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"A REVIEW PAPER ON FRICTION STIR WELDING – PROCESS"

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ABSTRACT

Friction Stir Welding (FSW) was invented by Wayne Thomas at TWI (The Welding Institute), and the first patent applications were filed in the UK in December 1991. Initially, the process was regarded as a "laboratory" curiosity, but it soon became clear that FSW offers numerous benefits in the fabrication of aluminium products. Friction Stir Welding (FSW) has become a major joining process in the aerospace, railway and ship building industries especially in the fabrication of aluminium alloys. The process uses a spinning non-consumable tool to generate frictional heat in the work piece. Worldwide, there are now over 135 licensees of FSW and new techniques and applications are being developed daily. This paper looks at the review, on friction stir welding process, various welding variables like tool rotation, transverse speed, tool tilt, plunge depth and tool design, for the welding of aluminium alloys or various dissimilar alloys. Applications, future aspects and several key problems are also described.

Keyword: *Friction Stir Welding (FSW), Tool, Aluminium Alloy, Speed, Tool, Fabricartion*

I. INTRODUCTION

Friction stir welding (FSW) is a relatively new joining process produces no fumes; uses no filler material; environmentally friendly and can join several metal alloys such as aluminium, copper, magnesium, zinc, steels, and titanium. FSW sometimes produces a weld that is stronger than the base material. FSW is a solid-state joining process, where metal is not melted uses a cylindrical, shouldered tool with a profiled probe rotated and slowly plunged into the weld joint between two metal pieces of sheet or plate that are to be welded together . The parts must be clamped onto a backing bar in a manner that prevents the abutting joint faces from being forced apart or in any other way moved out of position. Frictional heat is generated between the tool and material causing the work pieces to soften without reaching the melting point, and then mechanically intermixes the two pieces of metal at the place of the joint, further softened metal due to the elevated temperature is joined using mechanical pressure, applied by the tool. This leaves a solid-phase bond between the two pieces. Because melting does not occur and joining takes place below the melting temperature of the material, a high-quality weld is created. This characteristic greatly reduces the ill effects of high heat input, including distortion, and eliminating solidification defects. The process originally was limited to low melting temperature materials because initial tool materials could not hold up to the stress of stirring higher temperature materials such as steels and its alloys, other high-strength materials. This problem was addressed recently with the introduction of new tool material technologies such as polycrystalline cubic boron nitride (PCBN), tungsten rhenium, and ceramics. The use of a liquid cooled tool holder and telemetry system has further refined the process and capability. Tool materials required for FSW of high-melting temperature materials need high "hot" hardness for

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abrasion resistance, along with chemical stability and adequate toughness at high temperature. Material developments are advancing rapidly in different tool materials, each material offering specific advantages for different applications.

II. HISTORY

Friction Stir Welding (FSW) was invented by Wayne Thomas at The Welding Institute (TWI) Ltd in 1991 and overcomes many of the problems associated with traditional fusion welding techniques such as shrinkage, solidification cracking and porosity. FSW is a solid state process which produces welds of high quality in difficult to weld materials such as aluminium and is fast becoming the process of choice for manufacturing light weight transport structures such as boats, trains and aero planes. 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.

FSW has been proven to be an effective process for welding aluminium, brass, copper, and other low melting temperature materials. The latest phase in FSW research has been aimed at expanding the usefulness of this procedure in high melting temperature materials, such as carbon and stainless steels and nickel-based alloys, by developing tools that can withstand the high temperatures and pressures needed to effectively join these materials.Fabricators are under increasing pressure to produce stronger and lighter products whilst using less energy, less environmentally harmful materials, at lower cost and more quickly than ever before. FSW, being a solid state, low energy input, repeatable mechanical process capable of producing very high strength welds in a wide range of materials, offers a potentially lower cost.

III. PRINCIPLE OF FRICTION STIR WELDING

The basic principal of Friction stir welding is heating the metal to a temperature below re-crystallization temperature using Friction generated by the cylindrical shouldered tool on metal. This tool having characteristic profile pin, which is rotated and plunged into the joint area between two pieces of sheet or plate material. The parts have to be securely clamped using fixtures to prevent the joint faces from being forced apart. The Frictional heat is produced between the wear-resistant welding tool and the workpieces, which causes the metals or alloys to soften without reaching the melting point.

The tool moves along the joint line of the work materials as shown in fig. 1. The plasticized material gets transferred to the trailing edge of the tool pin and forged through intimate contact with the tool shoulder and pin profile. The cooling of the material leads to the creation of a solid phase bond between the clamped workpieces.

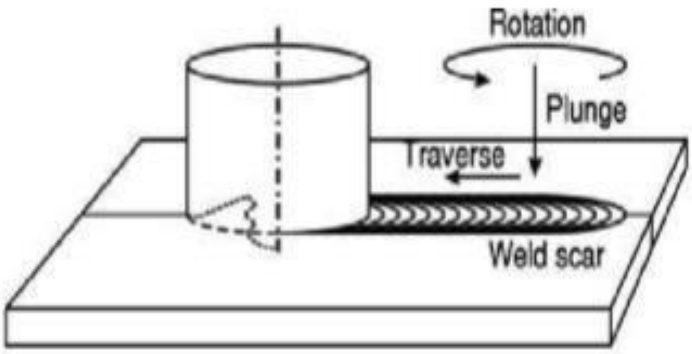

Fig. 1 Schematic of Principle of Friction Stir Weld

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IV. WELDING TOOL

The welding tool of FSW plays a prominent role welding process which has an impact in the mechanical properties and quality of microstructure of the material. Therefore the tool is designed carefully which may alter the weld quality. The tool should have idealistic and higher mechanical properties than weld materials .The difficulty associated are mainly with finding proper tool material;

The material that can withstand the high temperatures that experience during the process. The high-temperature tool materials are suitable FSW. The resistance to wear (durability) is one of the important factors; which causes because of lack of tool hardening or due to process parameters.

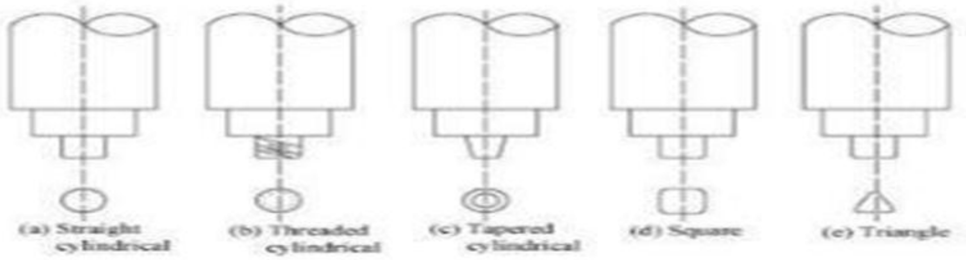

Fig. 2 Schematic diagram of different types of FSW pin profile (a) Straight cylindrical, (b) threaded cylindrical, (c) tapered cylindrical, (d) square and (e) triangle

V. PROCESS PARAMETERS

The study of the variation of the process parameter input to the output effects and causes play a vital role in RSM. Using the FSW, there is four major process parameter that should be controlled; they are down force, welding speed, the rotation speed of the welding tool and tilting angle. This four parameter need to be mastered for making FSW ideal for mechanized welding.

Different parameters must be studied for the variations in the outcome of the weld. The process parameter like down force, welding speed, the rotation speed of the welding tool and tilting angle play a major role in the Mechanical Properties and hardness of the welded material. The different parameter produces the different effect on welded material. The effect of this parameter are rotation speed produce effects like frictional heat, stirring, mixing of material and oxide layer breaking, tilting angle produce the effect of the appearance of the weld and thinning, welding speed produce Appearance and heat control and downforce produce frictional heat and maintaining contact conditions.

VI. MECHANICAL PROPERTIES EVOLUTION

Once the metallographic analysis is performed the work material is subjected to various tests to calibrate the mechanical properties of the weld materials. The work material is cut into specific dimensions for the particular test performs. The tests performed are:

- Tensile test: The tensile properties of a welded joint are considerably the first tests performed to check the joint quality and its ‘joint efficiency’, which defines the tensile strength ratio of the weld to the parent plate. The tensile tests are carried o ut at the room temperature using an MTS 810 testing machine capacity of 250MPa with the initial strain rate of 10-3/s.
- Fatigue test: The Fatigue test is carried out in servo-hydraulic MTS testing machine. The specimen dimension is taken according to the ASTM standard E466. The weld is kept at a perpendicular to load direction in the S-N tests. Maximum stress level is chosen as a function of yield stress for each type of joint. Also, the stress ratio and no. of cycles to failure are decided for the test. Then the specimens are tested on the machine with the input. The S-N fatigue curve is drawn with the data.
- Hardness test: Hardness test of the weld material is carried out by Brinell hardness testing machine. The weld material is placed over the anvil, which can be adjusted by elevating screw. The weld area is placed exactly

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below the indenter. The lever is pushed down so that indenter with pointed edge penetrates into the weld material and hardness is tested. The hardness at nugget zone generally harder than the TMAZ and HAZ zones of the weld material and an area located at the centre of the weld, hardness reduces at TMAZ and HAZ zones, and rises sharply at the base plates. The simulated temperature profiles and the kinetics of natural aging were correlated to predict the hardness profiles in the FSW plate. The predicted minimum hardness locations are consistent with the measured hardness profiles in that the hardness moves away from the weld centreline as the aging time increases. More interestingly, the predicted minimum hardness is located at a similar position of failure in cross-weld tensile samples.

VII. LITERATURE REVIEW

Koilraj et al., (2012) in their work, optimization of process parameters of friction stir welding of dissimilar aluminium alloys (copper, aluminium and magnesium alloys)using Taguchi technique (Taguchi L16 orthogonal design of experiments), considered parameters rotational speed, traverse speed, tool geometry and ratio between tool and shoulder diameter and pin diameter for optimization to investigate tensile strength of the joint. The results were analysed with the help of analysis of variance (ANOVA) and concluded that optimum levels of tool rotational speed is 700 rpm, traverse speed is 15mm/min , ratio between tool shoulder diameter and pin diameter is 3, pin tool profile is cylindrical threaded and finally friction stir welding produces satisfactory butt welds. Yahya Bozkurt (2012) has done work on optimization of friction stir welding process parameters to achieve maximum tensile strength in the polyethylene slab. Three process parameters, tool rotational speeds, tool traverse speed, and tilt angle of the tool were identified for optimization. The material taken for study is high density polyethylene sheet which is a thermoplastic to determine welding process parameters on ultimate tensile strength of the weld for good joint efficiency. The optimization technique applied is Taguch's L9 orthogonal array, signal to noise ratio and ANOVA. The results depicted are tool rotational speed of 3000rpm contributes 73.85% to the overall welding parameters for the weld strength and the tool tilt angle has least contribution. Elatharasan et al (2013) in their research study, experimental analysis of process parameters of friction stir welding and its optimization.

They identified different process parameters like tool rotational speed, welding speed and axial force that have significant role in deciding joint characteristics on an aluminium alloy. They have adopted Response Surface Methodology (RSM) and ANOVA for the optimization of process parameters. The outcomes of the experimentation are ultimate tensile strength, yield strength increased with increase in tool rotational speed, welding speed and tool axial force. The percentage of total elongation increased with increase in rotational speeds and axial force but decreased when there is increase in welding speed continuously. The results documented as maximum tensile strength is 197.50MPa, yield strength is 175.25 MPa, percentage of total elongation is 6.96 was exhibited by the friction stir welding joints fabricated with optimized parameters of 1199rpm rotational speed, 30mm/min welding speed and 9 KN

axial force. Further authors like, Luijendijk T, Bala Srinivasan P, Dietzel W. Zettler R, dos Santos JF, Sivan V, Amancio-Filho ST, Sheikhi S and Cavaliere P, De Santis A, Panella F, Squillace A, have contributed towards this friction stir welding applications by selecting different parameters, dissimilar metal alloys, joints, and their micro structures, mechanical properties were analysed in terms of stress, corrosion cracking, fatigue strength, apart from the influence of process parameters. So it can be understood that many research works are aimed towards parameters like microstructure behaviour, tool traverse, tool profile etc and aluminium based metal alloys and there is every scope to analyse with other metal alloys depending on the need. Ex., Advanced Tool steels, Mild steel alloys (as work piece) with cubic boron nitride (as tool). Therefore suitable research works can be extended in this area.

VIII. BENEFITS OF FSW

The benefits of FSW are large in the field of the welding process. FSW does not require joint preparation between two plates only degreasing is needed. It offers the high quality of welding with increased tensile strength, outstanding fatigue properties and corrosion resistance from the oxidation and chemical action. It is an economical method of welding with low operation cost, which has no consumable with less energy cost unlike consumption of electrode in arc welding process. Friction stir welding has no post heat treatment with low distortion and shrinkage of material. FSW is one of the most environment-friendly compared to arc welding (or) gas welding, which has no arc, fumes or spotter

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during the procession. It neither requires shielding gas to continue the operations nor does it require surface cleaning after the welding process. It eliminates grinding wastes. It can consume materials like rugs, wire, and any other gasses.

IX. ADVANTAGES AND LIMITATIONS

1. Good mechanical properties
2. Improved safety due to the absence of toxic fumes or the spatter of moltan material.
3. Can operate in all positions (horizontal, vertical, etc.), as there is no weld pool.
4. Generally good weld appearance and minimal thickness under/over-matching, thus reducing the need for expensive machining after welding.
5. Low environmental impact.

However, some disadvantages of the process have been identified as,

1. Exit holes are left when tool is withdrawn.
2. Large down forces required with heavy-duty clamping necessary to hold the plates together.
3. Less flexible than manual and arc welding processes (difficulties with thickness variations and non-linear welds).
4. Often slower traverse rate than some fusion welding techniques, although this may be offset if fewer welding passes are required.

X. CONCLUSION

The friction stir welding is very recent trends in the manufacturing technology of metal joining processes especially for aluminium alloys. It is found that many research works are done on the aluminium alloys. Moreover various engineering industries will not only give importance for aluminium and aluminium based alloys but also for mild steel and its alloys. This paper highlights the principle of FSW and vital factors that influence the quality of weld and the critical analysis realize the possible research works on other than aluminium alloys such as mild steel (work piece) and cubic boron nitride (tool), with same process parameters.

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