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FRICTION STIR WELDING OF ALUMINIUM ALLOY PLATES WITH THREADED PIN TOOL: A REVIEW

Abey Vishnu Narayana ,
Vinesh Rajendran Nair, Ajin J
Department Of Mechanical Engineering
Snit Adoor

Abstract— Aluminium alloys have remarkably contributed to lightweight and long-lasting constructions seen in high precision applications (marine industry, aircraft industries). This paper discusses the friction stir welding of different aluminium plates with a threaded pin tool. FSW of aluminium alloys has the potential to hold good mechanical and metallurgical properties. The tools used in friction stir welding of aluminium plates have significant effects. Different types of tools are used, such as cylindrical, square, triangular etc. The effects of threaded pin profile tools on the aluminium alloys. Various researchers found that more mechanical and microstructural properties that given by the thread pin tool than the other shapes. Rotational speed, welding speed, axial force, and tilt angle are the main parameters considered for the FSW process.

Keywords: Friction stir welding, Aluminium alloys, Threaded pin tool

I. INTRODUCTION

Friction stir welding is a solid-state joining process invented at The Welding Institute (UK) in 1991 [1],[2]. This invention gives a drastic change in the manufacturing field industries of aluminium alloys [3]. These aluminium alloys has a wide range of application in the fields like automotive, aerospace, offshore and ship building due to their high strength to weight ratio. But the welding of aluminium alloy is very difficult to perform the conventional welding processes, then arises the new techniques that is Friction stir welding [4]. Mostly used non-precipitation hardenable series of Al alloys in aeronautical applications are 3xxx, 5xxx and precipitation hardenable series of Al alloys are 2xxx, 6xxx, and 7xxx. The 2xxx series have good mechanical properties at low temperatures and also exhibits a greater range of high corrosion resistance properties [5]. In FSW, the parameters will influence the weld quality of the joint, and it is categorized into primary and secondary parameters. The traverse speed, rotational speed and tool geometry are the primary parameters. The secondary parameters are the thickness of the work piece, work piece material, welding tool material and pin profile. There are more number of studies that deals with the effects of pin profile of the tool in the FSW processes. In the more journals detailing that threaded tool pin gives more strength. The strength of the weld joint is affected not only the pin profile but also the other parameters such as rotation and transverse speeds, and force.

Elangovan et al., [6],[7] research the influence of pin profile on aluminium alloys. They analysed the influence of rotational speed, pin profiles, traversing speed, shoulder diameter, and axial force on the formation of friction stir processing zone was investigated. In addition, the microstructure and mechanical properties of welded aluminium alloys with various pin profiles by the FSW process were investigated [8]. Hattingh et al. [9] reported the force footprints to systematically study the role of tool geometry on FSW

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process parameters and weld tensile strength to optimize the tool design, thereby producing welds with 97 per cent of the parent metal strength in AL 5083-H321 alloy. Research on the relationship between tool profiles, rotational speeds, traverse speed and the microstructure using force footprint plots was reported by Hattingh [10] et al.

Suresh D. Meshram et al [11] found the role of threaded pin profile and rotational speed on the generation of defect-free friction stir AA 2014 Aluminium Alloy welds. Here, Aluminium 2014 T6 alloy with 6mm thickness was used. These paper uses a conical tool with a thread where given joints are free from defects like pin holes, tunnels, cracks etc. In the case of the threaded pin tool causes positive displacement of the plasicide material from the advancing to the retreating side, the other details of the threaded pin profile are discussed detail in this paper.

Salari et al. [12] studied the tool geometry and rotational speed on defect generation. In their work, they studied AA5456 aluminium alloy for the lap joints with two different thicknesses, 5 and 2.5 mm. In their study, they used 600 and 800 rpm for the rotational speeds with four different pin profiles (conical threaded, cylindrical–conical thread, stepped conical thread, and Neutral Flared Triflute). The results showed significant influence of tool geometry on material flow as well as the mechanical properties. Furthermore, highest joint performance is achieved with the stepped conical threaded and highest tensile properties is obtained at rotational speed of 600 rpm irrespective of pin profiles.

Motalleb-Nejad et al. [13] studied the effect of pin profile on microstructure and mechanical properties of AZ31B magnesium alloy. Three pin profiles which are cylindrical, screw threaded cylindrical, and tapered were used in the study. The joints arewelded at different traverse and rotational speeds. From the results they found that taper and screw threaded cylindrical produce defect free joints. Moreover they found that the rotational speed have higher effect on microstructure and mechanical properties.

II. Methodology Of Fsw Process

A FSW tool is rotating at high rpm and plunged into the work piece, and stir over the area and traverse movement occurs then due to the friction the material is welded together by the action of the friction. Due to this friction heat is generate the welded zone this is the primary cause for the welding . In case of a profiled threaded or unthreaded pin is rotated in AA6061-t6 alloy at a constant rotational speed and at a constant traverse rate into the joint line between two pieces of material, which are butted together. The length of the tool pin is slightly less than that of the work thickness most preferable is the 0.35 less than that of the job thickness. Frictional heat is produced between the wear-resistant welding tool shoulder and pin and the work piece material. In the welding zone an adiabatic heat is produced there, that heat is develop the welding process which gives the mechanical mixing procedure, causes the softening of the agitating elements in the material without ever reaching the melting point. **Figure 1** shows the schematic of the FSW process. The welded joints were cut and machined to the required dimensions. ASTM standards are followed for test specimens. There are four different micro structural zones existing after friction stir welding such as Base metal , Heat affected zones (HAZ), Thermo-mechanically affected zone (TMAZ), Weld nugget zone. The use of threaded pin tool in different aluminium alloys gives fine elongated equi-axed grains and these grains were rustled because of dynamic recrystallization produced by heat generation and plastic strains.But recrystallization effect is absent in TMAZ. HAZ consist of coarse grain because of high heat and lesser plastic deformation. Increment in the grain size of nugget zone is evident with increasing rotational speed. The distribution of nugget zone grain size reveals comparatively finer grains are attained by TTh tool.

The **figure 2** shows the different weld zones produced after FSW process.

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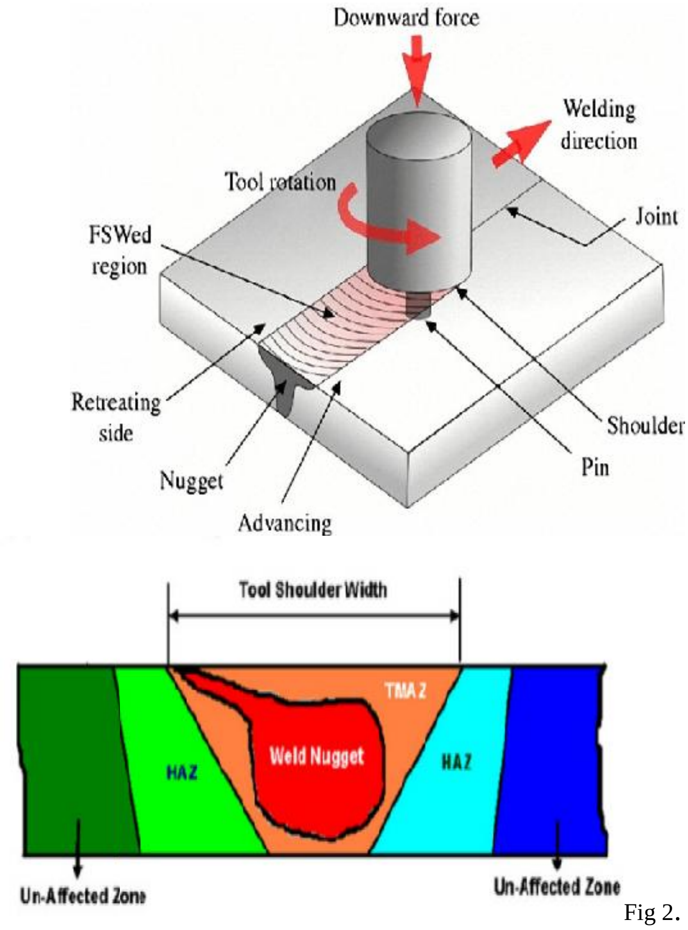

Fig 2.

III. TYPES OF TOOLS USED FOR FSW

There are variety of FSW tools are available for welding process according to the shape of the pin they are classified as cylindrical, tapered, threaded and conical pins etc. This paper discusses the effects of the threaded pin tools in the different aluminium alloy plates for the welding. The threaded pin tools areclassified as follows,. **Figure 3** shows the schematic of the threaded pin tool. **Figure 4** shows the threaded pin geometries used in the FSW tool. The different threaded pin tool and their applications are listed in **Figure 5.**

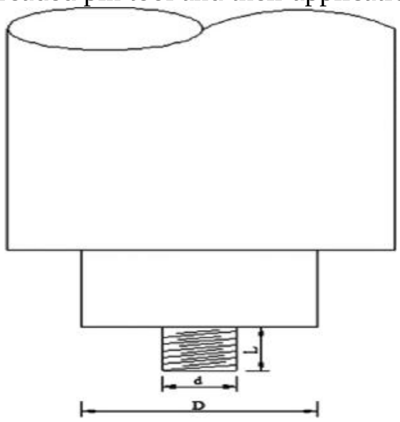

Fig 3:Schematic figure of the threaded pin tool

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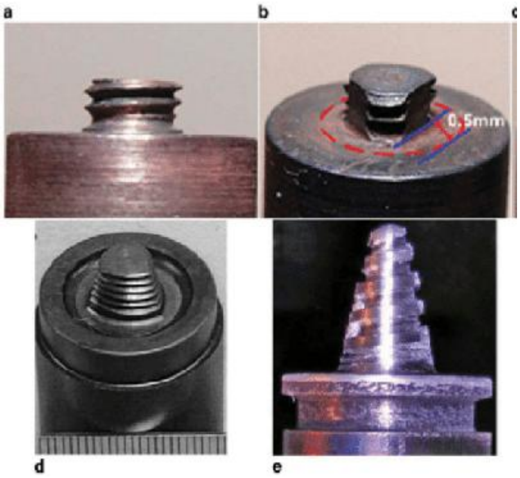
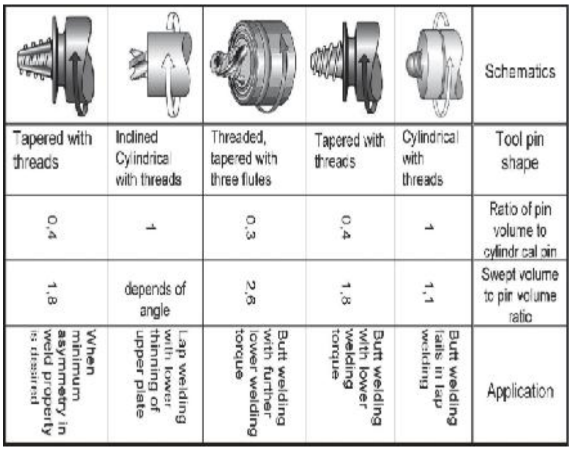


Fig 4 :(a) Cylindrical threaded, (b) Three flat threaded, (c) Trivex, (d) Threaded conical



					Schematics
Tapered with threads	Inclined Cylindrical with threads	Threaded, tapered with three flutes	Tapered with threads	Cylindrical with threads	Tool pin shape
0,4	1	0,3	0,4	1	Ratio of pin volume to cylindrical pin
1,8	depends of angle	2,6	1,8	1,1	Swept volume to pin volume ratio
When minimum asymmetry in weld property is desired	Lap welding with lower thinning of upper plate	Butt welding with further lower welding torque	Butt welding with lower welding torque	Butt welding fails in lap welding	Application

Fig 5:Different pin tools with its applications

IV. Different Aluminium Alloys Welded With Threaded Pin Tool

Gaoqiang Chen et al [14], analyse the effect of material flow behaviour during friction stir welding by using numerical simulation based on computational fluid dynamics. The temperature field and material flow behaviour during FSW of aluminium alloy with threaded pin and the smooth pin is analysed and compared by using CFD-based numerical simulations and they found that 3 effects of pin thread such as (a) accelerated flow velocity and enhanced strain rate, (b) effect to trap material in the high-velocity zone inside the thread groove opening, (c) the pin thread contributes to a vertical pressure gradient.

Umasankar Das et al [15], analyse the mechanical properties of friction stir welded joints of AA6101 and AA6351 aluminium alloys under T6 condition. The parameters that are chosen for the experiment are rotational speed, welding speed, axial force and cylindrical threaded pin profile tool pin have been used. In this paper, the visual observations of weld joints, microstructure studies, X-ray diffraction analysis of base metal, mechanical properties and tensile strength behaviour were elucidated.

AdeebaBatool et al [16], study the impact of different pin tool geometries on hardness, microstructure, and tensile strength of welded AA6061 and AA7075 butt joints. Three distinct pin geometries were used such as (a) threaded cylindrical (b) straight cylindrical (c) tapered cylindrical. In this paper, they concluded that threaded pin tool gives maximum tensile strength offered than the remain ones. Also got a drastic result, which is with in the threaded pin tool cylindrical thread and tapered cylindrical pin can give defect free weld in the FSW processes.

Anna Janeczek et al [17] the FSW of AW-3004 aluminium alloy gives the influence of tool shape and mechanical properties by process parameters. The cylindrical threaded and tapered threaded pin tool is used here. They found that the material outflow is lower in tapered threaded and tensile strength and elongation are higher in cylindrical threaded pin tool.

Table 1: major findings of FSW of different aluminium alloys with a threaded pin tool

Sl no	Material	Tool	Major findings
1	AA6101-AA6351	Cylindrical threaded [15]	Analyse the mechanical microstructure properties. Dissimilar materials were butt joined by using FSW without any defects.
2	AW-3004	Cylindrical threaded and Tapered threaded [17]	Found the tensile strength, comparison of the tool pin shape, and comparison of the welding parameters.
3	2024-T3	Conical threaded pin [18]	The geometrical features of the brushed and as-clad joints are similar. The brushing of the oxides before welding has no significant impact on the mechanical strength of the joints during uniaxial monotonous loading. The AlClad material promotes failure in shear through the welded zone.
4	AA7075- AA6061	Cylindrical threaded, straight Cylindrical, and Tapered probes [16]	Compare the three types of pin tools and found that THC and TAC produced the defect-free joint.
5	AA7A52	Threaded pin [14]	Temperature field, material flow field and three effects of pin thread in the material
6	AA2024-T3-AA7075-T6	Threaded pin [19] [20]	Microstructure analysis and material flow, Investigation of hardness and tensile testing [19] and microstructure and mechanical properties of dissimilar joints. They found that the maximum tensile strength of joints is 423 Mpa [19]
7	2014 Al alloy	Column screw thread pin, Taper screw thread pin, Column pin, Taper pin [21]	With the use of four different friction stir pins have studied the influence of the pin geometry on the weld shape and mechanical properties.

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8	Alclad 7N01-T4	full-threaded pin, bottom-half-threaded pin [22]	Check the cross-section and microstructure of the lap joints, and lap shear failure load fracture modes. They found that shear failure is attained by 2 pins [22]
9	7075-T6 Al alloy	Threaded conical, non-threaded conical and triangular pins [23]	Found that due to producing fine grain size, the threaded conical pin is good for this aluminium alloy.
10	7075-O Al alloy	Threaded pin [24]	Their major finding is that hardness and strength are compared with the FSW of AA7075-T6. The strength of FS welded AA7075-O is higher than its base metal.

V. CONCLUSION

The threaded pins significantly improve downward movement by eliminating obvious wormhole defects as compared to unthreaded pins. Threaded pin gives fine grain size in the weld nugget and better mechanical properties in AA6061-T6. In AA7075 tensile strength is higher in triangular pin geometry compared to threaded pin tool. Cylindrical pin tool gives defect-free weld joint in FSW of dissimilar aluminium alloy. Most of the paper concluded that threaded cylindrical and threaded taper gives proper joints in FSW of aluminium alloy.

The cylindrical threaded and tapered threaded pin tool were used in FSW on AW-3004 Aluminium alloy. Most of the joints were produced with material outflow on the retreating side. The lowest amount was observed in the joints made with a tapered threaded tool pin. Tensile strength and elongation figures were higher for joints made with a cylindrical threaded tool pin than those made with a tapered threaded pin. In here rotational speed is key parameter for the welding conditions and mechanical properties of aluminium alloy joints.

The effect of tool pin thread forms and the process control parameters on the FSW of AA7050 and AA6061 alloys gives the wormhole defects can be removed by inserting helical features such as threads in tool pin during FSW. Defects contents reduced when welding was done in lower rpm. Using threaded pin tool in FSW of aluminium alloy gives fine grain size in weld zones and also different analysis done based on threaded pin tool usage in FSW process, it says that give better mechanical property and defect free weld joint.

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