A Review On Experimental And Numerical Investigation Of Friction Stir Welds Of Aa6063-T6 Aluminium Alloy

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ABSTRACT

Welding is a manufacturing process, which is carried out for joining of metals. Friction-stir welding (FSW) is a solid-state joining process (the metal is not melted) and is used when the original metal characteristics must remain unchanged as much as possible. It mechanically intermixes the two pieces of metal at the place of the join, then softens them so the metal can be fused using mechanical pressure, much like joining clay, dough, or plasticine. It is primarily used on aluminium, and most often on large pieces that cannot be easily heat-treated after welding to recover temper characteristics.

Friction stir welding is a relatively new joining process, which involves the joining of metals without fusion or filler materials. The amount of the heat conducted into the work piece dictates a successful process which is defined by the quality, shape and microstructure of the processed zone, as well as the residual stress and the distortion of the work piece. The amount of the heat gone to the tool dictates the life of the tool and the capability of the tool to produce a good processed zone. Hence, understanding the heat transfer aspect of the friction stir welding is extremely important for improving the process. Many research works were carried out to simulate the friction stir welding using various soft wares to determine the temperature distribution for a given set of welding conditions. Very few attempted to determine the maximum temperature by varying the input parameters using ANSYS. The objective of this research is to develop a finite element simulation of friction stir welding of AA6063-T6 Aluminium alloy. Trend line equations will develope for thermal conductivity, specific heat and density to know the relationship of these factors with peak temperature. Tensile and hardness values for the welded specimens are found for different rotational speed and feed. Variation of temperature with input parameters is also observe. The simulation model will be test with experimental results. The results of the simulation are in good agreement with that of experimental results. .

Keywords: Friction stir welding, Peak temperature, Trend line equation, Temperature distribution, Hardness.

1. INTRODUCTION

Friction stir welding is a relatively new joining process, which involves the joining of metals without fusion or filler materials. The amount of the heat conducted into the work piece dictates a successful process which is defined by the quality, shape and microstructure of the processed zone, as well as the residual stress and the distortion of the work piece. The amount of the heat gone to the tool dictates the life of the tool and the capability of the tool to produce a good processed zone. Hence, understanding the heat transfer aspect of the friction stir welding is extremely important for improving the process.

Friction stir welding was invented by The Welding Institute (TWI) in December 1991. TWI filed successfully for patents in Europe, the U.S., Japan, and Australia. TWI then established TWI Group-Sponsored Project 5651,"Development of the New Friction Stir Technique for Welding Aluminum," in 1992 to further study this technique.

Why welding is used- Because it is,

- ➢ Suitable for thicknesses ranging from fractions of a millimeter to a third of a meter.
- ➢ Versatile, being applicable to a wide range of component shapes and sizes.

As per American Welding Society (AWS)

It is defines weld as a localized coalescence of metals or non-metals produced either by heating the materials to suitable temperatures with or without the application of pressure alone and with or without the use of filler material.

CLASSIFICATION OF WELDING PROCESSES

- Arc welding
- Gas welding
- Resistance welding
- Solid state welding
- Thermo chemical welding
- Radiant energy welding

WORKING PRINCIPLE OF FSW

A constantly rotated cylindrical-shouldered tool with a profiled nib is transversely fed at a constant rate into a butt joint between two clamped pieces of butted material. The nib is slightly shorter than the weld depth required, with the tool shoulder riding atop the work surface.

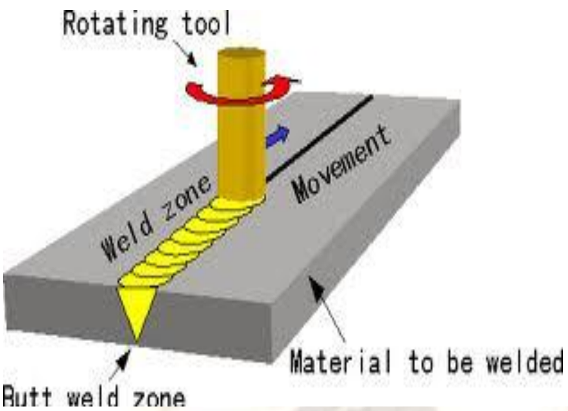

FIG: 1 FRICTION STIR WELDING

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.

How Does FSW Work?

In FSW, a cylindrical, shouldered tool with a profiled probe is rotated and slowly plunged into the weld joint between two pieces of sheet or plate material that are to be welded together (**Figure**). 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.

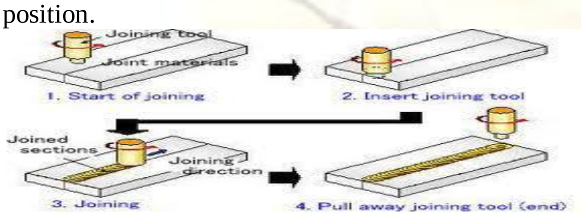

FIG: 2 WORKING OF FSW

Frictional heat is generated between the wear-resistant welding tool and the material of the workpieces. This heat causes the workpieces to soften without reaching the melting point and allows the tool to traverse along the weld line. The resultant plasticized material is transferred from the leading edge of the tool to the trailing edge of the tool probe and is forged together by the intimate contact of the tool shoulder and the pin profile. This leaves a solid-phase bond between the two pieces. The process can be regarded as a solid-phase keyhole welding technique since a hole to accommodate the probe is generated, then moved along the weld during the welding sequence.

Important Welding Parameter

- **Tool rotation and traverse speeds**

There are two tool speeds to be considered in friction-stir welding; 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. The relationship between the welding speeds and the heat input during welding is complex but, in general, it can be said that increasing the rotation speed or decreasing the traverse speed will result in a hotter weld. In order to produce a successful weld it is necessary that the material surrounding the tool is hot enough to enable the extensive plastic flow required and minimise the forces acting on the tool. If the material is too cold then voids or other flaws may be present in the stir zone and in extreme cases the tool may break.

- **Tool tilt and plunge depth**

The plunge depth is defined as the depth of the lowest point of the shoulder below the surface of the welded plate and has been found to be a critical parameter for ensuring weld quality. 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 2–4 degrees, such that the rear of the tool is lower than the front, has been found to assist this forging process. The plunge depth needs to be correctly set, both to ensure the necessary downward pressure is achieved and to ensure that the tool fully penetrates the weld. Given the high loads required, the welding machine may deflect and so reduce the plunge depth compared to the nominal setting, which may result in flaws in the weld. On the other hand, an excessive plunge depth may result in the pin rubbing on the backing plate surface or a significant undermatch of the weld thickness compared to the base material. Variable load welders have been developed to automatically compensate for changes in the tool displacement while TWI have demonstrated a roller system that maintains the tool position above the weld plate.

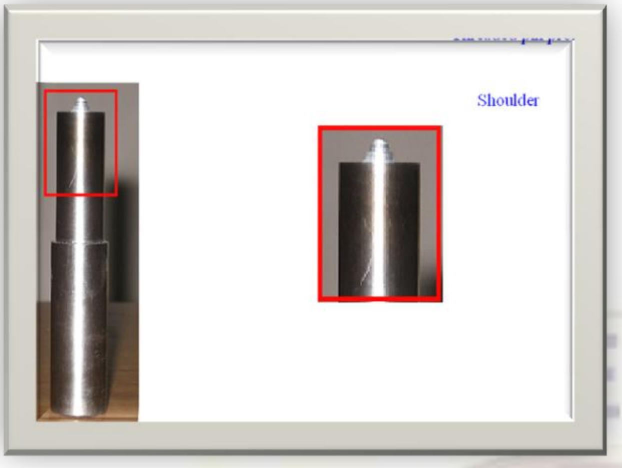

FIG: 3 WORKING OF FSW TOOL

- **Tool Design**

The design of the tool is a critical factor as a good tool can improve both the quality of the weld and the maximum possible welding speed. It is desirable that the tool material is sufficiently strong, tough, and hard wearing at the welding temperature. Further it should have a good oxidation resistance and a low thermal conductivity to minimise heat loss and thermal damage to the machinery further up the drive train. Hot-worked tool steel such as AISI H13 has proven perfectly acceptable for welding aluminium alloys within thickness ranges of 0.5 – 50 mm [8] but more advanced tool materials are necessary for more demanding applications such as highly abrasive metal or higher melting point materials such as steel or titanium. Widespread commercial applications of friction stir welding process for steels and other hard alloys such as titanium alloys will require the development of cost-effective and durable tools. Material selection, design and cost are important considerations in the search for commercially useful tools for the welding of hard materials. Work is continuing to better understand the effects of tool material's composition, structure, properties and geometry on their performance, durability and cost.

Flow of Material

Early work on the mode of material flow around the tool used inserts of a different alloy, which had a different contrast to the normal material when viewed through a microscope, in an effort to determine where material was moved as the tool passed. The data was interpreted as representing a form of in-situ extrusion where the tool, backing plate and cold base material form the "extrusion chamber" through which the hot, plasticized material is forced. In this model the rotation of the tool draws little or no material around the front of the pin instead the material parts in front of the pin and passes down either side.

After the material has passed the pin the side pressure exerted by the "die" forces the material back together and consolidation of the join occurs as the rear of the tool shoulder passes overhead and the large down force forges the material. More recently, an alternative theory has been advanced that advocates considerable material movement in certain locations. This theory holds that some material does rotate around the pin, for at least one rotation, and it is this material movement that produces the "onion-ring" structure in the stir zone.

The researchers used a combination of thin copper strip inserts and a "frozen pin" technique, where the tool is rapidly stopped in place. They suggested that material motion occurs by two processes:

1. Material on the advancing front side of a weld enters into a zone that rotates and advances with the pin. This material was very highly deformed and sloughs off behind the pin to form arc-shaped features when viewed from above (i.e. down the tool axis). It was noted that the copper entered the rotational zone around the pin, where it was broken up into fragments. These fragments were only found in the arc shaped features of material behind the tool.
2. The lighter material came from the retreating front side of the pin and was dragged around to the rear of the tool and filled in the gaps between the arcs of advancing side material. This material did not rotate around the pin and the lower level of deformation resulted in a larger grain size.

ADVENTAGES OF FSW

- Good mechanical properties in the as-welded condition.
- Improved safety due to the absence of toxic fumes or the spatter of molten material.
- No consumables — A threaded pin made of conventional tool steel, e.g., hardened H13, can weld over 1 km (1 mi) of aluminium, and no filler or gas shield is required for aluminium.
- Easily automated on simple milling machines — 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.

DISADVENTAGES OF FSW

- Exit hole 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 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.

2. LITERATURE SURVEY

Many investigators have suggested various methods to explain the experimental and numerical investigation of friction stir welding.

A. Scialpi et al[1],was carried out FSW process shows several advantages, in particular the possibility to weld dissimilar aluminium alloys. In this paper, thin aluminium alloy 2024-T3 and 6082-T6 sheets, 0.8 mm thick, have been welded in the rolling direction by lFSW (FSW for ultra-thin sheets). Both similar and dissimilar joints have been successfully produced and analysed. Mechanical characterization has been executed through static and uniaxial fatigue tests with a constant load amplitude. Finally, microhardness and residual stress measurements have been executed on welded sheets for each joint typology.

Dr. Muhsin Jaber Jweeg et al[2] was investigated Finite element modeling of transient temperature distribution is used to understand physical phenomena occurring during the dwell (penetration) phase and moving of welding tool in friction stir welding (FSW) of 5mm plate made of 7020-T53 aluminum alloy at 1400rpm and 40mm/min. Thermocouples are used in locations near to the pin and under shoulder surface to study the welding tool penetration in the workpiece in advance and retreate sides along welding line in three positions (penetrate (start welding) , mid, pullout (end welding)). Numerical results of ANSYS 12.0 package are compared to experimental data including axial load measurements at different tool rotational speeds (710rpm.900rpm.1120rpm and 1400rpm) Based on the experimental records of transient temperature at several specific locations of thermocouples during the friction stir welding process the temperatures are higher on the advancing side (629.2 oK) than the retreating side (605 oK) along welding line and temperature in the top of workpiece under tool shoulder is higher(645 oK) than bottom (635.79oK). The results of the simulation are in good agreement with that of experimental results. The peak temperature obtained was 70% of the melting point of parent metal.

Selvamani S.T et al[3] was carried out A three dimensional finite element model is developed to study the thermal history in the butt welding of 6061 aluminum alloy using ANSYS package. Solid 70 elements are used to develop the model. The heat source incorporated in the model involves the friction among the material, probe and shoulder. In this work, a moving co-ordinate has been introduced to model the three-dimensional heat transfer process because it reduces the difficulty of modeling the moving tool. In this model the main parameter considered is the heat input from the tool shoulder and tool pin. The temperature distributions of the weld at various welding speeds are obtained. The friction stir welding experiments are carried out at a transverse speed of 0.75 mm/sec of tool. Brinell's Hardness test, tensile test and micro structure analysis are performed on the welded material.

Yuh J. Chao et al[4] was formulate the heat transfer of the FSW process into two boundary value problems (BVP)—a steady state BVP for the tool and a transient BVP for the workpiece. To quantify the physical values of the process the temperatures in the workpiece and the tool are measured during FSW. Using the measured transient temperature fields finite element numerical analyses were performed to determine the heat flux generated from the friction to the workpiece and the tool. Detailed temperature distributions in the workpiece and the tool are presented. Discussions relative to the FSW process are then given. In particular, the results show that (1) the majority of the heat generated from the friction, i.e., about 95%, is transferred into the workpiece and only 5% flows into the tool and (2) the fraction of the rate of plastic work dissipated as heat is about 80%.

Basil M. Darras[5] was worked commercial 5052 Aluminum alloy sheets are friction stir processed at different rotational and translational speeds. The effects of process parameters on the resulting microstructure and mechanical properties are investigated. The results show that FSP produces very fine and homogenous grain structure, and it is observed that smaller grain size structure is obtained at lower rotational speeds. It is also observed that the hardness of the processed sheet depends strongly on the rotational and translational speeds and varies widely within the processed region. The results suggest that the temperature achieved during processing plays an important role in determining the microstructure and properties of the processed sheet. In addition, a new modeling approach based on experiments and theory is proposed to predict the grain size of the friction stir processed material as a function of process parameters. The proposed approach involves determination of the strain rate distribution in the processed (deformation) zone based on the velocity fields of the material and correlating the strain rate distribution with the average grain size of the resulting microstructure using Zener-Holloman parameter.

M Song and **R Kovacevic[6]** was formulate A mathematical model to describe the detailed three-dimensional transient heat transfer process in friction stir welding (FSW) is presented. This work is both theoretical and experimental. An explicit central diVerential scheme is used in solving the control equations, the heat transfer phenomena during the tool penetrating, the welding and the tool-removing periods that are studied dynamically. The heat input from the tool shoulder is modelled as a frictional heat and the heat from the tool pin is modelled as a uniform volumetric heat generated by the plastic deformation near the pin. The temperature variation during the welding is also measured to validate the calculated results. The calculated results are in good agreement with the experimental data.

G. Buffa, L. Fratini, S. Pasta[7] was worked on the effects of the thermal and mechanical actions on the residual stress field occurring in friction stir welding (FSW) of AA7075-T6 were investigated. Both numerical and experimental analyses were carried out to highlight the metallurgical phenomena and induced residual stresses in FS welded blanks. The welding process was simulated using a continuous rigid-viscoplastic finite element model (FEM) in a single block approach through the software DEFORM-3DTM, Lagrangian implicit code designed for metal forming processes. Then, the temperature histories at each node of the FE model were extracted and transferred to a further FE model of the joint considering an elasto-plastic behavior of the AA7075-T6 material. The map of the residual stress were extrapolated from the numerical model along several directions. Thus the cut-compliance methodology was used to compare the residual stress profiles with those of the numerical model.
The numerical-experimental comparisons have shown how the numerical model can be successfully used to predict the residual stress field in FSW joint by considering all the local mechanical action of the tool.

P. BISWAS AND N. R. MANDAL[8] was worked on three-dimensional finite element (FE) transient thermal analysis of friction stir welding (FSW) was presented for different tool geometries and different process parameters. The source of heat generation was assumed to be pure friction between the tool and workpiece interface. Thermal history of FSW of 6 mmthick AA1100 plates for different tool geometries was calculated. The estimated thermal profiles compared well with those of the experimental results, thus validating the various assumptions made in the work. It was observed that in FSW of AA1100 with SS310 tool, friction is the major contributor to heat generation. Tool geometry with concave shoulder and conical pin was found to be preferable for FSW of AA 1100. It is preferable to keep the tool pin diameter as small as possible to avoid occurrence of a wormhole defect. Tool plunging force reduced significantly with an increase in tool rotational speed; however, the increase in heat generation was marginal.

Tran Hung Tra et al[9] was investigated Behavior of fatigue crack which was propagated at some representative areas in the friction stir welded (FSWed) joint of aluminum alloy 6063 T5 was studied. By extracting the T–L orientation specimens so that the loading axis on the fatigue test and the crack propagation direction were transverse and longitudinal to the welding direction, respectively, the crack propagation tests were carried out for both the as-welded and post-weld heat treated (PWHTed) FSWs at room temperature and 200 _C. The experiments showed that the fatigue crack propagation (FCP) rates were sensitive to the propagating location, the test temperature, and the PWHT condition as well. It was also found that the different FCP rates were driven by the microstructural influences in and around the welded zone. While the residual stress was remarkable in the shoulder limit areas, it had a minor effect on the FCP behavior.

3. CONCLUSION

From the above literature survey we find that there are many researches done on experimental and numerical investigation of friction stir welding. But I found that there are very few researches done on AA6063-T6 Aluminium alloy so we want to do research on this material. We like to use Finite Element analysis for optimization.

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