four-flute pin profiled tool exhibits superior tensile properties compared to taper screw thread pin profile, irrespective of rotational speed. The ultimate tensile strength of the four-flute pin reaches to the 90% and Taper screw thread pin ultimate strength goes up to the 84% of the base metal ultimate strength. The four-flute joints fabricated at the rotational speed of 800rpm have demonstrated more ultimate and yield strength in comparison with other rotational speed 600, 1000rpm.The taper screw thread joints fabricated at a rotational speed of 600 rpm show superior tensile properties compared to 400, 800rpm.The percentage of elongation increases due to increasing the rotational speed. This is noticeable that four flute pin profile gives better then tapper screw threads, where another researcher done same study by taking different pin profiles.

Elangovan K. [4]is same study of the influence of the pin geometry on the weld shape and effect of different rotational speed. AA2219 aluminium alloy used. And Five different tool pin profiles (straight cylindrical, tapered cylindrical, threaded cylindrical, triangular and square) have been used to fabricate the joints at three different tool rotational speeds.

Table 2.3 The Welding parameters and tool dimensions

Rotational speed (rpm)	1500, 1600, 1700
Welding speed (mm/s)	0.76
Axial force (kN)	12
D/d ratio of tool	3.0
Pin length (mm)	5.7
Tool shoulder dia. D (mm)	18
Pin dia. d (mm)	6
Tool inclined angle (^{0})	0^0
include angle of taper pin	7.5

From this investigation it is found that the square tool pin profile produces mechanically sound and metallurgic ally defect free welds compared to other tool pin profiles. Of the five tool pin profiles used in this investigation to fabricate the joints, square pin profiled tool produced defect free FSP region, irrespective of rotational speeds. Of the three tool rotational speeds used in this investigation to fabricate the joints, the joints fabricated at a rotational speed of 1600 rpm showed better tensile properties, irrespective of tool pin profiles. Of the 15 joints fabricated in this investigation, the joint fabricated using square pin profiled tool at a rotational speed of 1600 rpm showed superior tensile properties. Hence here it shows that square tool pin profile gives better results as compare to other profiles.

It is understandable that different pin profiles gives optimum results at different parameters so **Patil H. S.**[5] **has** study the effects of different welding speeds and tool pin profiles on the weld quality of AA6082-O aluminium and the effect of different welding speed and pin profiles on yield strength ultimate tensile strength and elongation. In this research Tri flutes and taper screw thread tool pin are used.

Table 2.4 The geometrical configuration of the tools

Description of the pin	Big diameter of the pin	Small diameter of the pin
Tri-flute pin	5.50mm	4.90mm
Taper screw thread pin	5.54mm	4.30mm

In this paper also Single pass welding procedure was used to fabricate the joints.

Table 2.5 The welding parameters used to fabricate the joints.

Rotating speeds(rpm)	1200
Welding speeds (mm/min)	60,70,75,85
Pin length (mm)	4.7
Tool shoulder diameter (mm)	18

The appearance of the weld is well and no obvious defect is found using these tools. It is found that the joint fabricated using taper screw thread pin exhibits superior tensile properties compared tri -flute pin profile, irrespective of welding speed. The ultimate tensile strength of the taper screw thread reaches to the 92.30% and the tri-flute pin ultimate strength goes up to the 58.97% of the base metal ultimate strength. The taper screw thread joints fabricated at the welding speed of 70mm/min have demonstrated more ultimate and yield strength in comparison with other welding speed of 60, 75mm/min. The four-flute joints fabricated at a welding speed of 60mm/sec show superior tensile properties compared to 70, 85mm/min. tapper screw thread given better results in manner of tensile property of joint. It's desirable that tensile property of joint must have to be neat its base metals tensile property.

As tool pin profile acts major role similarly tool shoulder plays important role in stirring effect. Shoulder profile captures the material during stirring process and increases heat due to friction **Scialpi A.**[6] Has done work regarding tool shoulder in this work, a study of three shoulder geometries has been carried out. TFC - (fillet + cavity) tool, TFS - (fillet + scroll) tool, TF - (only fillet) tool, AA 6082 T6 1.5 mm thick sheets used. The welding process was carried out rotating the tool at 1810 rpm and at a feed rate of 460 mm/min.

Table 2.6 Mechanical properties

	$\sigma_{y\ (MPa)}$	UTS (MPa)	Elongation (%)
Base material	283	324.8	12.2
T_{FS}	193	281.5	17.5
T_{FC}	181	270	20.1
T_F	194	256	7.9

By visual inspection the crown and root quality has been evaluated. TFC tool crown can be considered the best in terms of crown quality. With 460 mm/min and 1810 rpm, TFC can be considered the best tool because the combination of fillet and cavity increases the longitudinal and transverse strength of the joint and provide the best crown surface.

Till now more tensile performance obtained from threaded tool only hence **Bilici M. K**. [7] has done research on threaded tool and tried to find index number o=from pin diameter, tool rotation and feed**.** In this Research, The effects of tool geometry and properties on friction stir spot welding properties of polypropylene sheets were studied. Four different tool pin geometries, with varying pin angles, pin lengths, shoulder diameters and shoulder angles were used for friction stir spot welding. The tapered cylindrical pin gave the biggest and the straight cylindrical pin gave the lowest lap-shear fracture load. The biggest tensile strength were obtained with threaded tool (Pitch length 0.8 mm, 7.5 mm pin diameter, 5.5 mm pin length, 30 mm shoulder diameter and 6° shoulder angle. The optimum straight tool geometry for 4 mm thick sheets was determined as 7.5 mm pin diameter, 15° pin angle, 5.5 mm pin length, 30 mm shoulder diameter and 6° shoulder angle. After his research he obtained same result that threaded pin profile gives better result.

Mustafa Kemal Kulekci [8] The objective of this study was to determine the effects of the tool pin diameter and tool rotation on the fatigue behavior of friction stir welded (FSW) lap joints. FSW lap joints of AA 5754 aluminium alloy plates were used. Within this study, tool rotation and the tool pin diameter were accepted as variable parameters, while others held fixed.

FSW lap joints were obtained with different pin diameters and tool rotation. These variable parameters for FSW are listed in Table.

Table 2.7

Pin diameter (mm)	Pin height (mm)	Tool rotation (rpm)	Traverse speed (mm/min)	Index (I) related to pin diameter, tool rotation and traverse speed
3	5	1000	100	6
3	5	1300	100	7.8
4	5	1000	100	8
4	5	1300	100	10.4
5	5	1000	100	10
5	5	1300	100	13

The results of this research, increasing tool rotation for a fixed tool pin diameter reduces fatigue strength of joints. Increasing tool pin diameter for a fixed tool rotation, decreases fatigue strength of joints. In FSW lap joints, an optimization between tool pin diameter, tool rotation and tool
Traverse speed is needed to obtain better fatigue strength.

Panneerselvama K [9] In this research, During FSW, Forces acting on the tool along the travel distance and defects occurred in the joints are observed with respect constant rotational speed and different welding feeds. To use the polypropylene plate of 10 mm thickness with different tool pin profiles (square, triangular, threaded and grooved with square pin profile). the joint fabricated using threaded pin profile tool produce less amount of force and square, triangular & grooved with square pin profile produced defect free welds. The threaded pin tool profile produce less amount of linear tool force at different feed rate, it also soften the material sufficiently for good joint formation. The joint fabricated with square pin profile was taken minimum linear force compare with threaded pin profile. Even though the square pin tool profile produce good joint at initially, blowholes were observed on the middle of the joined region.

III. CONCLUSION

The joint fabricated using four-flute pin profiled tool exhibits superior tensile properties compared to taper screw thread pin profile, irrespective of rotational speed.

Similarly square tool pin profile shows better result and metallurgically defect free welds compared to other tool pin profiles.

A swept volume of tool pin profile acts well for better weld joints because it increases stirring effect.

T_{FC} can be considered the best tool because the combination of fillet and cavity increases the longitudinal and transverse strength of the joint and provide the best crown surface.

The tapered cylindrical pin gave the biggest and the straight cylindrical pin gave the lowest lap-shear fracture load.

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