Study of mechanical behavior on Al-Li alloys on Friction Stir Welded joints

Rachna Pandey[1], Dr. R.S Jadoun[2]
Department of Industrial and Production Engineering[1, 2], G.B.P.U.A&T, PantNagar-263145

Abstract - Friction Stir Welding (FSW) is one of the new entrants to the solid state joining technique which have made a remarkable progress in welding technology. It is widely used in automobile and aerospace sectors for the smooth finishing and strength of the materials, there is a wider scope to take up further research in this area. FSW is also a filler-free process, which would considerably lighten the structure. FSW has made realization of high strength aluminium alloy possible. Normally, these alloys are considered non-weldable with conventional welding techniques. The alloys series, for example, are defined non-weldable because they form brittle chemical compounds in the heat affected zone and are characterized by high porosity in the welded metal; these features provides the joint mechanical properties significantly lower than those of the base material. In this paper, we have analyzed the tensile strength of two similar materials of Al-Li alloy, after the FSW welding is performed on two similar aluminium plates adjacent to each other. After completing the welding process, it is finalized that the tensile strength of the material increased after welding is performed also the development of cracks were identified.

Key words: Friction Stir Welding, similar metals, tensile strength, hardness.

I. INTRODUCTION

In the previous chapter, a brief presentation of the friction-friction (FSW) friction process, of the microstructural areas in fused aluminum alloys, objectives and field of activity were presented. Since its inception, FSW has been a very active research area in the field of metal joining. FSW initially requested alloying of aluminum alloys, was implemented in the joining process

Steel alloys and other non-ferrous alloys with advancing tools. Microstructural characterization, mechanical properties evaluation and process parameter optimization, heat transfer analysis, and material flow in the workpiece are some important areas that researchers have focused on. Estimation of mechanical properties and optimization of process parameters Involve the application of an optimization algorithm. Heat transfer studies help estimate the process efficiency, ie the amount of heat transferred to the workpiece and the tool. When coupled with structural models, heat transfer studies help to predict residual heat

The stresses generated and the forces acting on the tool. This chapter presents a review of similar and disguised FSW literature on aluminum alloys, microstructure and mechanical properties of FS welded alloys, the effect of process parameters, aspects of heat transfer and material flow during FSW.

II. BASIC PRINCIPLE OF WELDING

At a basic level, welding consists of using heat, pressure, or a combination of both to bond two pieces of metal together. If you were not familiar with welding, however, you would be surprised at the number of welding techniques out there and the science behind each of those methods. Welding isn't just a simple task but one that requires a high level of skill along with a working knowledge of basic physics, chemistry, and metallurgy principles.

III. WELDING PROCESSES

There are a number of welding processes that can be employed depending on the form and thickness of the material to be joined. However, most welding falls into two categories: arc welding and torch welding. If you're interested in pursuing a welding career in arc welding, you should know that it requires a good eye for detail and steady hands. In this type of welding, the materials as well as filler material are melted together using an electrical arc. Common types of arc welding include the following:

- Gas metal arc welding.
- Gas tungsten arc welding.
- Plasma arc welding.
- Shielded-metal arc welding.
- Submerged arc welding.

IV. MECHANICAL PROPERTIES AND MICROSTRUCTURAL STUDIES

The evolution of microstructure and its properties due to FSW depend on several factors. Some factors include the parameters of the FSW process, base metal, composition and temperament, tool geometry and tool material. The mechanical properties and microstructural studies for aluminum alloys are presented in this section. Rhodes et al. (1997) joined AA7075 plates using FSW at a 5 min / min welding rate and studied changes in alloy microstructure due to FSW. It is noted that the nugget is recrystallized, the displacement density was reduced, and it was found that the cure precipitations were resolved. Mahoney et al. (1998b) studied the effect of FSW and subsequent thermal aging on the longitudinal and transverse properties of 7075T651

Krishnan (2002) discussed the formation of onion rings, theirs the significance and effect on the properties of friction stirring welds. Friction heating due to tool rotation and metal extrusion due to feed the movement of the tool forms the onion ring. The distance between onion rings is equal to the forward movement of the tool in a rotation and spacing was wider in the center and narrower at the edges. The spacing was the other way roundproportional to TRS. Lockwood et al. (2002) reported that transitions from TMAZ to HAZ and HAZ to base material for AA 2024 are gradually. The areas did not differ from a sharp change microstructure. **Sato et al. (2002),** aluminum alloy 6063 friction welded toTemperature T4 and T5 at different rotational speeds. Increase you're the rotation speed caused an increase in the maximum welding temperature which resulted in an exponential increase in the size of the granules. 6063-T5 showed a reducing the hardness around the welding center, while the hardness was homogeneous for 6063-T4. The increase in hardness due to aging after welding was small in the shaking area of welds produced at low speeds due to rotation increasing the volume fraction of PFZ. **Peel et al. (2003)** fused AA5083 welded alloys under different conditions.

Cavaliere et al (2006) analyzed the effect of process parameters on the mechanical and microstructural properties of AA6056 friction welding. Traction tests at room temperature indicated that the ductility of the material decreased by increasing TRS and WS. The highest TRS and highest WS have produced the highest value traction resistant. At low TRS and WS, the hardness profile was very uniform. To the higher TRS and WS hardness profiles have become less uniform. The microstructure of the nugget material has emerged as very grainy beans in all Conditions.

Cabibbo et al. (2007) reported fine and recrystallized cereals structure due to the mixing and forging of the Alloy 6056 female FSW. Nugget has very refined grains and a balanced grain structure with a lot of it a distinct transition in granule size on the advanced and retracted side. **Sutton et al., (2004)** also reported a very good size of the upper surface granules of the nugget in which the contact with the instrumental shoulder arose**. De Giorgi et al (2009)** investigated the influence of the shoulders state of residual stress, microhardness profile and mechanical properties of 1.5 mm friction-welded friction joints AA6082-T6. Three geometry of tools namely a scroll shoulder (TFS), a small cavity shoulder (TFC), and a flat shoulder (TF). The temperature of the longitudinal chamber and transversal traction tests were performed to evaluate mechanical properties joints and the agitated area. Fatigue tests were performed on transversal specimens. The TF shoulders produced the freshest recrystallized grains. Of traction power was not affected by shoulder geometry. Joints made with TFS have experienced the worst fatigue behavior, while the TF and TFC shoulders have produced excellent fatigue properties**.**

V. PROCESS PARAMETERS IN FSW

An advantage with shaking friction welding is that the parameters can be controlled, thus controlling the energy input into the system. TRS and WS are the two process parameters that affect the thermal history, flow of materials, microstructural evolution and properties common. The downward force applied parallel to the axis of rotation is another process which affect the generation of heat. Other factors that affect welding the features of the FSW process include the initial condition of heat treatment a workpiece, type of material and tool hardness, material and thickness of the work piece the support plate, the type of cooling device and the clamping device.

Selection of friction welding parameters that produce acceptability mechanical, microstructural, fatigue and corrosion properties the requirement to obtain welded, seamless, seamless friction joints. Tool geometry (size and profile) and process parameters affect the heat generation, material flow, microstructure evolution and properties common. The life of the tool depends on the parameters of the process used. The effect process parameters and instrument design on thermal and temperature history distribution, material flow, evolution and properties of the microstructure studied extensively and reported in literature.

Effect of heat on welding treatment of mechanical properties, microstructure and corrosion behavior has also been studied. **Mishra and Ma (2005)** provided a detailed description review on friction welding, mechanisms responsible for training welding and microstructural refining, and the effects of process parameters on resulting microstructure and final mechanical properties**. Lee et al. (2003)** studied the common characteristics of the friction aggregate Alloys A356 and reported improvement of mechanical properties at welding area, with different welding speeds. Mechanical properties and the hardness of the welding area was greatly improved compared to a base metal (BM). Remarkably low defects and very high traction SZ power has also been reported. **Liu et al (2003)** studied the relationship between welding parameters and the traction properties of the aluminum alloy 2017-T351. They reported a weld tensile strength equivalent to 82% of the base material at a tool rotation speed 1500 rpm and welding speed of 100 mm / min and occurrence of fractures at interface between WN and TMAZ. **Peel et al (2003)** FS welded AA5083 alloy under different conditions and reported the results of microstructural, mechanical analysis tests and residual stress analysis. It was found to be warmth than mechanical deformation of the tool dominated the welding properties. **Boz and Kurt (2004)** investigated the effect of agitator geometry on FSW aluminum AA1080. Five different stirrers, one square geometry and the other with cylindrical geometries with another screw on the screw they were used. Binding was better with square, but mechanical and metallographic properties were poor due to a large mass transfer. Of traction fractures occurred in the base metal and a UMP of 110 MPa was achieved with With shaking of 0.85 and 1.1 mm screws**. Lim et al (2004)** examined the effect of TRS and WS on traction FSM alloy behavior 4 mm thick AA6061-T651. The plates were friction mix high-speed welding of 1000, 1400, 1600, 2000 and 2500 rpm gears, and welding speeds of 0.1, 0.2, 0.3 and 0.4 m / min. Resistance to yield, final tensile strength and traction elongation have been affected by parameters, with elongation decreases with WS decrease and TRS increase. Group of coarse precipitates of Mg_2Si due to the action of motion and biting throughthe serious plastic flow in the welding area was the cause of the traction behavior. Low WS and high TRS encourage platic flow and therefore clustering precipitate. **Chen et al. (2005)** reported a significant improvement in traction the strength of the FSW joints of the 2219-O aluminum alloy through a welding posture Thermal treatment (PWHT). PWHT joints were broken into wire Area **Zhao et al (2005)** investigated the effect of tool pocket geometry on the welding structure and the mechanical properties of the aluminum alloy AA2014 using different pin geometries. The flow of plastic differs for different pins geometry. Microscopic examination of the welding area and tests on mechanical properties have shown that bolts with inclined screws has produced the best link. The appearance of the weld was not obvious Defects The welding nugget cereals were very fine with a fine distribution of precipitate.

Cavaliere et al (2006) analyzed the effect of process parameters on mechanical and microstructural properties of AA6056 joints produced by FSW at TRS different from 500, 800 and 1000 rpm and welding speeds of 40, 56 and 80 mm / min. Optical microstructure analysis, traction at room temperature tests, micro hardness tests (HV) and axial fatigue tests (LCF and HCF) made on welds for all WS and TRS used in the study was observed that WS welded samples of 56 mm / min showed the best low cycle behavior. **Minton and Mynors (2006)** presented a methodology for determining whether it is possible to use a conventional milling machine engages friction welding and finding the process window. **Okuyucu et al (2007)** developed an artificial neural network model to correlate the mechanical properties of pressurized aluminum alloys with process parameters. The input model parameters were TRS and WS, while tensile strength, flow resistance, elongation, hardness of the weld metal and the hardness of the heat affected area (HAZ) was the result. Influence the mechanical properties parameters were simulated and a good agreement between predicted and measured data.

VI. Heat Transfer and Material Flow Studies

A clear picture of the heat history and flow of materials during the friction process is a necessity to understand the process phenomena and the effect of process parameters. Numerical and experimental approaches have been used in the past to study heat transfer and material flow. Analytical and numerical modeling based on friction and frictiongenerating viscosplastic heat, heat transfer theories, and fluid mechanics have been developed in the past to explore the friction welding process mechanism. Computational methods are cost-effective and have been compared to faster means, for heat transfer and material flow analysis.

VII. Experimental Studies

Initial FSW studies were experimental using thermocouples measure the temperature at different locations of the workpiece. Experimental material flow studies were performed by inserting markers at different sites places in welded plates and tracking their position and track after welding. **Tang et al (1998)** measured experimental temperature data for FSW of AA6061-T6 and concluded that the generation of heat in the FSW was mainly due to friction at the instrument's shoulder. **Hwang et al (2008)** determined the thermal and thermal history temperature distribution in a workpiece during a head - to - head friction welding A6061-T6. History of welding temperature during FSW at different places on the workpiece were measured using different typesThermocouples. It was found that a second-order polynomial curve fits best the experimental values of the temperature in the width direction of the work piece.

Vickering hardness tests and traction tests were also performed, and in comparison with that of the base metal**. Li et al (1999)** reported metallographic flux patterns cross sections in friction mixing welds made between different aluminum alloys 2024/6061 using differential grading. The presence of the complex vortex, whorl and the characteristic turbulence characteristics of the chaotic-dynamic mixture have been reported. **Colligan (1999)** used steel balls with a diameter of 0.38 mm as markers for study material flow during FSW. Balls are embedded in different positions in the welding path and a "stop action" technique was used to study the material motion models in the FSW. The welded specimens were analyzed using radiograph to observe marker position after welding. The material in the upper part of the welding tool path has been agitated and has been forced down the threads on the pine and deposit in the weld nugget, while much of the material movement took place through simple extrusion. His inertia balls were found to affect the precision of the analysis. **Seidel and Reynolds (2001)** and Reynolds **Reynolds (2000)**analyzed the flow of material in AA 2195-T8 friction welds, based on a post welding determination of the position of AA5454-H32 markers placed in welding surface. Full 3D display of distorted markers was obtained from the material positions before and after welding inthermo-mechanically affected areas by a serial cutting technique.

Analytical and numerical modeling

The modeling of heat transfer and material flow in FSW was made using Lagrangean, Eulerian, or Lagrangean Eulerian Arbitrary approaches. Finite Differential Method (FDM), Finite Element Method (FEM) and Finite Volume Method (FVM) were numerical preferred methods, for simulations, while other methods have also been used. The results of these models were validated by experimental data. The heat the transfer and distribution of temperature in the work piece have been proven to be asymmetric due to asymmetry in stretch velocity and viscous dissipation. Material the flow was found dependent on the material contact with the instrument. **Heurtier et al (2002)** used an analytical model to predict the work piece Temperatures. Schmidt and **Hattel (2004)** developed an analytical model for generating heat in shaking friction welding. The model represented both contact surfaces and contact conditions. Contact condition between the surface of the tool and the workpiece have been defined as sliding, gluing or partial sliding / gluing. The heat generation mechanism for each contact condition was different. The contact condition was determined from the experimental results for each slip force and torque. The sliding condition provided a link the relationship between the bending force and the heat generation. However, it was not so well demonstrated by experimental validation**. Roy et al (2006)** developed a non-dimensional correlation to estimate peak temperature during friction welding.

The correlation used thermal properties of the workpiece and tool, tool shoulder area, tool rotation the speed and speed of crossing the tool. **Heurtier. P et.al (2006)** proposed a semi-analytic thermal mechanical model based on speed fields to obtain strains, stem rates and temperature estimates and micro-hardness in different welding areas. The micro hardness profile was derived from thermal history and denoted the homogeneity of the weld that can be reduced by reducing the average temperature by increasing tool speed. The pattern also predicted the weakened welding area due to the distribution of oxide after welding process.

Solid mechanics Based Modeling

The main principle of the lagrangean model is to analyze the FSW process in Solid Computational Mechanics. With this approach, thermomechanical modeling and residual analysis can be performed efficiently. With particle tracking, the flow of material during FSW can also be analyzed. **Gould and Feng (1998)** have developed a simple model of heat flow relates the variation of the temperature field to the welding parameters. The pattern which uses the heat source used by**Rosenthal (1938) and Rosenthal (1941)** considered only friction heating by the shoulder. Many simplification assumptions were used to obtain a solution in closed form for result.

Chao and Qi (1998) have developed the first 3-D thermal and thermal mechanical model for FSW based on FEM. Generation of heat due the friction contact between the instrument shoulder and the work piece was only taken into account. The model uses thermal convection and temperature dependence properties of materials. The model includes the support plate and low yield stress was used for the nugget. Total heat input to welding and heat the bottom transfer was repeated in a test and error mode, until predicted temperatures are matched with validation experiments. Post welding Residual resistance and distortion could be predicted using the calculated calculation temperature distribution. The model considered the heat of friction generated between the shoulder and the workpiece and the effect of the tool pin was not taken into account in the model.

Material Flow Modeling

Modeling material flow in FSW using models to consider the flow of materials is a recent research area. There are two essential elements approaches in shaping the material flow, namely, the Eulerian approach and Arbitrary Lagrangean Eulerian (ALE). In the Eulerian approach, deformed plastic material is treated as a very viscous fluid and Dynamics of Computational Fluids (CFD) is used to obtain the flow field. In the ALE, solid mechanics are used for the analysis of plastic deformation and a displacement field is found using the finite volume method.

Eulerian Model

Eulerian models are based on CFD, the results obtained by solving the continuity, impulse and energy equation for obtaining the necessary results. The CFD method is convenient for temperature estimation distribution and flow of materials. The method has the advantage that the particle tracking is not required, as with the Lagrangean method, as a material flowing through the field. Seidel and Reynolds (2003) developed a fully coupled couple dimensional FSW process model based on fluid mechanics in which the FSW the process was simulated as a laminar, viscous flow of a non-Newtonian fluid passed through a rotating cylinder. The pine diameter material has been transported only in the direction of rotation around the pin. Deviation estimated by the model of the normal flow for certain combinations of process parameters, could predicts defect formation. **Colegrove and Shercliff (2004)** analyzed material flow during FSW of the AA7075 model using a CFD-based model. The model was applied to analyze material flow around the Trivex and MX-Trivex tools.

The results were compared toTriflu's analysis. Result from the analysis indicates that the transverse and downward forces have been reduced by The Trivex tool. Lines around the instruments were used to examine the material flow. It has been found that the downward force increases with the Triflu tool. The strong action of augmentation of the trifal instrument caused this increase. Reynolds et al (2005) used the thermal welding simulation to provide time-temperature for a series of aluminum alloy welds 7050-T7. Heating and cooling rate during FSW of the 7050 aluminum alloy was affected by WS. Temperatures during FSW correlated well with welding power and peak temperature was a complex function of TRS and WS.The maximum hardness of the nugget corresponds to the highest welding temperature. **Colegrove**and **Shercliff.H.R (2005)** analyzed the three flow of dimensional material and temperature around a threaded tool by variation the rotation speed and the tool angle of inclination. The model predicted size and distribution of the deformation zone temperature as dipping the material that is above the solid temperature and the slip between the tool and the interface were not incorporated into the model. **Cho and collaborators (2005)** developed a heat of two stationary sizes transfer and material flow model for FSW stainless steel 304 L.

VIII. CONCLUSION

From the study of the published FSW literature, it was found that FSW process parameters, tool geometry (size and profile), and the basic temperament of the metal affects the heat history, temperature distribution, heat the transfer, the flow of material, and consequently the microstructural evolution and its properties friction welding mixtures. Effect of Process and Instrument Parameters geometry on heat transfer aspects and material flow has been studied by experimentation and modeling. The Eulerian model may be the best implemented in determining the temperature and flow of material that has taken place during the welding process. In the Eulerian configuration, the results are analyzed either by implementing the heat flow on the faces, as in **Atharifar et al (2009)** and **Nandan et.al (2006a**) or by viscous dissipation of the fluid due to the rotation of the tools as in **Colegrove and Shercliff (2005)** and Long and Reynolds (2006). Most of the literature focuses on it modeling of temperature and material flow of similar metals. With the material flow pattern around the instrument for different process parameters, the formation of defects was explained by **Long and Reynolds.A.P (2006)**.While the modeling approach was quick and cost-effective, the results were supposed to be validated by experimental data. The effect of the factors mentioned above on mechanical properties and microstructure welded by friction disparity joints has also been studied. In this present study, aluminum formed differently the alloys are joined by the FSW method with different welding conditions.

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