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Investigate the Properties of FSW Aluminum Alloy by Varying the Tool Geometry: A Literature Review

Abhishek R. Solanki [1], Brijesh A. Gandhi [2], Amol A. Patil [3], Keyur J. Patel [4], Mr. Saumil Joshi [5]

[1-4] Student, Mechanical Engineering Department, Sigma Institute of Engineering, (India)

[5] Assistant Professor, Mechanical Engineering Department, Sigma Institute of Engineering, (India)

ABSTRACT

FSW (Friction stir welding) is a newest green welding process. It's a solid-state joining process that uses a non-consumable rotating tool to join the two same or different metal. During the process, heat is generated by friction between the rotating tool and the work piece material, which leads joining two facing of work pieces before the melting point of the metal reached. Quality of the weld zone depends on tool geometry and welding parameters. This review presents the effect of different pin and shoulder geometry on aluminum alloy.

Keyword: Friction stir welding, Aluminum alloy, Pin geometry, Shoulder geometry, Welding Parameters

I. INTRODUCTION

Friction stir welding was invented by The Welding Institute (TWI) in UK, December 1991. TWI filed successfully for patents in Europe, the U.S., Japan, and Australia.

Since its invention, the process has received world-wide attention, and today FSW is used in research and production in many sectors, including aerospace, automotive, railway, shipbuilding, electronic housings, coolers, heat exchangers, and nuclear waste containers.

A rotating non-consumable tool with a probe profile is feed between two clamped work pieces; the rotating cylindrical tool's shoulder touches the surface of the work pieces. Because of this, friction is generated between two mating work pieces and thus heat is produced. So, further welding is prepared, and tool is move in forward direction which provide. It should be noted that, frictional coupling of tool surface with work piece is going to govern the heating. The temperature within the stirred zone is likely to be around 475^0 c.

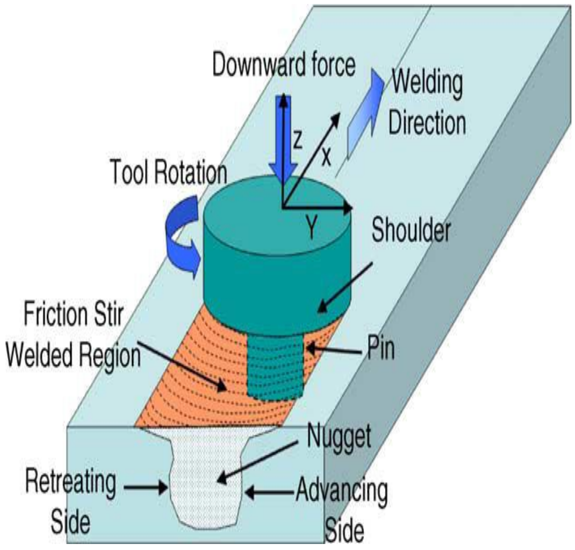

Figure 1 Principle of friction stir welding [1]

A. Merits of Friction stir welding:

- The main advantages of this process are that it does not generate any crack as discuss above.
- It can able to weld dissimilar material or alloys.
- It does not have shielding gases or consumable.
- Continual weld superiority can be attained.
- Another main benefit of friction stir welding is that it has very less maintenance, so maintenance charge decreases.
- Ensure safety of operation like it does not produce any UV Radiation, welding fume.

B. Demerits of Friction stir welding:

- Main disadvantage of this process this that it requires rigid clamping of tool and workpiece.
- Very huge force requires for welding process.

II. WELD QUALITY

FSW generate excellent weld quality with these features:

Less distortion: In this there is negligible distortion produce. In thinner materials, a slight upward bend occurred, but no twist or side bends were seen.

Less shrinkage: Because this process is carried out below melting point temperature.

No porosity: Because the base material does not melt, there is no porosity.

No lack of fusion: Because this is an extruding and forging joining method with a more accurate control of the heat, no lack of fusion is seen.

No change in material: When joining aluminum, material properties change little from the parent material as the maximum temperature during the joining process is approximately 450 degrees C, and no filler material or anything other than heat is added to the join.

Microstructure evolution of FSW:

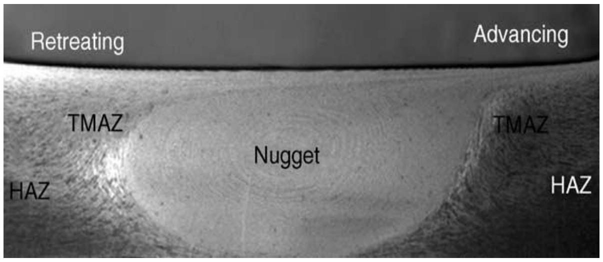

Figure 2 Microstructure of FSW Welded joint [2]

Above figure shown the weld joint during working of friction stir welding process. Based on microstructural characterization of grains and precipitates, three distinct zones, stirred (nugget) zone, thermo-mechanically affected zone (TMAZ), and heat-affected zone (HAZ).

Nugget zone: Intense plastic deformation and frictional heating during FSW result in generation of a recrystallized fine-grained microstructure within stirred zone. This region is usually referred to as nugget zone (or weld nugget) or dynamically recrystallized zone.

Thermo-mechanically affected zone: Unique to the FSW process is the creation of a transition zone—thermo-mechanically affected zone (TMAZ) between the parent material and the nugget zone. The TMAZ experiences both temperature and deformation during FSW.

Heat-affected zone: Beyond the TMAZ there is a heat-affected zone (HAZ). This zone experiences a thermal cycle but does not undergo any plastic deformation.

Base Metal Zone: This zone is outside zone of the workpiece. Which are away from the weld zone. So, effect of frictional heat is not see there.

III. RELATED STUDIES ON DIFFERENT SHOULDER AND PIN GEOMETRY OF FSW

P Satish Kumar et al. (2017) [2] used 5083 Al alloy, shoulder and tool geometry are 24 and 8 respectively. H13 tool steel is selected as tool material. They observed that at rotation speed of 710 rpm, 40 mm/min welding speed with taper with threaded profile resulted in good mechanical properties.

Joaquin M. et al. (2017) [3] tested and analyzed with material of AA5052 and taking tool and shoulder geometry of 16 and 7 diameter respectively. He concludes that Friction stir spot welds on dissimilar joints of 0.65 mm thick AA5052-LCS, have been made with tools made of conventional, low cost, H13 tool steel. Defects free and excellent appearance joints have been achieved.

Ashish bist, j et al. (2016) [4], Conducted various experiment with threaded tool pin. They took total seven experiment and conclude that the wear rate of the tool increases with increase in welding distance and tool rotation. The increase in wear rate with tool rotation was up to a certain limit of revolution. They also found that the wear also depends upon the tool profile and material. Increasing the hardness ratio of the tool material from 0.31 to 0.77 decreases the wear rate by about 60%–80%.

Y. Gao et al. (2016) [5] undertake the effect of tool diameter on microstructure and mechanical properties of the joints was studied. They concluded the tensile shear strength of the lap joints decreased with the increase of probe and shoulder diameters due to the increase of the grain size of the stir zone of brass.

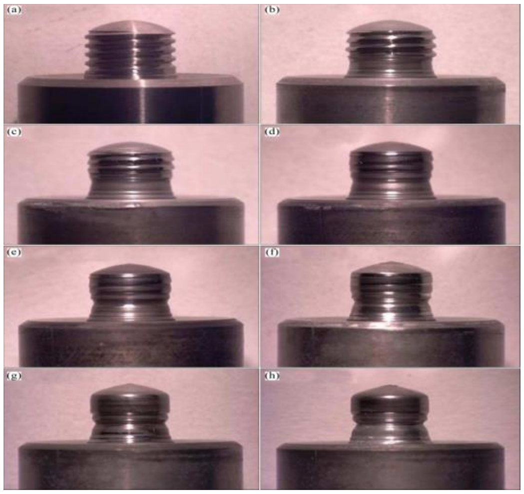

Figure 3 Appearance of threaded tool after each FSW experiment [4]

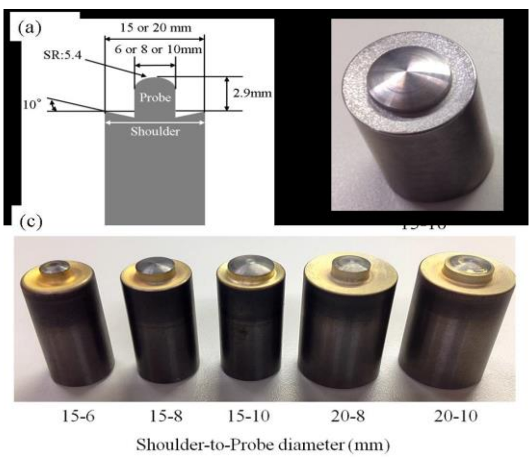

Figure 4 Shoulder to probe diameter [5]

Landry Giraud et al. (2016) [6], the goals of this paper was to demonstrate the feasibility of FSW to join AA7020-T651 and AA6060-T6. They provide satisfactory results. In this Friction stir welded samples are made with 300x150 mm butt joined sheets of AA7020-T651 and AA6060-T6 in 5 mm thick. The grains are highly affected by strain which induce large deformations in HAZ and TMAZ. Grain size examination was done on the nugget zone of the weld. This region exhibits the most

severe grain evolution as various mechanisms, such as recovery and recrystallization, are active at the temperatures and strain rates reached by the material in this location of the joint.

H. I. Dawood, kahtan s. et al. (2015) [7] weld 6061 aluminum alloy by FSW tool which has pin and shoulder diameter of 20 and 9 mm respectively. In this they conclude that geometry and dimension of the welding tool used in the FSW process influence the mechanical properties of the joints. The best mechanical properties are obtained for the FSW joint produced by a triangular tool pin profile when compared with their counterparts.

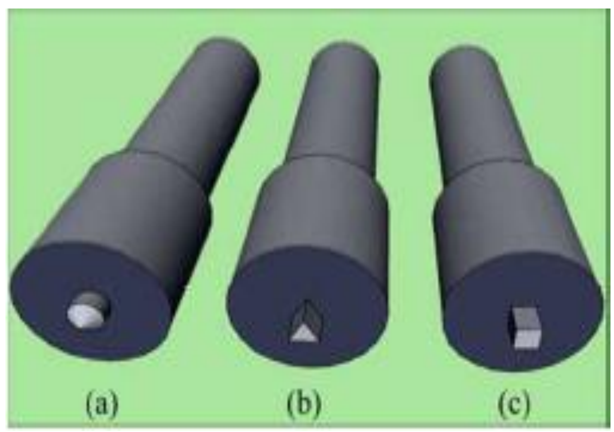

Figure 5 Tool pin geometries: (a) Threaded tapered cylindrical pin (b) Triangular pin (c) Square pin [7]

H. Doude et al. (2015) [8] used threaded tool pin profile to weld aluminum alloy, they found voids present near the crown indicated rotational speed above the optimal parameters and voids present in the root indicated rotational speeds below the optimal weld parameters. These features allow for visual cues to determine FSW parameters for production.

A.F. Hasan et al. (2015) [9] welded 6061 aluminum alloy with the help of tool which has shoulder and pin diameter about 19 and 6.3 mm respectively. During the study they devlope a 3D-CFD model of the FSW process and used it to compare the strain rate distribution and the size of the MAZ for the use of unworn and worn tool geometries at rotational speeds of 300 and 600 rpm.

K.K. Ramachandran et al. (2015) [10] checked the effect of tool axis offset and geometry of the tool pin profile on the mechanical and metallographic characteristics of dissimilar friction stir butt welded joints of Al alloy, AA5052H32 and HSLA steel, IRSM42-93 were investigated. FSW tools with three different tapers cylindrical (TC) tool pin profiles and one straight cylindrical (SC) tool pin profile were experimented. The tool shoulder diameter, tool pin tip diameter, tool pin length and all welding parameters were held constant.

J.S. Jesusa et al [11] studied the effect of three different tool geometries and two joint geometries on quality of AA 5083-H111 T welds done using the friction stir welding process (FSW). All the tools have concave shoulder with different pin geometries: tapered and threaded, quadrangular pyramidal and progressive pin, part threaded cylindrical and part pyramidal. T-lap and T-butt joints configurations have been studied.

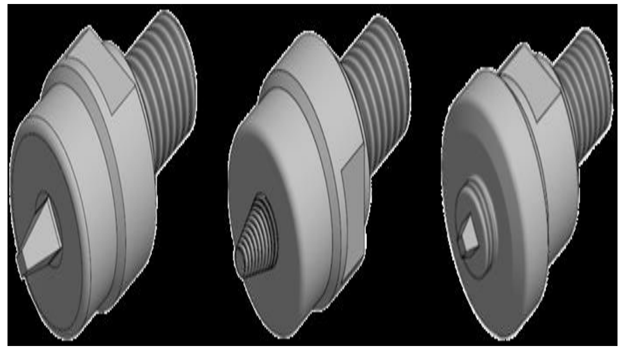

Figure 6 Tool geometries tested: a) Pyramidal pin; b) Tapered and threaded pin; c) Progressive [11]

IV. CONCLUSION

From above study, mainly two points are concluded:

- Tool shoulder and pin geometry are the main two parameters to achieve good quality welding. Shoulder and pin geometry mainly affects the material flow and heat generation. So, after all tensile strength, hardness, bending strength and all other properties are vary.

- If there is small wear on tool than it directly affects the quality of the weld zone. So, it reduces the quality of the weld. So, tool material should select as per the work piece to maintain the tool life.

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