Journal of Material Science and Mechanical Engineering (JMSME)
Print ISSN: 2393-9095; Online ISSN: 2393-9109; Volume 2, Number 2; January-March, 2015 pp. 158-161

http://www.krishisanskriti.org/jmsme.html

Analysis on Parameters of Friction Stir Welding when Joining Aluminum Alloy to Steel

Subbarao Chamarthi[1], Nagarjuna Thota[2] and Rohan Kalia[3]

[1]*SRM University Delhi NCR –Campus*
[2]*Graduate SRM University Delhi NCR -Campus*
[3]*Graduate SRM University Delhi NCR -Campus*
E-mail: [1]rao2chamarthi@gmail.com, [2]thota.nagarjuna09@gmail.com, [3]rohan.capricorn@gmail.com

Abstract— *Friction welding (FW) is a technique that utilizes a non-consumable welding tool to generate frictional heat and plastic deformation at the welding location, there by affecting the formation of a joint while the material is in solid state. The principal advantage of frictional welding, being a solid state process, low distortion, absence of melt-related defects and high joint strength, even in those alloys that are that are considered non-weldable by conventional welding techniques. Furthermore, friction welded joints are characterized by the absence of filler-induced problems or defects, since the technique requires no filler, and by the low hydrogen contents in the joints, an important consideration in welding steel and other alloys susceptible to hydrogen damage. This document reviews some of the FW work performed to date, presents a brief account of mechanical testing of welded joints, tackles the issue of generating joint allowable, and offers some remarks and observation. The overall aim of this study is to get the optimum parameters for the materials under considerations, to investigate the Heated Affected Zone (HAZ), Thermo – Mechanical Affected Zone (TMAZ) and Weld Nugget (WN) besides to study the defects occurring during welding process by applying different parameters chosen. The welding process was done by using conventional milling machine. Three experiments being used are the Tensile Testing, Optical Microscopy (OM) and Electron Scanning Microscopy (SEM) to get the strength of the joint and the metallographic studies. The observations noticed during the analysis are at higher speed and lower tool plunge length, the joint strength decreased due to lack of bonding between aluminium and steel.*

Keywords*: Friction welding (FW), Heated Affected Zone (HAZ), Thermo – Mechanical Affected Zone (TMAZ) and Weld Nugget (WN).Optical Microscopy (OM) and Electron Scanning Microscopy (SEM).*

1. INTRODUCTION

The development of new welding tool materials and geometries has made it possible to join materials such as steel and aluminum in the laboratory environment and in a limited number of production applications. In FSW, of steel it has been shown that the lower welding temperature can lead to very low distortion and unique joint properties. FSW of steel is an area of active research, so it is reasonable to expect other production applications to emerge over time. A very attractive application is FSW of steel plate for ship building applications, based primarily on the reduction of welding distortion, but the development of low-cost welding equipment and more robust welding tool materials is required before this application can be exploited. The basic concept of FSW is remarkably simple. A non-consumable rotating tool with a specially designed pin and shoulder is inserted into the abutting edges of sheets or plates to be joined and traversed along the line of joint .The tool serves two primary functions: (a) heating of workpiece, and (b) movement of material to produce the joint. The heating is accomplished by friction between the tool and the workpiece and plastic deformation of workpiece. The localized heating softens the material around the pin and combination of tool rotation and translation leads to movement of material from the front of the pin to the back of the pin. As a result of this process a joint is produced in 'solid state'. Generated heat and mechanical work results different welding zone in FSW compared with fusion methods At first P.L. Threadgill as a first one divided this into four different zones: Parent metal (PM): where material not deformed, also may be subjected to thermal cycles but there is no micro-structural or mechanical change.

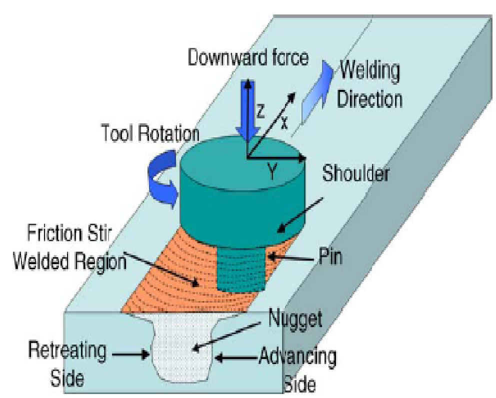
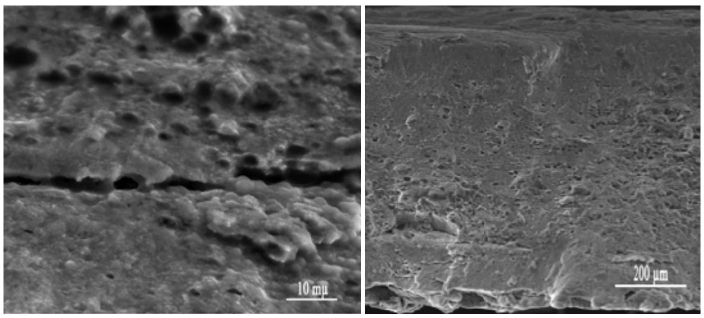


Fig. 1

Heat affected zone (HAZ): in this zone microstructure and mechanical properties change because of thermal cycles. Mahuti describes HAZ as a zone that is subjected to temperature more than 250 °C which will affect precipitations. Thermo-mechanical affected zone (TMAZ): in this zone material not only is subjected to thermal cycles but also deformed plastically, microstructure is extremely deformed. Parent metal grains are stretched upward in direction of material flow in the welding zone.



lso this zone is subjected to plastic deformation but because there is no enough plastic strain, there is no recrystallization. Stir zone (SZ): where recrystallization completely occurred. In this zone because of sever deformation at high temperature fine grain size can be seen which increases strength and hardness of welded metal.

2. EXPERIMENTAL SET UP

The following experiments are conducted to study the friction wear mechanism of the aluminium alloy when joining with steel.

1. Tensile testing

2.Optical microscopy
3. Scanning electron scope

2.1 Tensile Testing

A tensile test measures the resistance of a material to a static or slowly applied force. A machined specimen is placed in the testing machine and load is applied. Two Aluminium plates of diameter 15cm and thickness 14mm are taken initially. One Aluminium rod and one dead centre of tail stock is taken for the experimental work .Dimensions of Steel plate Diameter are 15cm and Thickness is 14mm. A strain gage or extensometer is used to measure elongation. The stress obtained at the highest applied force is the Tensile Strength. The Yield Strength is the stress at which a prescribed amount of plastic deformation (commonly 0.2%) is produced. Elongation describes the extent to which the specimen stretched before fracture. Information concerning the strength, stiffness, and ductility of a material can be obtained from a tensile test.

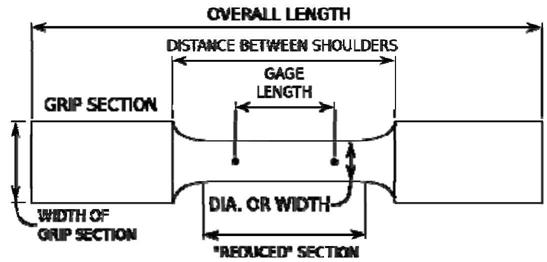


Fig. 2: Tensile test specimen

Table 1: Nominal chemical composition of the Al 6061

Material	Cu	Si	Fe	Zn	Mn	Mg	Cr	Al
Al 6061	**0.1**	**0.50**	**0.3**	**0.66**	**0.13**	**0.10**	**0.6**	**balance**

Table 2: Welding Parameters of Al-6061 alloy

Material	Profile of mixer	Rotation speed rev/m	Feed rate mm/min	Sample number
EN Al-6061	Screw	900	100 100 100	W1
		1250	150 150 150	W2
		1500	180 180 180	W3

2.2 Optical Microscopy & SEM

After welding, the FSW samples were cross-sectioned perpendicular to the welding direction for micro structural examinations by optical microscopy (OM) and scanning electron microscopy. The macro and micro structural features of the welds were investigated using LeicaTM stereo- and optical metallurgical microscope attached to an image-capture system on polished specimens slightly etched in fresh Keller's reagent after successive steps of grinding and polishing. Polished specimens were also examined in a Philips XL-30 (FEG) scanning electron microscope (SEM) operating at 25 kV with an energy dispersive X-ray spectroscopy system for composition analysis of the second phase particles.

3. RESULTS AND DISCUSSION

No exterior defect on the surface of all the joints is observed. However, the surface cracks are partially observed on the top surface for conditions 1250 rpm and 150 mm/min and fully along the weld line for conditions 1500 rpm and 180 mm/min. Fig. 3 shows the cross-sectional macrostructures of near the welds with various welding conditions. The welds show wider the upper surface than the lower surface because the upper surface experienced an extreme deformation and frictional heat caused by contacting weld specimens with a cylindrical tool shoulder. The shape of the weld zone is mostly like wine cup.

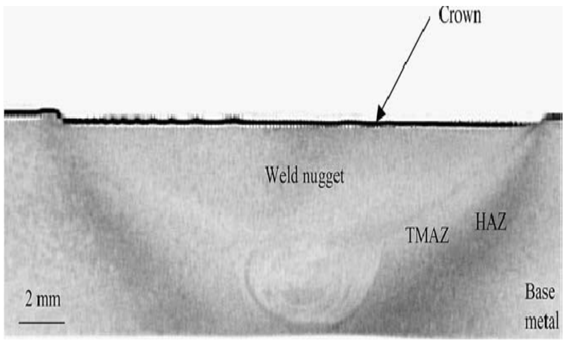


Fig. 3: Macro structural view of the welded zone

The weld itself forms a consolidated nugget of fine grained, fully recrystallised material, and this is surrounded by a thermo mechanically affected zone (TMAZ) which normally has a significantly different microstructure. Further away from the weld is a heat affected zone (HAZ), with the unaffected base metal on the outside. In the specimen, the distance from the nugget to the base metal is about 15 mm. Three zones were analysed using automated EBSD – the advancing zone (where the motion and rotation direction of the tool are in the same direction), the retreating zone (where the rotation direction is opposite to the tool movement) and the nugget itself.

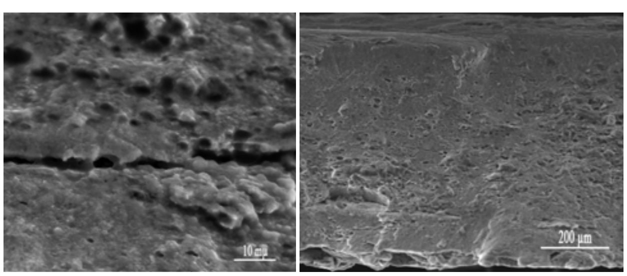


Fig. 3: SEM image

The HAZ surrounds the TMAZ on both shoulders. The HAZ is believed to be unaffected by any mechanical effects; only thermal caused by the heat generated by the friction effect associated by the shoulder and tool pin rotation

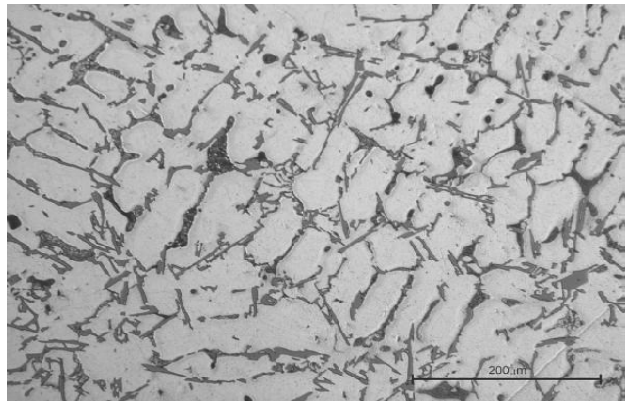


Fig. 5: Optical micrograph of the Al alloy

4. CONCLUSION

Friction stir welding has immensely high potential in the field of thermo mechanical processing of various alloys especially the aluminum alloys. From the present experimental investigation the following conclusions are derived:

1. Base metal Al 6061was found to exhibit the best characteristics for Friction Stir Welding.
2. . Tool material found to withstand for base metal without tool breakage. And also found that this tool material is amenable for friction stir welding with different tool profiles.
3. It is found that taper screw thread pin tool facilitates the stirring action from the tip to the collar and avoid the turbulence compared to cylindrical threaded tool, there by this tool profile is effective for getting defect free welds.
4. The micro hardness profiles (Hv) appear uniform for the plates joined using the lower rotating speed (630 rpm) and the lower welding speed (115mm/min).
5. Increase in tool rotation speed causes more heat input which, in turn, enlarges the TMAZ and HAZ consequently, results in low tensile strength. However, increasing the weld speed reduces the heat input resulting in smaller TMAZ and HAZ which leads to greater tensile strength.

REFERENCES

[1] M.A. Sutton, A.P. Reynolds, D.Q. Wang, C.R. Hubbard, A study of residual stresses and microstructure in 2024-T3 aluminum friction stir butt welds, Journal of Engineering Materials and Technology ASME 124 (4) (2002) 215–221.
[2] M Song, R. Kovacevic, Thermal modeling of friction stir welding in a moving coordinate and its validation, International Journal of Machine Tool and Manufacturing 43 (6) (2003) 605–615.
[3] M Song, R. Kovacevic, Numerical simulation and experimental analysis of heat transfer process in friction stir welding process, Proceeding of Institution of Mechanical Engineers, Part B, Journal of Engineering Manufacture 216 (12) (2002) 73–85.

[4] Y. Cao, X. Qi, Thermal and thermo-mechanical modeling of friction stir welding of aluminum alloy 6001-T6, Journal of Materials Processing and Manufacturing Science 7 (10) (1998) 215–233.
[5] P. Dong, F. Lu, J.K. Hong, Z. Cao, Coupled thermomechanical analysis of friction stir welding process using simplified models, Science and Technology of Welding and Joining 6 (5) (2001) 281–287.
[6] Handbook of Aluminum, Alcan Aluminum Corporation, 1970.
[7] AYSYS User's Manual: Elements, vol III, Swanson Analysis Systems, Inc.
[8] K. Masubuchi, Analysis of Welded Structures, Pergamon Press, Oxford, NY, 1980.
[9] L. Djapic Oosterkamp, P.J. Webster, P.A. Browne, G.B.M. Vaughan, P.J. Whiters, Residual stress field in a friction stir welded aluminum extrusion, Materials Science Forum 247-349 (2000) 678–683.
[10] X.L. Wang, Z. Feng, S.A. David, S. Spooner, C.R. Hubbard, Neutron diffraction study of residual stresses in friction stir welds, in: Proceedings of the ICRS 6 (Residual Stresses: International Conference on Residual Stresses), IOM Communications, London,UK, 2000, pp. 1408–1415.