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An Overview of Friction Stir Welding (FSW): A New Perspective

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ABSTRACT :*Friction Stir Welding (FSW), being a novel process and facilitates welding various joints required for several industrial applications. It is an attractive technology for solid state material joining, contrary to conventional welding methods, having ability to produce welds with higher integrity and minimum induced distortion and residual stresses. In this paper, the operation of FSW, critical parameters, history, advantages, and limitations were discussed. Further different applications of the process are presented along with critical review of literature; finally recognized areas of research work on materials such as cubic boron nitride, mild steel on tool profiles, boundary etc., and conditions to achieve better quality welds.*

KEY WORDS: *Welding, joint, parameter, material, tool profile*

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 aluminum, 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 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. 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 aluminum 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 aluminum, 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 LITERATURE REVIEW

Koilraj et al., (2012) in their work, optimization of process parameters of friction stir welding of dissimilar aluminum alloys (copper, aluminum 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 analyzed 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 aluminum 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 175.25MPa, 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 analyzed 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 behavior, tool traverse, tool profile etc and aluminum based metal alloys and there is every scope to analyze 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.

THE CRITICAL WELDING PARAMETERS identified which control the weld quality is,

1. Tool rotation and traverse speeds, to be considered in FSW; how fast the tool rotates and how quickly it traverses the interface. These two parameters have considerable importance and must be chosen with care to ensure a successful and efficient welding cycle. Further, the relation with heat input is complex, increasing the rotation speed or decreasing the traverse speed will result in a hotter weld also for good weld quality, and material surrounding the tool should be hot enough to enable the extensive plastic flow required and minimize the forces acting on the tool leading to tool breakage. On the other hand excessively high heat input may be detrimental to the final properties of the weld.

2. Tool tilt and plunge depth, plunge depth is defined as depth of the lowest point of the shoulder below the surface of the welded plate and plunging the shoulder below the plate surface increases the pressure below the tool and helps ensure adequate forging of the material at the rear of the tool. Tilting the tool by 2 to 4 degrees, such that the rear of the tool is lower than the front, will assist this forging process. This will ensure the necessary downward pressure such that the tool fully penetrates the weld addressing defects such as pin rubbing on the backing plate surface or a significant under-match of the weld thickness compared to the base material etc.

3. Tool Design, good tool can improve both quality of the weld and the maximum possible welding speed. So it is desirable that the tool material is sufficiently strong, tough, and hard wearing at the welding temperature

along with good oxidation resistance and low thermal conductivity. For example tool steel AISI H13 to weld aluminum alloys within thickness ranges of 0.5 – 50 mm but more advanced tool materials are necessary for more demanding applications such as highly abrasive metal matrix composites or higher melting point materials such as steel or titanium. (Majority of tools have a concave shoulder profile).

4. Welding forces, a number of forces will act on the tool during welding, a downward force to maintain the position of the tool, the traverse force acts parallel to the tool motion, and torque is required to rotate the tool. In order to prevent tool fracture and to minimize excessive wear and tear on the tool and associated machinery, the welding cycle is to be modified by finding the best combination of welding parameters.

5. Flow of material, mode of material flow thru extrusion chamber and frozen pin technique will lead to better forging of material.

PRINCIPLE OF OPERATION

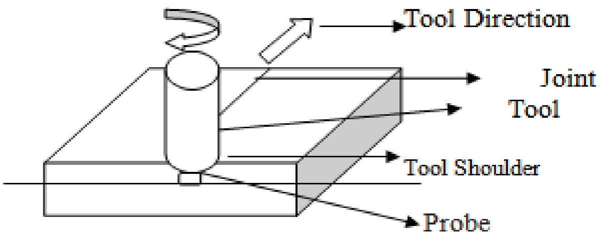

Figure1. Friction welding process

A constantly rotated non consumable cylindrical tool with a profiled probe is transversely fed at a constant rate into a butt joint between two clamped pieces of butted material. The probe is slightly shorter than the weld depth required, with the tool shoulder riding atop the work surface. Frictional heat is generated between the wear resistant welding components and the work pieces. This heat, along with that generated by the mechanical mixing process and the adiabatic heat within the material, cause the stirred materials to soften without melting. As the pin is moved forward, a special profile on its leading face forces plasticized material to the rear where clamping force assists in a forged consolidation of the weld.

This process of the tool traversing along the weld line in a plasticized tubular shaft of metal results in severe solid state deformation involving dynamic recrystallization of the base material.

VI ADVANTAGES AND LIMITATIONS

- Good mechanical properties
- Improved safety due to the absence of toxic fumes or the spatter of molten material.
- No consumables like filler material or gas shield.
- Easily automated on simple machine tools like milling machine
- Lower setup costs and less training.
- Can operate in all positions (horizontal, vertical, etc.), as there is no weld pool.
- Generally good weld appearance and minimal thickness under/over-matching, thus reducing the need for expensive machining after welding.
- Low environmental impact.

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

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

VII CONCLUSIONS

The friction stir welding is very recent trends in the manufacturing technology of metal joining processes especially for aluminum alloys. It is found that many research works are done on the aluminum alloys. Moreover various engineering industries will not only give importance for aluminum and aluminum 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 aluminum alloys such as mild steel (work piece) and cubic boron nitride (tool), with same process parameters.

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