Effect of tool pin profiles over FSW joint parameters

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***Abstract*—Friction stir processing (FSP) is based on the friction stir welding (FSW) techniquewhich was invented by the welding institute (TWI, Great Britain) in 1991. FSW process automation is essential to making consistent and reliable friction stir welds and this requires an understanding of how tool design can influence process parameters, which in turn can provide high joint strength and performance. FSW uses a non-consumable tool to generate frictional heat at the point of welding, inducing complex plastic deformation of the work piece along the joint line. Generally the plates to be joined are placed on a rigid backing plate and clamped to prevent the faying joint faces from separating.**

The research generally lies on characteristics of FSW tool pin's profile on FSW joint.Previous researches proven that Taper screw thread, 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.

***IndexTerms*— FSW**

I. Introduction

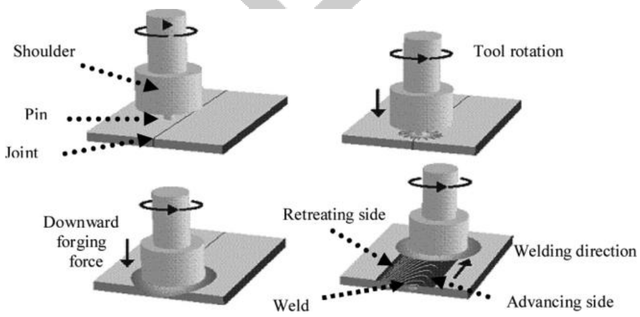
Welding and joining technology is fundamental to engineering and manufacturing. Without the ability to make strong and durable connections between materials it would not possible to produce the many different items upon which we all rely in our everyday lives, from the very large (building, pipelines, 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. Aluminum is the most widely used non-ferrous metal in the modern world. The welding of aluminum and its alloys has always represented a great challenge for designers and technologists. [1]

Conventional welding are proven and well established techniques for joining the 5xxx and 6xxx series aluminum 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. [2]It is energy efficient, environmental friendly and versatile.

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 this research the process of butt joints is investigated. These joints are when two work pieces are fixture (clamped) on a rigid back plate.



"Fig.1" Basic process of FSW [3]

The fixture 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 work piece normal. The tool is slowly plunged into the work piece 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. [3]

II. EFFECT OF FSW TOOL PIN PROFILE

RAVINDRA S. THUBE *

In this investigation an attempt has been made to study the effect of tool pin profiles and welding parameters on the formation of friction stir weld and tensile properties in AA5083 aluminum alloy. Friction stir welding betweenAA5083 aluminum alloy plates with a thickness of 2.5 mm was performed. Five different tool pin profiles **(Taper cylindrical, triangular, cylindrical, square and cone)** have been used to fabricate the joints at three different rotationalspeeds i.e. 900, 1400 and 1800 rpm under a constant traverse speed of 16 mm/min.

"Fig.2" different types of tool

Tensile properties of the joints have been evaluated and correlated with the friction stir weld zone formation.
From this investigation, the following important conclusions are derived.

1. For AA5083 whose deformation resistance is relatively high, tool pin profiled designs had little effect on heat input, power consumption and tensile properties.

2. Joints fabricated at rotational speed of 1400 rpm and weld speed of 16 mm/min exhibited superior tensile strength properties and produces defect free FSW zone irrespective of tool pin profile except triangular pin tool.

3. Weldability is significantly affected by the rotational speed. At high rotational speed (1800 rpm) straight cylindrical tool is the best; at the middle rotational speed (1400 rpm) straight cylindrical and square tool are the best; while for low rotational speed (900 rpm) triangular and square tool are the best.

4. Maximum strength properties of 105 MPa yield strength, 149 MPa of tensile strength and 84.9 % of joint efficiency respectively was attained without any defect for the joint fabricated using straight cylindrical tool at rotational speed of 1400 rpm and weld speed of 16 mm/min.

H. K. Mohanty

In marine application, marine grade steel is generally used for haul and superstructures. However, aluminum has also become a good choice due to its lightweight qualities, while rusting of aluminum is minimal compared to steel. In this paper a study on friction stir welding of aluminum alloys was presented. The present investigation deals with the effects of different friction stir welding tool geometries on mechanical strength and the micro structure properties of aluminum alloy welds. Three distinct tool geometries with different types of shoulder and tool probe profiles were used in the investigation according to the design matrix. The effects of each tool shoulder and probe geometry on the weld was evaluated. It was also observed that the friction stir weld tool geometry has a significant effect on the weldment reinforcement, micro hardness, and weld strength.

From the present investigation the following conclusions can be drawn:
1) Among 27 different tool pin profiles, use of a straightcylindrical tool with a 5 mm diameter and having a minimum shoulder flat contact surface leads to the highest tensile strength.

2) It was observed that the weld cross sectional area varies proportionally with the tensile strength of the joint.

3) For low deformation resistance, the alloy cylindrical tool produces welds with the best mechanical properties.

4) The micro hardness of the weld nugget and TMAZ was found to be slightly higher compared to the base metal used in the experiment.

5) Use of a trapezoidal and tapered cylindrical tool instead of straight cylindrical tools does not necessarily enhance weld properties for commercial grade aluminum alloys. However, at the start of the welding, the plunging force ofthe tool is smaller with trapezoidal and cylindrical tools.

6) For the material used in the present investigation, the concave shoulder is not affected much by the weld strength but acts as an escape volume for the material displaced during plunging and subsequent traversing.

L.V. Kamble

Friction stir welding (FSW) has a potential for wide-spread applications. However, it is necessary to overcome some challenges for its wide-spread usage. Tool design and selection of process variables are critical issues in the usage of this process. This paper tackles the same issues for AA6101-T6 alloy (material used for bus bar conductor, requiring minimum loss of electrical conductivity and good mechanical properties). Two different tool pin geometries **(square and hexagonal)** and three different process variables, i.e. rotational speeds and welding speeds were selected for the experimental investigation. The welded samples were tested for mechanical properties as well as micro structure. It was observed that square pin profile gave better mechanical properties and micro structure compared to the one prepared by hexagonal pin profile.

During the friction stir welding by hexagonal pin profile, oxide layer was found in most of the cases. Also, a continuous tunnel was found at the bottom side just above the bottom skin of the material.

Process parameters and tool profile had an effect on the quality of welding. During tensile test, fracture occurred at the base metal region at the advancing side of weld; indicating pure ductile behavior proving the welded joint stronger. Loss of conductivity after welding was found to be negligible.

Ajay S. Gupta

In this research rotational speed, welding speed, axial force was taken as process parameters. The aim of the research is toevaluate the effects of different welding speeds (50, 65 & 80 mm/min), rotational speeds (1200& 1500 rpm) and tool pin profiles on the weld quality of AA6082-T-6. **Straight cylindrical, taper threaded and hexagonal pin** are used as tool pin profiles in this research. There is no visual effect found, consequently obtained results explain the stress variation as a function of strain.

From the experiment, the following conclusions are derived.
The effect of rotational speed and welding speed on the appearance of the weld is presented and no obvious defect was found. The surface finish of weld sample welded at 1500 rpm was better than weld sample welded at 1200 rpm.

This confirms that as the tool rotation speed increases smooth surface is produced at the weldment. The results indicate that the pin profile effect on the mechanical properties of welded joints.

Among the eighteen joints in this experiment, the joints produced using the straight hexagonal pin profiled tool at a rotational speed 1500 rpm and welding speed 65 mm/min showed the best tensile properties.

The tensile strength of the straight hexagonal pin at 1500 rpm and 65 mm/min reaches to 71.77% of the base metal ultimate strength, but the UTL reaches 93.61% of the base metal UTL.

The straight cylindrical and taper threaded ultimate strength goes to 35.38% and 44.61% respectively of the base metal ultimate strength.

There is no elongation shown in the weld region.

Dr. M. Lakshman Rao

Friction Stir Welding Process (FSW) is a solid state welding method developed by The Welding Institute (TWI), and now being increasingly used in the welding of Aluminum including steels. FSW now extends to variety of materials including steels and polymers. Research towards further extension of the process to join dissimilar metal combinations like Fe-Al and Al-Cu is currently underway. This paper highlights the role of tool geometry, because tool geometry plays a major role in FSW. Proper selection of a tool material and shape of the pin reduces number of trials and tooling cost. In addition this study also highlights the wear effect due to friction between sliding surfaces.

“Fig.3” Trivex series design of FSW tool.

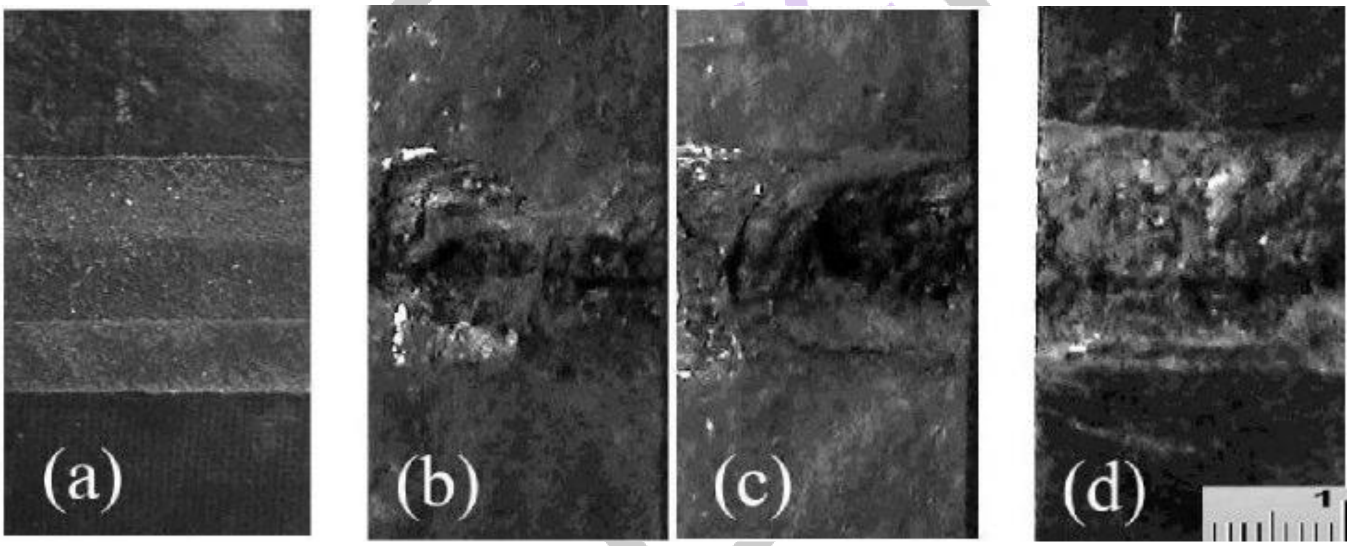
"Fig.4" Triflute series design FSW tool.

A Flow chart of suggested design methodology for conducting experimental investigations on FSW process has been presented.
Different designs of tools in use are presented. Triflute design tools are complex when compared to the Trivex designs.
The effect of tool speeds on the quality of FSW joints is discussed.
The tool geometry for a tapered design is given for commonly welded materials.
A simple equation for estimating the wear rate of tool is given.
It is hoped that the material presented will be helpful for beginners in the field of Friction Stir welding.

G.H.Payganeh

Effect of tool geometry on weld appearance

Weld appearance is one of the important characteristics of a high quality weld whose properties must be similar to the base material as much as possible. Figure shows the surface appearance of welds made with different friction stir tools.



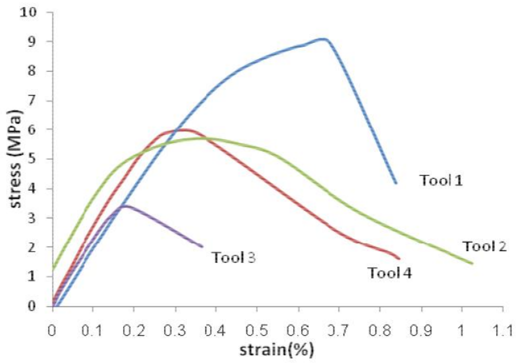
"Fig.5" effect of tool geometry on weld appearance

(a) Taper pin with groove
(b) Triangle pin with screw thread
(c) Triangle pin
(d) Cylindrical pin with groove

The visual examination of these welds shows that the best weld appearance was obtained using friction stir tool # 1 **(taper pin with groove).** The welds produced by this tool had a clean appearance with uniform width, and no obvious surface defects could be found. This feature of the weld may be because of larger contact surface between this tool and the plates which causes more frictional heat. The higher generated heat and better mixing of the material through the weld may be the reasons for better surface appearance. Tool # 3 **Triangle pin** which has a pin of triangular cross section contacts the work-piece at only three edges or points and therefore generates lowest frictional heat and consequently lowest stirring and mixing of the weld. Tool # 2 **triangle pin with screw thread** which has a pin of triangular cross section with screw thread stirs the weld better than tool # 3 **Triangle pin** and causes a better weld surface appearance. Similarly, the contact surface of tool # 4 **Cylindrical pin with groove** the work-piece is more than that of tools **# 2 Triangle pin with screw thread** and **# 3 Triangle pin** therefore the higher frictional heat generated results in better blending of the weld material and hence better weld surface appearance is obtained by this tool.

Effect of tool geometry on tensile strength

The effects of different tool pin geometries on tensile strength of friction stir welds are compared with the help of stress-strain curves shown in **Figure 6**.

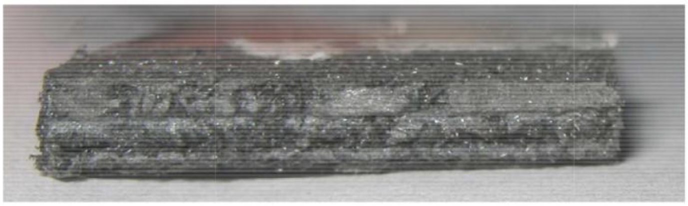


"Fig.6" the tensile test results.

All the tensile test specimens fractured from the weld zone as shown in **Figure 7** indicating this zone is the weakest part of the joint.

"Fig.7" the tensile test fractured specimen.

Figure 5 shows that the UTS of the weld made by tool # 1**(taper pin with groove)**is about 9 MPa which is almost 25% of the UTS of the parent PP composite Welds produced by other tools were much weaker in strength than the weld produced by tool #1 **(taper pin with groove).** The same argument mentioned earlier for better weld surface appearance when welding with tool #1 **(taper pin with groove)** could also be one of the reasons for higher tensile strength of welds with this tool. The presence of surface and probably subsurface defects, such as tunnel defects shown in **Figure 8** may be the other reasons for lower tensile strength of welds made by other tools.



"Fig.8" Tunnel defect in stir zone.

Venugopal S

In this work an effort has been made to analyze micro structure of aluminum AA 7075-T6 alloy. Three different tool profiles (Taper Threaded, cylindrical and square) have been used to construct the joints in particular rotational speed.Tensile, Impact, micro hardness of mechanical properties of the joints have been evaluated and the formation of FSP zone has been analyzed microscopically. From the investigation it is found that the threaded cylindrical profile produces highly (defined) Strength in welds.

Considerable grain refinement has been achieved due to friction stir welding and the plastic flow. Due to retracting and advanced force the grains size are formed dynamic recrystallized zone The Taper threaded cylindrical pin profile has been best suited at 800 rpm for better tensile strength, HAZ 172,168 and in weld zone 165,163 weld results and higher quality for this alloy.
The results can be applied for replacement of rivets in aircraft, rocket propulsion and automobile sectors where this alloy is used.

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