International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622
NATIONAL CONFERENCE on Developments, Advances & Trends in Engineering Sciences
(NCDATES- 09th & 10th January 2015)

RESEARCH ARTICLE OPEN ACCESS

Evaluation Of Microstructure And Mechanical Properties Of Al3003-H18, Al6082-H30 And Commercial Grade Aluminum Under Friction Stir

[1]T.Vijay Kumar
[1]Assistant professor, Department of Mechanical Engineering, CMR Engineering College, Hyderabad..

ABSTRACT
Friction stir welding (FSW) is a relatively new solid-state joining process that can be beneficially used for various transportation and defense applications. This joining technique is energy efficient, environment friendly, and versatile. In particular, it can be used to join high-strength aerospace aluminum alloys and other metallic alloys that are hard to weld by conventional fusion welding. FSW is considered to be the most significant development in metal joining in a decade. Understanding the microstructure evolution and properties of friction stir welded components is necessary to use this new process in critical structural applications. In this project we put forth the knowledge base regarding friction stir welding under static load which is performed on three different Al alloys namely Al-3003(H18), Al-6082(H30) and commercial grade. The effects of critical FSW process parameters were also studied. The resulting micro structural changes, micro hardness profiles and tensile testing have been reported. Comparison of micro hardness values has also been performed. The findings from these investigations will be presented and discussed.
Keywords: FSW,AL Alloys,Profiles.

I. INTRODUCTION

Friction stir welding (FSW) is a significant manufacturing process for producing welded structures in solid state. This process offers several advantages compared to the conventional welding methods including higher mechanical properties and lower residual stresses as well as reduced occurrence of defects. In FSW process, a rotating tool having a shoulder moves along the welding line. Rotational motion of the shoulder generates frictional heat leading to a softened region around the pin while the shoulder prevents deforming material from being expelled. In fact, a weld joint is produced by the extrusion of material from the leading side to the trailing side of the tool.

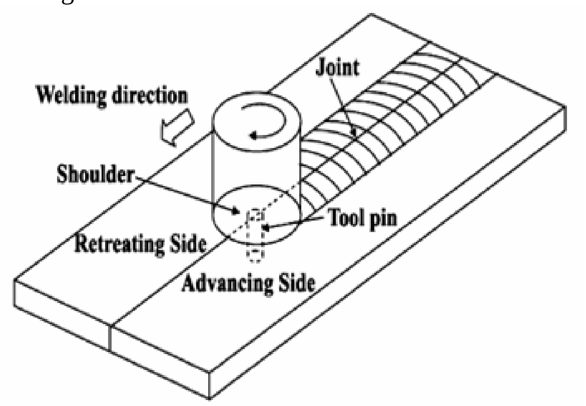

Figure: 1.1: Schematic diagram shows friction stir welding process and terminology.

Several works on modeling of heat

1.1. WHAT IS FRICTION STIR WELDING??

Stir friction welding is a solid-state joining process where in metal adjoins to be welded do not melt and recast at the interface, rather, rather remain in solid state and is typically used when the original metal characteristics (such as grain structure, alloy composition) must remain unchanged as much as possible at the weld interface. It mechanically intermixes the two pieces of metal at the place of join, then softens them so the metal can be fused using mechanical pressure. It is primarily used on aluminum and its alloys which are difficult to weld using conventional welding process and most often on large piece that cannot be easily heat-treated after welding to recover temper characterizes. Welding defects such as porosity and hot cracking is not an issued in FSW and welds with low residual stresses at the interface.FSW can be a slower process than other forms of welding, such as arc or laser welding. This is because the cylindrical tool must turn to generate heat on the joint, and then traverse the length of the joint transmitting that heat.

Fig: 1.1.1: Friction stir welding process

1.2. HISTORICAL BACKGROUND AND PRINCIPLES

Radically new joining processes do not come along very often: friction stir welding (FSW) was one such event, being invented by the TWI in 1991. Since then research and development in FSW and associated technologies has mushroomed, with many companies, research institutes and universities investing heavily in the process and international conference series dedicated to its study. By the end of 2007, TWI had issued 200 licenses for use of the process, and 1900 patent applications had been filed relating to FSW. The number of research papers has also grown exponentially.

In essence, FSW is very simple, although a brief consideration of the process reveals many subtleties. The principal features are shown in Fig.1.1.1. A rotating tool is pressed against the surface of two abutting plates. The side of the weld for which the rotating tool moves in the same direction as the traversing direction, is commonly known as the 'advancing side'; the other side, where tool rotation opposes the traversing direction, is known as the 'retreating side'. An important feature of the tool is a probe (pin) which protrudes from the base of the tool (the shoulder), and is of a length only marginally less than the thickness of the plate. Frictional heat is generated, principally due to the high normal pressure and shearing action of the shoulder. The frictional heating causes a softened zone of material to form around the probe. This softened material cannot escape as it is constrained by the tool shoulder. As the tool is traversed along the joint line, material is swept around the tool probe between the retreating side of the tool and the surrounding un-deformed material. The extruded material is deposited to form a solid phase joint behind the tool. The process is by definition asymmetrical, as most of the deformed material is extruded past the retreating side of the tool. The process generates very high strains and strain rates, both of which are substantially higher than found in other solid state metalworking processes (extrusion, rolling, forging, etc.).

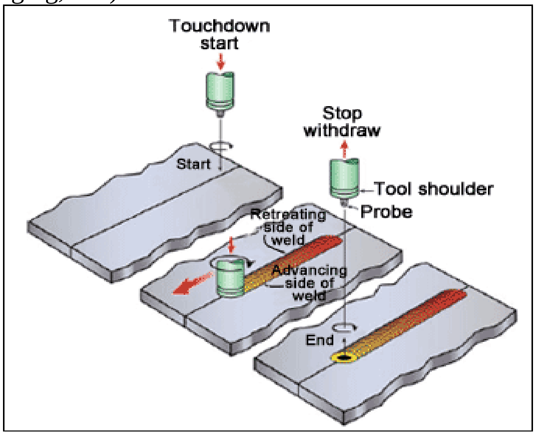

Fig: 1.2.1. Schematic diagram of FSW process

Friction stir welding is therefore both a deformation and a thermal process (thermo-mechanical), even though there is a atomistic fusion and intermixing. The maximum temperature reached is a matter of some debate. Thermocouple measurements during FSW of aluminum alloys suggest that, in general, the temperature stays below 500°C. These values must be treated with some care, as the position of the thermocouple in the rapidly moving nugget can be difficult to ascertain. Micro structural evidence seems to corroborate the thermocouple based conclusion that unless extreme processing parameters are chosen, the maximum temperature usually lies between 425 and 500°C[in contrary to this the working models suggests the…..]. It has been suggested that the temperature of the material in contact with the pin may reach the solidus temperature, although experimental validation is difficult due to the intense deformation at the interface. There is evidence of incipient melting for some aluminum alloys (e.g. 7010) for fast weld speeds. It was also argued that the peak temperature is inherently self-limiting. The work piece flow stress will fall rapidly as the solidus is approached, so that heating of the nugget at the tool/work piece interface limits the available heat generation by reducing the torque.

To date, the predominant focus of FSW has been for welding aluminum alloys [especially difficult to weld AL 2series and 7 series], although the process has been well developed for both copper alloys and magnesium alloys. Work is under way to develop the process for materials such as titanium alloys, steels, nickel alloys and even molybdenum. The welding process in these materials takes place at considerably higher temperatures, and thus, further work is needed to improve the basis for selection, performance and longevity of tool materials. In addition considerable work has focused on using FSW to join dissimilar aluminum alloys. Furthermore the steady push to lightweight vehicles has largely been responsible for research in joining aluminum alloys to other metals, including aluminum to magnesium, aluminum to metal matrix composites, aluminum to steel and aluminum to copper.

Coverage of the present review is confined to the FSW of aluminum alloys. A summary of the AWS designations for wrought Al alloy groups and AWS basic temper designations applicable to heat-treatable Al alloys is contained within Table 1.2. Since FSW is a solid state process, it can be used to join all common aluminum alloys, including the 2xxx, 7xxx and 8xxx series which are normally challenging or impractical to weld by fusion processes. A key distinction is between non-heat-treatable and heat-treatable alloy series. In work hardened alloys (e.g. 5xxx), the heat from the friction welding process will allow thermal recovery and recrystallisation of dislocation substructures, although this is partly countered in the intensely deformed region where new dislocation structures are generated. In age hardened alloys, the weld will normally be heated well above the dissolution temperature of the initial precipitates, enabling dissolution, re-precipitation and over aging to occur. Friction stir welded aluminum alloys can therefore contain microstructures covering the entire spectrum of normal tempers.

TABLE-1.2: Aluminum alloy specifications

Major Alloying Element	**Wrought**	**Cast**
None (99% + Aluminum)	1XXX	1XXX0
Copper	2XXX	2XXX0
Manganese	3XXX	
Silicon	4XXX	4XXX0
Magnesium	5XXX	5XXX0
Magnesium + Silicon	6XXX	6XXX0
Zinc	7XXX	7XXX0

Since its inception, many papers and articles have been published on FSW of aluminum alloys, many of them dealing with microstructure and properties. Recently there have been excellent general reviews of FSW covering a wide range of materials by Mishra and Ma, which also includes friction stir processing, and by Nandan *et al.* which concentrates on the heat generation, heat transfer and tool/material flow interactions of FSW. A recent ASM specialty handbook also covers FSW and friction stir processing. Nevertheless, no critical and comprehensive review focusing specifically on aluminum FSW is available in the public domain. It is therefore considered timely to correct this omission. The present review draws on a wide selection of published data to summarize current understanding of the complex relationship between welding parameters, microstructure and properties for FSW of many aluminum alloys. Process modeling of FSW has evolved in parallel with empirical process development, and provides physical insight into all of these relationships. Since FSW modeling has been reviewed elsewhere, this aspect is not explicitly covered in the present review, except where modeling helps to interpret and complement the experimental observations or to clarify issues debated in the literature.

1.3. PROJECT OBJECTIVES

The objective of this project was to build the knowledge base regarding static performance of friction stir welded joints. Achievements in this area would contribute to the viability of using the FSW process in this alloy in the transportation industry, leading to significant improvements in component strength and cost of production over traditional joining methods used with the alloy. This project has another objective of the micro structural characteristics resulting from different sets of variables in the FSW process, micro hardness profiles generation and flow of heat.

1.4. APPROACH TO THE PROBLEM

In industrial applications, joints are subjected to compound forces and moments as well as a large variety of environmental conditions. In addition to complex loading scenarios, friction stir welded joints have highly variable microstructures that affect the performance of the material.

If all loads and environmental conditions were combined in a single test, isolation of factors that determine failure would be difficult. In order to approximate the behavior of friction stir welds in actual applications, tests for static loading are used.

1.5. ACHIEVEMENTS

This project investigates static properties of FSW in Al 3003-H18, Al 6082-H30 and commercial grade and the microstructure of the FSW joint. Determining the microstructure and micro hardness profiles of the joint is imperative in understanding methods for improving the process. Using information gathered from static load testing of sample butt joints, links between micro structural features and processing parameters that affect the static performance of the joints are identified.

II. RESULTS AND DISCUSSIONS MICRO STRUCTURE

The microstructures of welds produced for this project demonstrated all the characteristics of friction stir welds found in reviewed literature. All welds had a distinct DXZ, TMAZ, and HAZ that were clearly defined by the standard FSW geometries.

Al 3003-H18, Al 6082-H30 & Commercial grade were used as the base material in this study. The material is readily available and was acquired from a local provider.

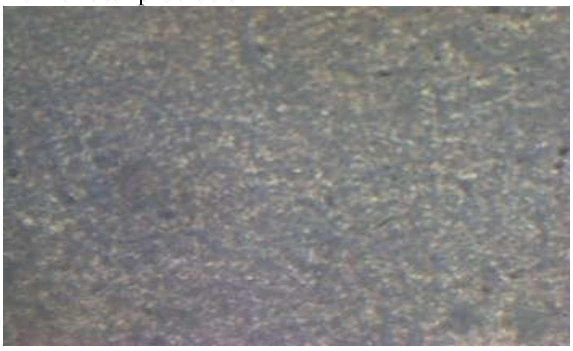

Fig: Al 6082-H30, Speed-1400rpm, Feed-6mm/min.

COMPARISON OF MICRO STRUCTURE OF BASE METAL:

Fig: Wrought (Al 6082-H30)

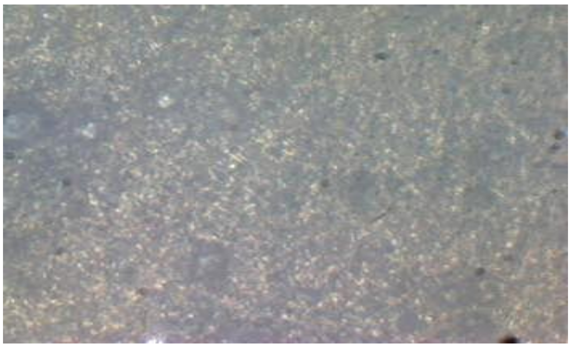

Fig: Wrought (Commercial Grade)

- The micro structural analysis performed on Al 6082-H30 and commercial grade aluminium has revealed a progressive change in grain size leading to Abnormal Grain Growth in the weld zone. Lower tool rotation speed (1400rpm) and higher feed rate (8mm/min) provided more homogeneous microstructures in the friction stir welding process.

III. TENSILETESTING METHODOLOGY:

Tensile Test Samples

Tensile samples were cut from sections of the 100mm X 100mm weld. Cohesive sections of weld were selected of dimension 10mm X 100mm in the tool traverse direction. All samples were produced with minimal defects and conformed to specified dimensions with a tolerance of 0.01”. Figure 5.4.1.1 shows a dimensioned image of the tensile samples used in testing

Fig: Sample before tensile testing.

Fig: Sample after tensile testing.

Alloy	Speed (rpm)	Feed (mm/ min)	Tensile Strength At breaking point (N/mm²)	Elongation (mm)
Commercial Grade	1400	4	80	7
AL-6082	2000	4	66.67	6
AL-6082	1400	8	93.34	6

Table: Results of Universal testing machine

IV. CONCLUSION

The samples were characterised by means of micro hardness, micro structure and tensile strength. From the investigations it is found that an increase in weld speed increases tensile strength and increase in tool rotation speed decreases the tensile strength. Increase in tool rotation speed causes more heat input which in turn enlarges the TMAZ and HAZ consequently resulting in low tensile strength. Furthermore the increase in weld speed decreases the heat input resulting in smaller TMAZ and HAZ which results to greater tensile strength.

Among all the samples welded, the samples with tool rotation speed of 2000 rpm and weld speed (feed) of 4 mm/min has given the highest value of micro hardness and tensile strength for Al 6082-H30, whereas for commercial grade aluminum the highest value of micro hardness and tensile strength were obtained for a tool rotation speed of 1400 rpm and weld speed (feed) of 8 mm/min.

V. FUTURE SCOPE:

The conclusions presented in this section may be used to develop methods to enhance specific properties for industrial applications. The selection of the welding parameters used fully determines the tensile behaviour of the material. Accordingly, specific parameter combinations may be chosen for industrial applications in order to develop enhanced properties of friction stir welds in the Al-3003, Al-6082, Commercial grade alloy.

There are several suggestions for future work to build upon this study:

- Further tests and analysis of sample response to both static and dynamic loads can be performed.
- Perform tensile testing on a larger set of welding parameters with multiple tests for each set of welding parameters.

References

[1] Aydın, H., Bayram, A., Uğuz, A., & Akay, K. S. (2009). Tensile properties of friction stir welded joints of 2024 aluminum alloys in different heat-treated-state. *Materials & Design, 30*(6), 2211-2221. doi: 10.1016/j.matdes.2008.08.034

[2] Elangovan, K., & Balasubramanian, V. (2008). Influences of tool pin profile and tool shoulder diameter on the formation of friction stir processing zone in AA6061 aluminium alloy. *Materials & Design, 29*(2), 362-373. doi: 10.1016/j.matdes.2007.01.030

[3] Ma, Z. Y., Pilchak, A. L., Juhas, M. C., & Williams, J. C. (2008). Micro structural refinement and property enhancement of cast light alloys via friction stir processing. *Scripta Materialia, 58*(5), 361-366. doi: 10.1016/j.scriptamat.2007.09.062

[4] Pouget, G., & Reynolds, A. P. (2008). Residual stress and microstructure effects on fatigue crack growth in AA2050 friction stir welds. *International Journal of Fatigue, 30*(3), 463-472. doi: 10.1016/j.ijfatigue.2007.04.016

[5] Woo, W., Choo, H., Brown, D. W., Feng, Z., & Liaw, P. K. (2006). Angular distortion and through-thickness residual stress distribution in the friction-stir processed 6061-T6 aluminum alloy. *Materials Science and Engineering: A, 437*(1), 64-69. doi: 10.1016/j.msea.2006.04.066

[6] Colegrove, P. A., & Shercliff, H. R. (2005). 3-dimensional CFD modelling of flow round a threaded friction stir welding tool profile. *Journal of Materials Processing Technology, 169*(2), 320-327. doi: 10.1016/j.jmatprotec.2005.03.015

[7] Mishra, R. S., & Ma, Z. Y. (2005). Friction stir welding and processing. *Materials Science and Engineering: R: Reports, 50*(1-2), 1-78. doi: 10.1016/j.mser.2005.07.001

[8] Soundararajan, V., Zekovic, S., & Kovacevic, R. (2005). Thermo-mechanical model with adaptive boundary conditions for friction stir welding of al 6061. *International Journal of Machine Tools and Manufacture, 45*(14), 1577-1587. doi: 10.1016/j.ijmachtools.2005.02.008

[9] Genevois, C. C. (2005). Quantitative investigation of precipitation and mechanical behaviour for AA2024 friction stir welds. *Acta Materialia, 53*(8), 2447-2458.

[10] Lim, S., Kim, S., Lee, C., & Kim, S. (2004). Tensile behavior of friction-stri-welded al 6061-T651. *Metallurgical and Materials Transactions A, 35*(9), 2829

[11] Liu, H., Fujii, H., Maeda, M., & Nogi, K. (2003). Tensile properties and fracture locations of friction-stir welded joints of 6061-T6 aluminum alloy. *Journal of Materials Science Letters, 22*(15), 1061.

[12] Heinz, B., & Skrotzki, B. (2002). Characterization of a friction-stir-welded aluminum alloy 6013. *Metallurgical and Materials Transactions B, 33*(3), 489

[13] Krishnan, K. N. (2002). On the formation of onion rings in friction stir welds. *Materials Science and Engineering A, 327*(2), 246-251. doi: 10.1016/S0921-5093(01)01474-5

[14] Kwon, Y. J., Saito, N., & Shigematsu, I. (2002). Friction stir process as a new manufacturing technique of ultrafine grained aluminum alloy. *Journal of Materials Science Letters, 21*(19), 1473.

[15] Ulysse, P. (2002). Three-dimensional modeling of the friction stir-welding

process. *International Journal of Machine Tools and Manufacture, 42*(14), 1549-1557. doi: 10.1016/S0890-6955(02)00114-1

[16] Frigaard, O., Grong, O., & Midling, O. T. (2001). A process model for friction stirs welding of age hardening aluminum alloys. *Metallurgical and Materials Transactions A, 32*(5), 1189.

[17] Schubert, E., Klassen, M., Zerner, I., Walz, C., & Sepold, G. (2001). Light-weight structures produced by laser beam joining for future applications in automobile and aerospace industry. *Journal of Materials Processing Technology, 115*(1), 2-8. doi: 10.1016/S0924-0136(01)00756-7

[18] Jata, K. V., Sankaran, K. K., & Ruschau, J. J. (2000). Friction-stir welding effects on microstructure and fatigue of aluminum alloy 7050-T7451. *Metallurgical and Materials Transactions A, 31*(9), 2181.

[19] Jata, K. V., & Semiatin, S. L. (2000). Continuous dynamic recrystallisation during friction stirs welding of high strength aluminum alloys. *Scripta Materialia, 43*(8), 743.

[20] Zhang, Y. M. (1999). Welding aluminum alloy 6061 with the opposing dual-torch GTAW process. *Welding Journal, 78*, 202