TOOL GEOMETRY EFFECTS ON ALUMINIUM WELDS IN FSW PROCESS-REVIEW

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Abstract:

Friction stir welding (FSW) is a novel technique used to join similar alloys. Aluminium alloys of AA6065 are reviewed and presented in this paper. In FSW welding process, heat is generated during the process and workpieces are joined without melting the aluminium alloys. The tool moves along the soften surface for joining aluminium alloys. Tool materials, tool geometry, welding speed, rotational speed, axial forces are examined and the effects on welding surfaces after welding process has been analysed. Friction stir welding can be widely used in aviation, marine and vehicle body construction industries because of its mechanical properties where fusion welding process revealed deformities on the welding materials to be joined. In this review article, the recent research of friction stir joining of aluminium alloys and its applications in various industries are explicated, including the quality of weld of aluminium alloys, the evaluation on microstructure in weld nuggets, and tool wear. The conclusion of this review is unequivocally recommended that aluminium alloys are suggested for future research with numerous industrial applications.

Key words: *Tool geometry, FSW, AA6065, Review*

1.0 INTRODUCTION

FRICTION STIR WELDING (FSW) is a solid-state joining process developed in 1991 by The Welding Institute (TWI) of the United Kingdom for use with aluminum alloys. FSW has a deceptively simple premise. Pins and shoulders on a non-consumable rotating tool are placed into the mating edges of sheets or plates to be connected, and the tool is then moved along the joint line. Almost all of the definitions are self-explanatory, but the ones for "advancing side" and "retreating side" need some more perspective. It is necessary to understand the rotation and movement directions of the instrument in order to go forward and backward in the side orientations. In Fig. 1the FSW tool rotates in the counter clockwise direction and travels into the page (or left to right). the advancing side is on the right, where the tool rotation direction is the same as the tool travel direction (opposite the direction of metal flow), and the retreating side is on the left, where the tool rotation is opposite the tool travel direction (parallel to the direction of metal flow). The tool serves three primary functions, that is, heating of the workpiece, movement of material to produce the joint, and containment of the hot metal beneath the tool shoulder. Heating is created within the workpiece both by friction between the rotating tool pin and shoulder and by severe plastic deformation of the workpiece. The localized heating softens material around the pin and, combined with the tool rotation and translation, leads to movement of material from the front to the back of the pin, thus filling the hole in the tool wake as the tool moves forward. The tool shoulder restricts metal flow to a level equivalent to the shoulder position, that is, approximately to the initial workpiece top surface. As a result of the tool action and influence on the workpiece, when performed properly, a solid-state joint is produced, that is, no melting.

Because of various geometrical features on the tool, material movement around the pin can be complex, with gradients in strain, temperature, and strain rate. Accordingly, the resulting nugget zone microstructure reflects these different thermo mechanical histories and is not homogeneous.

Principle of FSW:

A solid-state joining process called FSW which utilizes a solid and round shape non-consumable carried apparatus pivots on the outside of the plates to be fabricated. In the apparatus of FSW machine, the plates are which solidly clinched on the welding surface the axial force is applied. Device is encouraged to join plates with no softening it for the period of the welding procedure and the plates are deformed because of the age of warmth and contact. Warmth is produced by erosion between the pivoting instrument and the workpiece material, which prompts a relaxed locale close to the FSW device.

2.0 LITERATURE REVIEW

M.Mostafa et.al., **[1]** at unique circumstances, friction stir welding of 6 mm with plates AA5083-O were done; the equipment used was tapered smooth and cylindrical threaded pin geometries, and under various welding speeds, tool rotational speeds. At all welding speeds, values of tensile power by a threaded tool pin profile obtained are higher as compared with conical tool probe profile. Indira rani et.al. **[2]** square profiled device facilitates the rotating motion from tip to the collar causes in prevention of the turbulence. With the square profiled tool, the defect-free welds had been feasible. K. Kumar et.al., **[3]** in this paper, the impact of geometry of tool was studied on al alloys using FSW. Chamfered shoulder with frustum shaped rounded end pin produced a higher first-rate weld. P. Satish Kumar et al **[4]** tested the motive of Tool Rotational pace on FSW 5083Aluminum composite. By threaded profile carried approximately remarkable mechanical properties found at revolution velocity of 710/40 traverse velocity. R. Palanivel et.al. **[5]** Unlike joints of AA5083-H111 alloy to AA6351-T6 alloy on the behavior of tensile making consciousness were produced by FSW. Five exceptional tool pin probes, consisting of (SS), (TS), (SH), (SO) and (TO) were used in this process. Welding speeds mm/min (63,50, and 75) for joints was considered. The joints produced on this research, at a welding pace of 63 mm/min using SS pin probe tool confirmed the pleasant tensile properties. V. Patel Chandresh et.al.,**[6]** Outcome investigation generally lies on traits of FSW tool pin profile on FSW joint. In this work, the usage of numerous tool pin profile like TCY, SQ, THEX, and THCY were studied. From acquire consequences and numerous exams, testing specimens has been prepared (bending and tensile and) could be finished to show its best joints. On the foundation of these outcomes and parameters used all over experiments, the effect of tool pin profile can be understood. Ilangovan et.al. **[7]** 5086 and 6061aluminium alloys made to combine using FSW tried in this research. SC, TC and THC pin profiles was used here. Using grooved pin probe of device contributes to advanced flow of substances between two alloys and the era of defect loose stir zone, become founded from this investigation. J. C. Verduzco Juárez et.al., **[8]** bolt-head pin profile in this work impacted on the performance of 6061-T6 al alloy using FSW process. This performance can be checked with conventional pin probes. Elangovan et al. **[9]** studied the pin and shoulder diameter of tool on FSW of AA6061 aluminum alloy and shoulder diameters with different profiles of tool pin are used to join the welds. Their study is shown observations such as macrostructure analysis and transverse tensile properties. Micro structure and mechanical properties are relatively improved based on tool shoulder and pin profile. Optimization Techniques such as Taguchi method is used to analyse the factors on tool geometry. Lakshminarayanan et al. **[10]** studied Taguchi method to find the factors which affect the tensile strength of the welded of FSW RDE-40 aluminium alloy and it observed that the influence of tensile strength of the weld is based on tool geometry. Mechanical properties such as tensile strength have been improved for FSW welded aluminium alloys.

Aim of review

The review aims to be focused on different tool geometries used for the FSW process for aluminium alloy materials. The review also focused on the analysis of FSW process objectives with respect to tool geometry.

3.0 FSW process

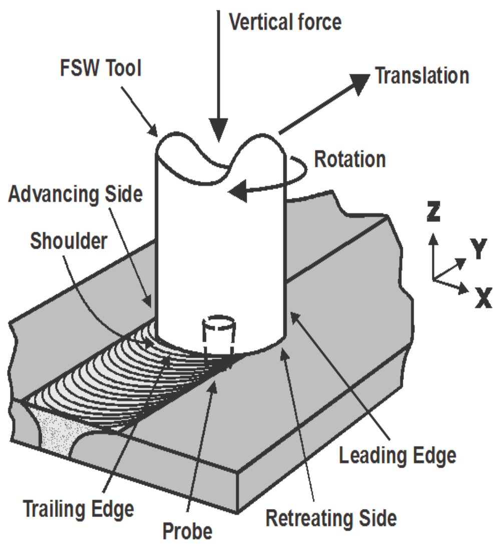

Figure:1 Schematic drawing of FSW process

TABLE:1 TOOL MATERIALS USED IN FSW FOR SOFT ALLOYS

Tool Material	Work Piece Material
Mild Steel	Magnesium alloys
High Carbon Steel	Magnesium alloys
Stainless Steel	Magnesium alloys
Armour Steel	Magnesium alloys
AISI Oil hardened Tool Steel	Aluminium matrix composite materials
AISI 4140	Dissimilar Materials
Tool Steel	Aluminium alloys, Dissimilar Materials
High Speed Steel	Magnesium alloys
SKD 61 Tool Steel	Dissimilar Materials
H13 Steel	Magnesium alloys
High Carbon High Chromium Steel	Magnesium alloys, Aluminium matrix composite materials, Dissimilar Materials

4.0 DIFFERENT TYPES OF FSW TOOLS:

There are several types of tool profile such as cylindrical, threaded pin and taper pin profile. However, each uses different uses different pin tool shape geometry and it affects the strength, macrostructure and microstructure of the specimen. For tapered and straight cylindrical tools, a higher possibility for tunnel defects were reported, and threaded pin tools provided the best results Tool pin profiles such as straight cylindrical, threaded cylindrical, square, tapered square, and tapered octagon were used for the purpose and the square straight tool provided the best result.

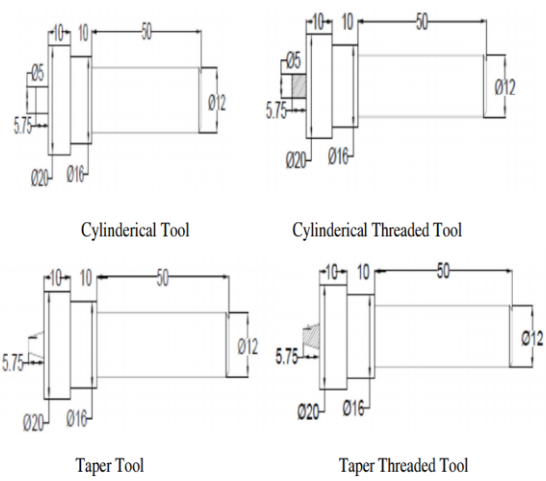

Figure:2 Different tools are used for fiction stir welding

4.1 Review on tool geometry effects

Lee et al [11] welded Al–Mg alloy with low carbon steel in lap joint configuration using tool steel as tool material without its excessive wear by placing the softer Al–Mg alloy on top of the steel plate and avoiding direct contact of the tool with the steel plate. Tungsten based alloys have also been used for the welding of both low and high melting point alloys. Prasanna et al [12] studied the effect of four different tool pin profiles on mechanical properties of AA 6061 aluminum alloy. Four different profiles have been used to fabricate the butt joints by keeping constant process parameters of tool rotational speed 1200rpm, welding speed 14mm/min and an axial force 7kN. Different heat treatment methods like annealing, normalizing and quenching have been applied on the joints and evaluation of the mechanical properties like tensile strength, percentage of elongation, hardness and microstructure in the friction stirring formation zone are evaluated. Shahabuddin and V.K. [13] Dwivedi In this research experiments an attempt has been made to analyze the result of mechanical properties as well as studying the effect of welding parameters like welding speed, pin diameter and shoulder diameter for friction stir welding (FSW). FSW is the most suitable methods for welding on aluminum alloy material AA7075- T6. Vimalraj, C.; Kah [14] The study also discusses the effect of welding parameters on reinforcement particles and the effect of nanoparticle reinforcement on weld microstructure and properties, as well as development trends using nanoparticles in FSW. Analysis shows that friction stir welding parameters have a significant influence on the dispersion of the reinforcement nanoparticles, which contributes to determining the joint properties Khaled, T [15] The friction stir welding process is a more common and emerging process in solid state processes. In FSW, heat for welding is generated with pressure applied between the rotational tool and base metal, leading to plastic deformation without melting of the base metal and without change in the primary microstructure of the base metal. Moreover, welding by fusion welding processes results in eminent microstructural transformation and mechanical properties, which can be avoided in the FSW process.

5.0 ANALYSIS ON TOOL GEOMETRY:

Microstructure, generation of heat, flow of material affects the tool geometry and the life of tool is an important feature which depends on parameter during the welding process. The parameters such as axial force, rotation, tool tilt angle, shoulder and pin diameter, welding speed have been studied and mechanical characteristics of Friction Stir Welded joints are also studied including tool life. Important parameters such as axial tool pressure (F), rotational speed (N) and traverse speed (S), on weld properties have been studied by researchers. Acerra.F et al. [16] investigated the aluminium alloy of AA6065 and observed that heat generation is higher when the diameter of shoulder in tool is increased after the welding process and the major defects are analysed in welding zone and the elements of coating blank. Tool geometry, shoulder diameter and pin are also an important parameter which affect the microstructure and mechanical properties. Fonda R.W. et al. [17] studied the morphology of aluminium alloys based on grain structure in FSW Process and observed that FSW tool has free from damages after the post welding process and grain structure is relatively improved near the welding tool. Finer type of grains is developed and texture follows FCC structure during the welding process. Texture of FSW welded aluminium alloys have been analysed and FCC structure is formed after the post welding process. Zaho et al. [18] the pin and shoulder plays a vital role in material flow which controls the characteristics of welding during the joining process. FSW has a weld defects and contours belong to the tool design and geometry. Material flow during the welding process is done based on pin and shoulder diameter. Researchers are also used simulations such as CFD (Computational fluid dynamics), Analysis of variance (ANOVA) based on FEM (finite element model) to analyse the FSW aluminium alloys. Buffa.G et al. [19] made a study on the simulation based on model has been developed in which studies the geometry of tool in weld nugget. The three-dimensional finite element model (FEM) based on cylindrical geometry has been investigated using FSW tool and behaviour of tool over the weld, microstructure of tool have been analysed. Mechanical properties and tensile strength has been analysed by Analysis of variance (ANOVA). Mohanty et al. [20] investigated the parameters such as speed of tool and other geometries of AA1100 aluminium alloys and Analysis of variance (ANOVA) are utilized to find the mechanical properties and tensile strength is relatively increased by increasing rotational and welding speeds. Colegrove [21] investigated the material flow of FSW process using the CFD. Trivex as well as MX are used to weld alloys and the result is compared with Triflute tools. The transverse and axial force are relatively decreased by using Trivex tool and increased by using Triflute tool. CFD analysis is also used for the comparisons of aluminium alloys. The morphology of aluminium alloys have been varied by Tool geometry, Transverse, longitudinal motions. Mahoney et al. [22] investigated the properties based on transverse and longitudinal motions. Tool geometry and microstructure have been analysed after the aging of 6065 Al alloy. It is observed that the yield strength, tensile strength is poor in HAZ after the post weld treatment process. F. Hidetoshi et al. [23] studied the microstructure and metallurgical properties after the post welding treatment and triangular type of profile is used to weld aluminium alloys. The tool has less impact at low welding speed.

Conclusion

In this review, the friction stir welded Aluminium alloys have been presented and the simulation techniques are also validated with its process parameters. It is observed that similar and dissimilar FSW welded aluminium alloys have been utilized for industrial applications owing to its mechanical properties The joints of different tool pin profiles like straight cylindrical, Taper cylindrical, triangular, square, trapezoidal and hexagonal tool etc., with different rotational speeds, weld speeds and axial force were reviewed in this paper. The diameter of the pin is equal to the thickness of the parts to be welded and its length is slightly shorter than the thickness of the part. Tool material properties such as strength, fracture toughness, hardness, thermal conductivity and thermal expansion coefficient affect the weld quality, tool wear and performance. Heat generation rate and plastic flow in the workpiece are affected by the shape and size of the tool shoulder and pin. Although the tool design affects weld properties, defects and the forces on the tool. The pin cross-sectional geometry and surface features such as threads influence the heat generation rates, axial forces on the tool and material flow in future, dissimilar aluminium alloys are recommended to enhance the quality of weld in industries and commercial applications. From the above literature it is clear that tapered tool gives better result than conical and cylindrical tool and triangular tool gives better result than square, rectangular, pentagonal and hexagonal tool.

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