Review on Application of Friction Stir Welding

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Abstract—Cast and wrought aluminum (Al) alloys, steels, along with titanium (W), copper (Cu) and magnesium (Mg) alloys, different metal cluster alloys and metal matrix amalgams. are widely used in aerospace, automotive, marine, defense, construction etc. due to their high strength, low weight, high machinability, good conductivity of heat and electricity etc. Friction stir welding is preferred for joining these materials as it is a solid state forge welding process and problems related with welding of such can be subdued through this process. This welding process is a solid state welding procedure that uses a non-consumable rotating tool that is permitted to rub against the work piece hence generating frictional heat. When the weld constraints such as tool or work piece rotation speed, welding time, axial load are optimum the friction between the work piece and the tool generates enough heat to create a plastic deformation layer at the weld interface. The process doesn't involve any melting process and whole process occurs in solid state through plastic deformation and mass flow among the work pieces. This review paper explains the mechanism of the Friction stir welding as well as studies investigated over friction stir welding by researchers.

Index Terms— Friction Stir welding, aerospace materials, rotating tool.

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1 INTRODUCTION

Friction Stir Welding (FSW) is a recently developed friction tion welding process which was developed at The Welding Institute (TWI), Cambridge, UK [19].This method uses a rotating non-consumable welding tool. This technique uses a non- consumable rotating tool to create frictional heat and distortion at the welding position, thereby upsetting the development of a joint, while the material is in the solid state. The main benefits of FSW, being a solid-state procedure, are low alteration, absenteeism of melt-related flaws and great joint strong point, even in those alloys that are considered non-joinable by conventional practices (e.g., 5xxx and 6xxx series aluminum alloys). In addition, friction stir welded joints are regarded as the absence of filler-induced glitches or defects, since the method necessitates no filler. Also the hydrogen damage that occurs during welding of steeland other iron alloys has to be avoided by decreasing the hydrogen contents of the friction stir welded joints. FSW has been effectively castoff to weld alike and unlike cast and wrought aluminum (Al) alloys, steels, along with titanium (W), copper (Cu) and magnesium (Mg) alloys, different metal cluster alloys and metal matrix amalgams. The skill can be used to crop butt, corner, lap, T, spot, fillet and hem links also to weld deep objects, for example tanks and tube and parts with 3-D outlines. In addition to producing joints, this process is besides appropriate for patch-up of present joint. The primary industrialized and research interests, nevertheless, are being focused on butt welding of aluminum alloy sheets and plate up to 7.62 cm thick. FSW can be done in all points (horizontal, vertical, above and detour). Replacement of secured joints with friction stir welded linkages can clue to substantial weight and cost stashes, striking plans for many engineering farms, together with the transport industry overall and the airframe industry in precise. The removal of the fasteners reduces the weight of FSW. The cost savings could be realized by a sophisticated design, engineering, gathering and upkeep times, carried out by the possible lessening in part amount. FSW joints can be used to replace fastened joints which would result in removal of strain concentration effects related with fastener pigpens, recover corrosion enactment by eradicating the clips by means of a source of contradictory metal contact and in the incident of butt linkages, by abolishing joint boundaries and the associated cracks and other sorts of corrosion.

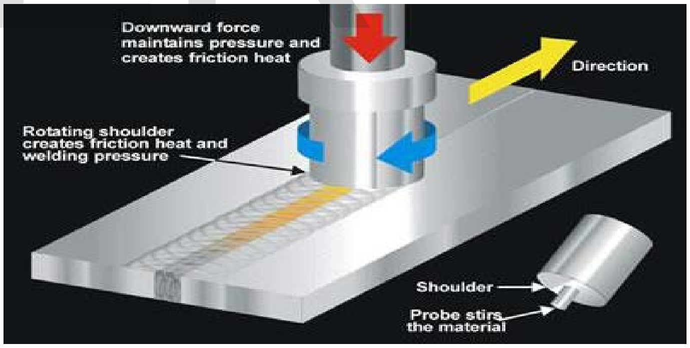

FIG: SCHEMATIC VIEW OF FRICTION STIR WELDING

2. PRINCIPLE, ADVANTAGE & APPLICATION OF FRICTION STIR WELDING.

Friction welding is carried out by translating or rotating one component comparative to another along a mutual boundary, whereas smearing a compressive force through the joint. The frictional heat gets spawned at the boundary softens both components and when they got altered the border material gets extruded out of the ends of the combined so that fresh material from each module is gone along the new interface. The relative cue is then stopped, and an advanced closing compressive power is applied earlier to the joint is permitted

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to cool. The main aspect of friction welding is that no liquefied solid is generated as the weld gets created in the solid state itself. The principle of this method is the changing of kinetic energy (it may be rotational or translational) energy into heat energy through friction. One piece is obsessed and revolved about its axis while the other part to be joined to it is engrossed and is not revolved but can be relocated axially to create interaction with the spinning component. When fusion temperature is reached, then gyration is clogged and forging pressure is smeared. Heat is produced due to friction and is focused and contained at the edge, grain structure is polished by scorching exertion. Then the joint gets formed but there is no melting of material.

Friction welding is cost-effective since it badges joining together dissimilar materials, one of them may be cheap and its quality controller cost may be minimal with an assurance of high strength welds. Furthermore, the weld cycle is very short, so that output is very eye-catching. Friction welding process may fit for mass manufacture. The friction welding route is right for non-homogeneous joints linking things having quite altered mechanical, chemical and thermal properties. The procedure is appropriate for automation and adoptable for robotic application.

As time passes friction welding has found many applications in Commercial, Aerospace, Hydraulic, Automotive industries etc.

3. LITERATURE REVIEW

According to the report of American Welding Society, the practice of friction welding has been carried out since 1891 which is proved by the fact that first patent of the process was dispensed in the USA in 1891. Since then number of patents has been increased as further work developed in Europe in between 1920 to 1944 and in Russia in 1956. In the sixties, this method was further industrialized in USA by Caterpillar, AMF and Rockwell International. Rockwell fabricated its own set ups for friction welding to weld spindles to lorry differential casings, AMF created machineries to weld steering worm shafts, and Caterpillar's developed machineries to weld turbochargers and hydraulic cylinders.

A British patent allotted in 1969 defined linear reciprocating machinery for welding mild steel but no further information was released. In the early 1980s, TWI revealed the feasibility of the LFW technique for metals using modified tools. The plan and construction of a prototype electro-mechanical device with a linear returning mechanism trailed in the mid1980.

Although LFW process was developed a long time ago, it has been only used in aircraft engine manufacture due to the high cost of the welding machines. It has showed to be an idyllic procedure for linking turbine blades to discs because the high cost of the components need a delicate welding process and LFW is just perfect for it. This method is cost-effective than machining blade/disc assemblies from solid lodgings

[1] **Yong-Jai Kwon et al**. investigated the friction stir welding between 5052 aluminum alloy plates with a thickness of 2 mm. The tool rotation speeds were ranging from 500 to 3000 rpm under a constant traverse speed of 100 mm/min. Welded joints were obtained at tool rotation speed 1 000, 2000 and 3000 rpm. At 500, 1000, and 2 000 rpm onion ring structure was clearly observed in the friction-stir-welded zone (SZ). The effect of tool rotation speed on the onion rings was observed. Gain size in the SZ is smaller than that in the base metal and is decreased with a decrease of the tool rotation speed. The study showed that the strength, tensile strength of the joint is more than that of the parent metal. The investigation also demonstrated that the joint is less ductile than the parent alloy.

[2] The study conducted by **G. CAO** and **S.KOU** was aimed at studying whether the extreme temperature in the work piece can extent the lower bound of the melting temperature range and trigger liquation during friction stir welding (FSW) of aluminum alloys which was observed in some computer simulation. AA 2219, an Al-Cu alloy was the work piece material due to its clear lower bound of the melting temperature array which is the eutectic temperature 548°C. Besides FSW, gas metal arc welding (GMAW) of Alloy 2219 was also accompanied to provide a benchmark for checking liquation in FSW of Alloy 2219.The study under both optical and scanning electron microscopy revealed found that in GMAW of Alloy 2219, q (Al2Cu) particles performed as in-situ micro sensors, which indicates liquation due to reaction between CU and Al forming eutectic particles upon reaching the eutectic temperature. But in FSW, no evidence of q-induced liquation was found suggesting that the eutectic temperature was not reached.

[3] **J. Adamowski et al.** analyzed the mechanical properties and microstructural variations in Friction Stir Welds in the AA 6082-T6 with varying process parameters. Tensile test of the welds was done and relation among the process parameter was judged. Microstructure of the weld interface was observed under optical microscope. Also micro hardness of the resulting joint was measured. It was observed that test welds show resistance to increment of welding speed, Hardness reduction was observed in weld nugget and heat affected zone (HAZ). The reason for this occurrence was the kinetic and thermal asymmetry of the FSW process. An initial stage of a longitudinal, volumetric defect was found at the interface of weld nugget and TMAZ. The hardness was inferior to that of fusion welding. Tunnel (worm hole) defects were found in the nugget zone.

[4] **H.J.LIU et al.** studied the characteristics of friction welding characteristics of AA 2017-T351 sheet in which they found that the relation between the parameters and also they have studied the microstructure of the weld joints. Graphs between revolutionary pitch and strength, distance from weld center and Vickers Hardness, revolutionary pitch and fracture location at the joints were plotted. From the hardness test and tension tests it was deducted that FSW makes the material soft and it also decreases the tensile strength of the material. Microscopic analysis confirms the generations of fractures in the joint at the interface among weld nugget and thermodynamically affected zone.

[5] **M.Vural et al.** scrutinized the friction stir welding competency of the EN AW 2024-0 and EN AW 5754-H22 Al alloys.

These two Aluminium alloys are extensively used in the industry. The experiment presented that the hardness value of EN AW 2024-0 at the weld area is increased about 10-40 Hv. This may be the result of recrystallization and compact grain structure formation. But hardness of EN AW 5754-H22 got decreased due recrystallization and loose grain structure formation. Welding performance of EN AW 2024-0 is 96.6 and for EN AW 5754-H22 it is 57%. Welding performance of dissimilar Aluminium alloys EN AW 2024-0 and EN AW 5754-H22 is reached a value of 66.39%. Analysis of Welding zone using scanning electron microscope showed no change in the microstructure in the welding zone. Hardness distribution at the weld zones didn't show any significant change in hardness

[6] **R. Nandan et al.** reviewed the recent trends in FSW process, weldment structure and properties of the resulting material at the weld joints. This study dealt with the essential understanding of the process and its consequences in the molecular level. Other characteristics that are studied are heat generation, heat transfer and plastic flow during welding, components of tool design, study of defect formations and the structure and properties of the welded materials. They described important factors that have to be optimized to reduce fracture and improve the uniformity of weld properties so that FSW can be expanded to new engineering fields. Principles of heat transfer, material flow, tool-work–piece contact conditions and properties of various process parameters, efficient tools have been formulated. Uncertain parameters of FSW like friction coefficient, the extent of slide between the tool and the work–piece, the heat transfer coefficients for different work–piece surfaces, splitting of the heat amongst the work–piece and the tool at the tool-work piece boundary are also counted for and processes to optimize these parameters are discussed.

[7] **S Yazdanian et al**. scrutinized the effect of pin length, welding speed and rotation rate on the weld strength using AA 6060 as work piece for FSW. The major factor in determining the weld strength is the rotation speed of the tool. Higher rotation rate made the joint weak and vice versa. Effect of rotation speed on heat generation and material flow was also enlightened. It was found that higher rotation rate may result in larger interface lifting and hence higher degree of hooking, reducing the effective weight bearing area.

[8] **Mohamed Merzoug et al**. described the main parameters of Friction stir spot welding (FSSW). The parameter under consideration is shape of the tool. It is established that shape of tool decides the resistance of the joint of welding. This may be due to the heat gradients and mechanical stresses experienced by material throughout welding. The nature of material and the selection of the parameters (geometry, positioning, tool rotating, penetration depth and the force applied of the pin and the shoulder) also decide the heat generation and the strength of the weld joint.

[9] Friction stir welding of different materials was done by **D.Muruganandam et al.** for four different tool rotation speeds namely 600, 800, 1000 and1200 rpm. Radiology was done to study the defects in the weld joint. The analysis indicated that defect concentration was maximum for the 600 rpm tool rotation. It was a little reduced for 800 rpm and even lesser for the 1000 rpm speed rotation. Least defects were found at the highest rpm (1200).

[10] Friction welding of austenitic stainless steel (AISI 304) and optimization of the welding parameters to establish weld quality was done by **P.Sathiya et al**. Austenitic stainless specimens were welded using the laboratory model friction welding machine. Aural emission originated during the tension test from the joints was acquired to evaluate the quality of the joints. They also proposed a genetic algorithm to decide near optimal configurations of process parameters. The tensile tests showed that the weld joints exhibited similar strength with the base material. The post welding analysis showed increase in hardness due to recrystallization. Micro vicker's hardness increases with increasing friction time may be due to the heating of material at the weld region. The objective function is formulated by regression analysis. Genetic Algorithm is then applied to the objective function for optimizing the process parameters. The minimum difference observed between theoretical and the experimental values confirm the applicability of GA for the friction welding process.

[11] Rotary friction welding of AA1050 aluminum and AISI 304 stainless steel was performed and tensile tests, Vickers microhardness, metallographic tests and SEM-EDX analysis etc. were conducted to assess the effect of weld parameters on microscopic as well as physical properties of the weld joint by **Eder Paduan Alves et al.** Joints were acquired with greater mechanical properties of the AA1050 aluminum, with fracture arising in the aluminum away from the bonding boundary. The inspection by EDX at the interface of the junction presented that inter-diffusion occurs between the main chemical components of the materials involved.

[12] **S.Senthil Kumaran et al.** carried out friction welding of tube to tube plate using an external tool and optimized the process parameters by Taguchi L8 orthogonal array. The arrangement of the process parameters was obtained and ANOVA had been accompanied to predict the statistical importance of the process parameters. They implemented Genetic Algorithm (GA) to optimize the parameters. The real-world viability of applying GA to friction welding process was ensured by studying the eccentricity between forecasted and experimentally acquired friction welding process parameters.

4. CONCLUSION

Now-a-days extensive studied on Friction stir welding is being carried out as this welding method has shown many promises such as welding of unweldable metals, polymers etc. The parameters of friction welding are weld speed, rpm of the work piece or tool, feed (axial force), welding time etc. These have to be optimized for getting good quality friction welding. Though FSW is being applied to weld able materials at present, further study is needed to make it cost effective and to make it flexible so that every configuration can be welded with the help of FSW.

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