A Review of Friction Stirs Welding

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ABSTRACT

Through this paper an attempt is made to study and review a special welding technology of friction stir welding (FSW) which is a solid-state joining process. Friction Stir Welding (FSW) is a recent advanced technique, invented by The Welding Institute (TWI) in 1991, that utilizes a non consumable rotating welding tool to generate frictional heat and plastic deformation at the welding location; thereby, affecting the formation of a joint while the material is in the solid state. In particular, FSW can be used to join high-strength aerospace aluminum alloys and other high temperature metallic alloys that are difficult to weld by conventional fusion welding method. FSW is considered to be the most significant development in metal joining process in a decade The comprehensive body of knowledge that has built up with respect to the friction stir welding (FSW) of aluminum alloys. This study addresses the current state of understanding and development of the FSW process. The principles of weld formation, welding parameters, design principles, including metal flow and thermal history, before discussing how process parameters affect the weld microstructure.

KEYWORDS

Friction stir welding, metal flow, process parameters, mechanical properties, Microstructure.

I. INTRODUCTION

The welding of aluminum and its alloys has always represented a great challenge for researchers and technologists. Friction stir welding (FSW) is a new welding process that has produced low-cost and high-quality joints of aluminum alloys. For carrying out research work in any area, the first and an important phase are to review the available literature on the selected topic and the research problem can be formulated with clear objectives. In order to formulate the present research problem along with the methodology that could be adopted for accomplishing this research work, the selective review of the relevant literature surveyed is presented briefly. It is worth mentioning The Tanta University, Egypt is one of the first university and research centers that has worked in the field of friction stir welding pipes of aluminum alloys since 2013.

Thomas (1997) focuses on this study the relatively new joining technology, friction stir welding (FSW). Friction stir welding can be used to join most aluminium alloys and surface oxide presents no difficulty to the process. On the basis of this study it was recommend that number of light weight materials suitable for the automotive, rail, marine and aerospace transportation industries can be fabricated by FSW.

Ying et al., (1999) used FSW to join the plates of 2024 Al and 6060 Al having thickness of 0.6 cm each. The tool rotation speed was varied between 400 to 1200 rpm. Dislocation spirals and loops are observed in the 2024 Al intercalation regions within the weld zones at higher speeds (>800 rpm). Micro hardness profiles follow microstructural variations which result in a 40% reduction in the 6061 Al workpiece micro hardness and a 50% reduction in the 2024 Al workpiece micro hardness just outside the FSW zone.

Sutton et al., (2002) prepared the weld joints of 7 mm thickness using 2024-T351 aluminium rolled sheet material by Friction stir welding. Metallurgical, hardness and quantitative energy dispersive X-ray measurements were performed. The tests demonstrated a segregated, banded, microstructure consisting of alternating hard particles. Since the band spacing is directly correlated with the welding tool advance per revolution, the results indicated that the opportunity exists to manipulate the friction stir weld process parameters in order to modify the weld microstructure and improve a range of material properties, including fracture resistance.

Lee et al., (2003) welded A356 alloys sheets using friction-stir-welding to observe the effect of mechanical properties at the weld zone by varying the welding speeds. The microstructures of the weld zone are composed of SZ (stir zone), TMAZ (thermo-mechanical affected zone) and BM (base metal). The microstructure of the SZ is very different from that of the BM. But the microstructure of TMAZ, where the original grains were greatly deformed, is characterized by dispersed eutectic Si particles aligned along the rotational direction of the welding tool. The mechanical properties of the weld zone are greatly improved in comparison to that of the BM.

Mustafa and Adem (2004) prepared the weld joints of Al 1080 alloy using five different stirrers, one of them square cross-sectioned and the rest were cylindrical with 0.85, 1.10, 1.40 and 2.1 mm screw pitch. The stirrers pitched 1.40 and 2.0 mm acted like a drill rather than a stirrer and compelled the weld metal outward in the form of chips. Bonding could be affected with square cross section stirrer but poor mechanical and metallographic properties were observed. The specimen welded with cross-section stirrer has 60 N/mm2 Tensile Strength and the fracture took place within the weld metal. This type of stir sweeps a large amount of metal from the plasticized zone and results in an inhomogeneous structure. But the specimen welded using 0.85 and 1.10 mm pitched stirrers, have 110 N/mm2 UTS. The higher strength of the weld metal can be attributed to heat generation during stirring.

Ahmed. M. El-Kassas et al. (2015) in this study effect to the mechanical properties in order to demonstrate the feasibility of friction stir welding for joining Al 6061 aluminum pipes with different thickness 2 to 4mm, rotational speeds 485 to 1400 RPM and a traverse speed 4 to 10 mm/min was applied. This work focuses on two methods such as artificial neural networks(ANN) using software (Pythia) and response surface methodology (RSM) to predict the tensile strength, the percentage of elongation and hardness of friction stir welded 6061 aluminum alloy. An artificial neural network (ANN) model was developed for the analysis of the friction stir welding parameters of Al 6061aluminum pipe. Response surface methodology (RSM) also developed and the values obtained for the response Tensile strengths, the percentage of elongation and hardness are compared with measured values.

Chena et al., (2006) used friction stir welding (FSW) for 2219-O and 2219-T6 aluminium alloy to investigate the effects of the base material conditions on the FSW characteristics. The experimental results indicated that the base material condition has a significant effect on weld morphologies, weld defects, and mechanical properties of joints. The strength efficiency of 2219-O joints is found to be 100%, while that of 2219-T6 joints is only up to 82%.

A M Khourshid and I. Sabry(2013) in this study effect Friction stir welding for pipes on Al 6063 alloy. The tool rotation 485 to 1400 rpm with a traverse speed 4 mm/min was applied. The Mechanical properties of welded joints were investigated using different mechanical tests including destructive test. Based on the stir welding experiments conducted in this The resultant microstructure was characterized using optical microscopy.

Hirata et al., (2007) developed the relationship between the microstructure of stir zone and the mechanical properties of FS-welded 5083 aluminium alloy. The microstructures of the stir zones consisted of fine equiaxed grains at various FSW conditions. The grain size of the stir zone decreased with the decrease in friction heat flow during FSW. The results shown that the micro structure and mechanical properties of the FS-welded 5083 Al alloy joints were improved by the refinement of grain size of the stir zone.

Cabibbo et al., (2007) investigated the microstructure and mechanical properties of a friction stir welded 6056-T6 aluminium alloy plates. The microstructure revealed different grain morphologies in the thermo-mechanically affected zones, in proximity of the weld nugget. The advancing side had fairly elongated, bent grains, whilst the broader retreating side had more elongated, narrower grains. Tensile tests showed yield and ultimate strength slightly lower across the weld as compared to the parent material. Reduction in ductility of the weld region was also observed.

Kumara and Kailas (2008) investigated the influence of axial load and the effect of position of the interface with respect to the tool axis on tensile strength of the friction stir welded joint of aluminium alloy 7020-T6. The axial load is continuously varied by linearly increasing the interference between the tool shoulder and the surface of the base material. It is found that there is an optimal axial load, above which the weld is defect-free, with joint efficiency of 84%.

Lombard et al., (2008) in this research work present a systematic approach to optimizing FSW process parameters (tool rotational speed and feed rate). Eleven experiments were conducted by varying the tool rotational speed and welding speed. The tensile strength of the joint was increased from 289 to 313 MPa by varying the tool rotational speed from 400 rpm to 200 rpm at the constant welding speed of 85 mm/min. The tensile strength of the joint increased from 254 MPa to 315 MPa by varying the tool rotational speed from 635 rpm to 254 rpm at the constant welding speed 135 mm/min. The work indicates that the tool rotational speed is the key parameter governing the tensile strength.

Ibraheem sabry et al., (2017) Aluminum can't successfully be arc welded in an air environment, due to the affinity for oxygen. If fusion welded in normal atmosphere oxidization readily happens and this outcome in both slag inclusion and porosity in the weld, greatly reducing its mechanical properties. To overcome these problems one of the most common ways of welding aluminum has been to a suggestion the friction stir welding. To work in this area needs to do a tremendous amount of experience and this thesis has provided general Specification of the process of friction stir welding pipes using three methods regression analysis (RA),Response surface methodology(RSM) and artificial neural networks (ANN) to infer the mechanical properties has this Specification so for the thickness of 2 to 4 mm, depending on the rotational speed from 485 to 1800(RPM) travel speed from 4 to 10 (mm/min to work comparative between three method ((RA), (RSM) and (ANN)) through total error.

Rajakumar et al., (2011) explored the influence of process and tool parameters on tensile strength properties of AA7075-T6 joints produced by friction stir welding. Tensile strength of the joints were evaluated and correlated with the microstructure, micro hardness of weld nugget. From this investigation it is found that the joint fabricated at a tool rotational speed of 1400 rpm, welding speed of 60 mm/min, axial force of 8 kN, using the tool with 15 mm shoulder diameter, 5 mm pin diameter, 45 HRC tool hardness yielded higher strength properties compared to other joints.

Chen et al., (2005) investigated that, the tensile strength of the FSW joints of 2219-O aluminium alloy significantly improved by the PWHT process. The tensile properties of the joints welded at different welding speeds, before and after the heat treatment were evaluated. The results indicate that the heat-treated joints possess a higher tensile strength and a lower elongation than the as-welded joints. The as welded joints fracture in the base material zone, while the heat-treated joints fracture in the weld zone (WZ). This implies that the PWHT process has a significant effect on the fracture locations of the joints.

Elangovana and Balasubramanian (2008) reported that the influences of various post-weld heat treatment procedures on tensile properties of friction stir-welded AA6061 aluminium alloy joints. Solution treatment, an artificial aging treatment and a combination of both were given to the welded joints. Mechanical properties such as yield strength, tensile strength, elongation and joint efficiency were evaluated. A simple artificial aging treatment was found to be more beneficial than other post weld treatment methods

Singh et al., (2011) reported the effect of post weld heat treatment (T6) on the microstructure and mechanical properties of friction stir welded 7039 aluminium alloy joints. FSW parameters were optimized by making welds at constant rotary speed of 635 rpm and welding speed of 8 and 12 mm/min. It was observed that the thermo-mechanically affected zone (TMAZ) showed coarser grains than that of nugget zone. As welded joint has highest joint efficiency (92.1%). Post weld heat treatment lowers yield strength, ultimate tensile strength but improves percentage elongation.

Wang et al., (2008) reported the effect of welding processes (FSW and TIG) on the fatigue properties of 5052 aluminium-welded joints was analyzed based on fatigue testing. The results show that the fatigue properties of FSW welded joints are better than those of TIG welded joints.

Cabello et al., (2008) made a comparative study on microstructural and mechanical characteristics of fusion welds (TIG) and solid-state welds (FSW) of Al–4.5 Mg–0.26 Sc heat-treatable aluminium alloy. The corresponding mechanical properties are evaluated through micro hardness measurements and tensile tests. The effect of a post-weld heat treatment on both microstructure and mechanical properties is further examined. The results suggest that hardening precipitates are comparatively more affected by the TIG than by the FSW process. This results in a substantial reduction of mechanical properties of TIG welds that can be partially recovered through a post-weld heat treatment.

Zhao et al., (2010) welded Al–Mg–Sc alloy plates by FSW and TIG welding. The effect of welding processes on mechanical and metallurgical properties of welded joints was analyzed. The results shown that the mechanical properties of FSW welded joint are much better than those of TIG welded joint. Moreover, tensile strength and yield strength of FSW joint are 19% and 31% higher than those of TIG joint, respectively. Due to the low welding temperature during FSW process and the excellent thermal stability of Al3(Sc,Zr) particles, the cold working microstructures can be well preserved.

Zhen et al., (2011) made a comparative study of the mechanical and metallurgical properties of Al-Mg-Mn-Sc-Zr alloy weld joints prepared by FSW and TIG welding. The strength of FSW and TIG welded joints decreased as compared to the base metal but strength of FSW welded joints higher than the TIG welded joints. The loss of substructure strengthening and a very little loss of precipitation strengthening of Al3(Sc, Zr) cause the decreased strength of FSW welded joint. But for the TIG welded joint, the disappearance of both the strain hardening and most precipitation strengthening effect of Al3(Sc, Zr) particles contributed to its softening. At the same time, the grains in weld nugget zone of FSW welded joints were finer than those in the molten zone of TIG welded joints

Lakshminarayanan and Balasubramanian (2008) applied Taguchi approach to determine the most influential control factors which will yield better tensile strength of the joints of friction stir welded RDE-40 aluminium alloy. Through the Taguchi parametric design approach, the optimum levels of process parameters (tool rotational speed, traverse speed and axial force) were determined. The results indicate that the rotational speed, welding speed and axial force are the significant parameters in deciding the tensile strength of the joint.

Sarsilmaz and Çaydaş (2008) applied the full factorial experimental design to study the effect of friction-stir welding (FSW) parameters such as spindle rotational speed, traverse speed, and stirrer geometry on mechanical properties of AA 1050/AA 5083 alloy. Ultimate tensile strength (UTS) and hardness of welded joints were determined for this purpose. Analysis of variance (ANOVA) and main effect plot were used to determine the significant parameters and set the optimal level for each parameter. A linear regression equation was derived to predict each output characteristic.

Ibraheem Sabry (2017) discusses the cost analysis of pipe friction stir welding spicily aluminum 6061.cost estimation were performed on pipe with different thickness 2 to 4 mm. rotational speeds 485 to 1800 RPM and a travel speed 4 to 10 mm/min. The each cost component of joining Al 6061 aluminum pipe welding was each component cost (Labor cost, Power cost, Machine cost and Tooling cost) has been closely analyzed and major cost components have been included in the cost model. We used these cost models to predict the cost of friction stir welded pipe joints. Initial results show that the rotational speed, material thickness and travel speed increased due to increase the total cost.

Ibraheem Sabry (2017) In this Work, a comprehensive practical study in total cost estimation of welded Aluminum 6061 pipes using three different types of welds, Metal Inert Gas (MIG), Tungsten Inert Gas (TIG) and Friction Stir Welding (FSW) . The cost component of joining Al 6061 aluminum pipe welding was each component cost (labor cost, Power cost, Ma-chine cost, shield gas cost(MIG,TIG), filler metal cost(MIG,TIG) and Tool cost(FSW)) has been closely analyzed and major cost components have been included in the cost model. We used these cost models to predict the cost of Metal Inert Gas (MIG), Tungsten Inert Gas (TIG) and friction stir welded pipe joints. Initial results show that MIG and TIG welding were less cost effective compared to FS welding, but it is possible that the cost of reduced friction stirs welding with quantitative prediction.

CONCLUSIONS

Still friction stir welding needs more research and study through the influence of the thickness of the metal, as well as the work of standardization of friction stir welding .

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