ISSN (Online) 2456-1290

International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)
Vol 3, Issue 4, April 2018

Experimental Investigation of Friction Stir Welding and its effect on Mechanical and Microstructure of Al-6063 Alloy

[1] Rajeev Satsangi, [2] V M Sai Prem Tammana
[1] Dept. Of Mechanical Engineering, Technical College, Dayalbagh Educational Institute, Agra-282110, India
[2] Student, Diploma in Mechanical Engineering., Technical College, Dayalbagh Educational Institute, Agra-India.

Abstract:-- **Friction stir welding (FSW) is also known as solid state joining process used for welding Aluminum and its alloy. Application of this FSW is widely used in ship-building, railway rolling stock, automobiles, marine, and aerospace etc. FWS is mainly carried out on vertical milling machine for welding AL and its alloys. Many researches have been done in this regarding Microstructure, tools parameter, tool materials, material flow and defect formation during welding process. Present study deals with experimental study of joining of Al-6063 alloy using FSW on vertical milling machine using high carbon steel tool rotating at different rpm at uniform pressure and uniform feed rate. After welding process Micro-Structure and hardness is carried out.**

I. INTRODUCTION

In this technique the metal me not heated up to its melting point. The metal is joined in its semi-solid state [1][2]. It can be used for the materials where the original characteristics are to be same. This process is used for joining aluminum parts, where fusion welding is not suitable.

In the procedure shown in Fig. 2.1, a cylindrical rod rotating at high speed (probe) is inserted into the metal to join the two parts. The friction of the tool on the metal softens the material and makes it into a paste. As the material is heated to its melting point by friction at high speed, so it is known as "friction stir". The jaws of the clamp apply a large force on the plates prevents the stirred metal from being expelled and produces a forging effect at the back of the material that was just softened out of shape and stirred. "The half–plate where the direction of rotation is the same as that of welding is called the forward side, with the other side designated as being the retreating side." Although Fig. 1 shows a butt joint for illustration, other types of joints such as lap joints and fillet joints can also be fabricated by FSW.

Since its discovery, FSW has evolved as a technique of choice in the routine joining of aluminum components; its applications for joining difficult metals and metals other than aluminum are growing rapidly. There have been widespread benefits resulting from the application of FSW for example in aerospace, shipbuilding, automotive and railway industries [3].

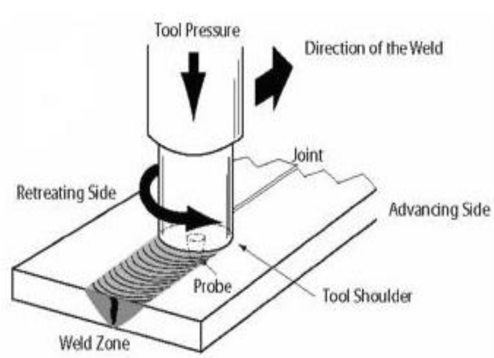
The benefits are:
This process can be used to improve microstructure and surface properties of metals.

FSW has the potential for joining similar and dissimilar materials that cannot be welded by conventional processes.
Because no melting of materials is involved, friction stir welding avoids the weaknesses caused by distortion and metallurgical reactions in conventional welding.

The friction heating is generated at the place of contact of the tool, so there is no widespread softening of the assembly.

The weld is formed across the entire cross-sectional area of the metal in a single shot manner.

The process is completed in a few seconds with very high reproducibility. has been conducted.



2.1 Mechanism of Joining in FSW

International Journal of Engineering Research in Mechanical and Civil Engineering
(IJERMCE)
Vol 3, Issue 4, April 2018

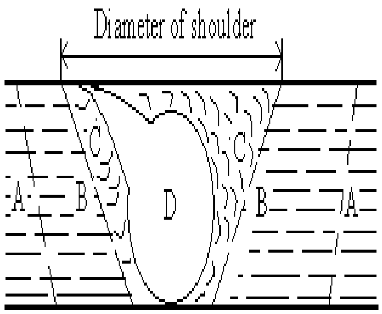


Figure 2: Schematic cross–section of a typical FSW weld showing four distinct zones.

2.0 LITERATURE REVIEW

2.1 Mechanism of Joining in FSW

FSW involves complex interactions between a variety of simultaneous thermo-mechanical processes. During FSW, the tool moves along the weld joint at a constant speed, as it rotates about its axis heat is generated by friction between the tool and the work piece and resulting plastic deformation. A typical cross-section of the FSW joint consists of four distinct number of zones: (A) base metal, (B) heat–affected, (C) thermo-mechanically affected and (D) stirred (nugget) zone (Fig. 2) [4,5]. The Heat–Affected Zone (HAZ) is similar to that in conventional welds although the maximum peak temperature is significantly less than the solidus temperature, and the heat–source is rather diffuse.

The central nugget region is the one which experiences the most severe deformation, and is a consequence of the way in which a tool deposits material from the front to the back of the weld. The Thermo Mechanically Affected Zone (TMAZ) lies between the HAZ and nugget; the grains of the original microstructure are retained in this region, but often in a deformed state. A unique feature of the friction stir welding process is that the transport of heat is aided by the plastic flow of the substrate close to the rotating tool. The heat and mass transfer depend on material properties as well as welding variables including the rotational and welding speeds of the tool and its geometry. In FSW, the joining takes place by extrusion and forging of the metal at high strain rates. Jata and Semiatin estimated a typical deformation strain rate of 10 s^{-1} by measuring grain-size and using a correlation between grain-size and Zener-Holloman parameter which is temperature compensated strain-rate [6]. Kokawa et al. estimated an effective strain rates in the range 2–3 s^{-1} [7].

2.2. Effect of Welding Variables in FSW

The process parameters or welding variables in FSW are tool geometry, axial force, tool rotation speed, traverse speed and tool tilt angle. Tool tilt angle is the angle between the tool axis and the normal to the surface of the sheets being welded. Tool geometry is considered to be one of the prime parameters which controls the material flow and heat input, and in turn the quality of the weld. Buffa et al. [8] numerically investigated the effect of tool pin angle on various weld zones, grain size and welding forces, and they had shown that there is a good agreement between the results of experiment and the model. The experimental work carried out by Kumar and Kailas [9] using different tool geometry explains the effect of shoulder diameter, pin diameter and pin profiles on size and location of defects, mechanical properties and final grain size. But, there is not enough conceptual background available on FSW tool design. In most of the research articles the tool geometry is not reported due to various reasons. As Mishra and Ma [10] pointed out, most of the tool design is based on intuitive concepts. The first step in deriving the concept of FSW tool design is to understand the role of tool in friction stir weld formation. There are a number of experimental studies [11]–[15], and computational work [16]–[18] has been carried out to analyze the material flow, and it is reported that the material flow in FSW is complex phenomenon.

In general, the flow visualization studies have been conducted by introducing a marker material in the weld line, or by welding dissimilar materials. After welding, the marker material position is traced back by suitable means, i.e., X-ray radiography or tomography or differential etching procedure, and compared with its initial position. On the other hand, the material flow in dissimilar materials of different flow properties cannot be compared with material flow in friction stir welds of similar materials. The important contribution to material flow visualization is done by Fratini et al. [19]. They incorporated the material flow and analysis with microstructural evolution. An interesting phenomenon in friction stir welds is formation of ring pattern. This has been studied by Fratini et al. [19] and Krishnan [20]. Krishnan [20] explained the onion ring formation using a clay model. He pointed out that the formation of onion ring is a geometric effect. He stated that semicylindrical sheets of material are extruded during each rotation of the tool and cross-sectional slice through such a set of semi cylinders results in the onion ring pattern. Fratini et al. [19] explained the reason for the onion ring pattern using numerical model that the material entering from the retreating side enters the action volume and rotates at the back of the tool. But, in general, there is no experimental evidence that confirms the mechanism of onion ring formation proposed by the researchers.

2.3. Defect Formation in FSW

The important aspect for the defect formation is the cavity formed after the weld. The causes of defect are excess force applied on the metal which cause excess heat and forms cracks, etc.

3.0. APPLICABILITY OF FSW IN POLYMERIC MATERIAL

The applicability of friction stir welding has been studied by Zoltán Kiss et al. [22] on polypropylene sheets. The joint strength has been analyzed in terms of rotation and translation speed. It has been demonstrated that in addition to the judicious selection of welding parameters the proper construction of the welding tool is also very important. Analysis of the flow circumstances during welding on seams produced by proper tool geometries it has been demonstrated that homogenization and, consequently the joint strength can be substantially improved.

4.0. EXPERIMENTATION OF FSW WITH IMPROVISED VERTICAL MILLING MACHINE

Initially Aluminium Plates are cut in Cross Section of 22 cm in length and 2.5 cm in width as shown in figure 3.

Figure 3 Al – 6063 Plates

After this these plates are clamped on improvised vertical milling machine as shown in figure-4 is manufactured as per design specified with a 3phase 1HP motor with two rpm 770 and 1200. and at constant feed range for doing the FSW experiments. Initially two 5mm thick Aluminum alloy pieces are welded together using the ingenious setup as shown in Figure 4 and

Figure 4 Friction Stir Welding Vertical Milling

Welded Plates

After Completion of Welding keep the specimen for get cool down. In Figure 7 Specimen welded at 770 rpm is shown and in Figure 87 Specimen welded at 1200 rpm is shown

ISSN (Online) 2456-1290

International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)

Vol 3, Issue 4, April 2018

Figure.7 Welded Specimen at 770 rpm

Figure.8 Welded Specimen at 1200 rpm

Tensile Specimen

As soon as the welding is completed weld Specimen is preparing to perform the tensile test Dimension shown in figure 9.

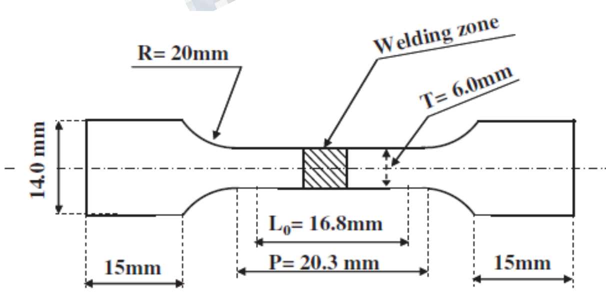


Figure.9 Tensile Test Specimen Dimensions

Hardness Test

Hardness test is performed using Pen Type Portable Hardness Tester Machine Shown in Figure 10 on the specimen produced after welding

Figure.10 Pen Type Portable Hardness Tester Machine

Micro Structure Equipment

Micro Structure of Specimen is inspected under Metal Microstructure Equipment shown in Figure.

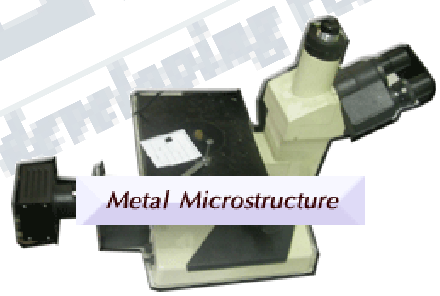


Figure.11 Metal Microstructure Equipment

After successful completion of welding some mechanical test are performed on the specimen and following results were obtained.

Micro hardness tests

Micro hardness tests following the ASTM E384-99 standard [44], were performed across the joint section, transverse to the weld seam, using a Pen Type Portable Hardness Tester Machine. The tests were carried out in brinell hardness number and following result were obtained.

Tensile Test

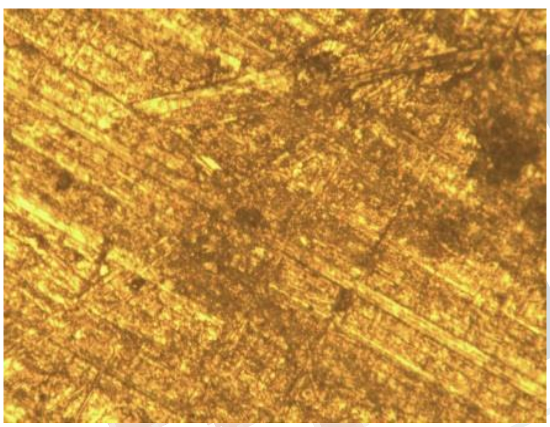
Tensile Test were carried out using universal testing machine and following result were obtained.

International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)
Vol 3, Issue 4, April 2018

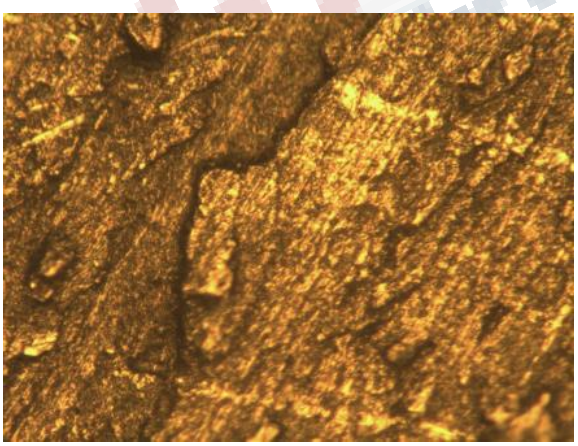
Specimen Type	Hardness
Uniform	32
FSW 770	54
FSW 1200	44

Surface Structure

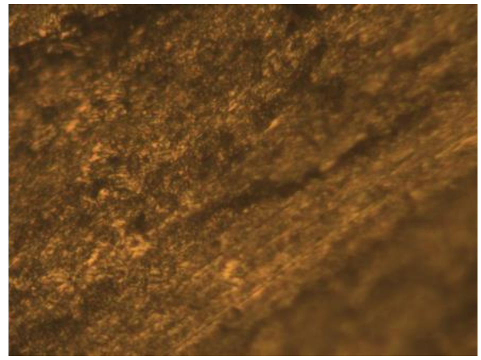
Surface Structure of the specimen at join section was observed at joint section in figure 12 and following Structure are appear on the computer for specimen at different rpm.



Uniform Specimen



Specimen 770 rpm



Specimen 1200 rpm

Figure.12 Micro Structure of Specimen at different rpm

CONCLUSION

In present study, the results were evaluated to determine the Mechanical and Microstructure Analysis of Al 6063 alloy, and it is found that

1. Yield Strength of FSW-770 Specimen is more than 55 percent and for FSW-1200 it is about 50 percent of Uniform Specimen.
2. Tensile Strength of FSW-770 is 28.4 Kqf/mm2 and for FSW-1200 specimen 26.3 Kqf/mm2 which is quit more than 50 percent so weld obtained by these joint are having high strength.
3. Hardness of FSW-770 is 54 and for FSW-1200 is 44 brineel hardness number so it reflects that the stiffness of the joint get increased after the

Specimen Type	Yield Strength	Tensile Test (Kqf/mm$^{2)}$	Elongation (mm)	Strain %	Hardness
Uniform	48	53.1	5.76	6.7	32
FSW 770	26	28.4	3.0	2.82	54
FSW 1200	24.2	26.3	3.2	2.92	44

REFERENCES

[1] W. M. Thomas, E. D. Nicholas, J. C. Needham, M. G. Murch, P. Temple-Smith, and C. J. Dawes "Friction stir butt welding," International Patent Application no. PCT/GB92/02203, (1991).

[2] C. J. Dawes and W. M. Thomas "Friction stir

process welds aluminum alloys," Welding Journal, 75(3), (1996), pp 41 – 45.

[3] W. M. Thomas and E. D. Nicholas, "Friction stir welding for the transportation industries," Materials & Design, 18, (1997), pp 269–273.

[4] C. G. Rhodes, M.W. Mahoney, W.H. Bingel, R.A. Spurling, and C.C. Bampton, "Effect of friction stir welding on microstructure of 7075 aluminum", Scripta Materialia, 36(1), (1997), pp 69 – 75.

[5] G. Liu, L.E. Murr, C.-S. Niou, J.C. McClure, and F.R. Vega, "Microstructural aspects of the friction-stir welding of 6061-T6 aluminum", Scripta Materialia, 37(3), (1997), pp 355 – 361.

[6] K. V. Jata and S. L. Semiatin, "Continuous dynamic recrystallization during friction stir welding", Scripta Materialia, 43, (2000), pp 743–748.

[7] K. Masaki, Y. S. Sato, M. Maeda, and H. Kokawa, "Experimental simulation of recrystallized microstructure in friction stir welded Al alloy using a plane-strain compression test", Scripta Materialia, 58, (2008), pp 355–360.

[8] G. Buffa, J. Hua, R. Shivpuri, L. Fratini, "Design of the friction stir welding tool using the continuum based FEM model", Mater. Science Eng., 419, (2006), pp 381–388.

[9] K. Kumar, S.V. Kailas, "Influence of tool geometry in friction stir welding", Proceedings of the 2nd International Conference on Advances in Production and Processing of aluminum, Kingdom of Bahrain, APPA, (2005), pp. III-8-1 to III-8-12.

[10] R.S. Mishra, Z.Y. Ma, "Friction Stir Welding and Processing", Mater. Sci. Eng. R 50, (2005), pp 1–78.

[11] K. Colligan, "Material flow behavior during friction stir welding of aluminum" Weld. J.,78 ,(1999), pp 229–237.

[12] H.N.B. Schmidt, T.L. Dickerson, J.H. Hattel, "Material flow in friction stir welding",Acta Mater. 54, (2006), pp 1199–2120.

[13] M. Guerraa, C. Schmidta, J.C. McClurea, L.E. Murr, A.C. Nunesb, "Effect of rprocess parameters on quality of friction stir welds", Mater. Charact, 49, (2003), pp 95–101.

[14] Y. Li, L.E. Murr, J.C. McClure, Scripta Mate,. 40, (2000), pp 1041–1046.

[15] A. P. Reynolds, Sci. Technol. Weld. Join., 5, (2000), pp 120–124.

[16] R. Nandan, G.G. Roy, T.J. Lienert, T. Debroy, "Three Dimensional Heat and Material Flow during Friction Stir Welding of Mild Steel", Acta Mater., 55 (2007), pp 883–895.

[17] H.W. Zhang, Z. Zhang, J.T. Chen, "Numerical studies on the effect of transverse speed in friction stir welding", J. Mater. Process. Technol., 183, (2007), pp 62–70.

[18] P.A. Colegrove, H.R. Shercliff, "Model for predicting heat generation and temperature in friction stir welding", J. Mater. Process. Technol., 169, (2005), pp 320–327.

[19] L. Fratini, G. Buffa,D. Palmeri, J. Hua, R. Shivpuri, "Numerical modeling of FSW processes", J. Eng. Mater. Technol., 128, (2006), pp 228–235.

[20] ASTM 384-99 "Standard Test Method for Microindentation Hardness Materials", AnnualBook of ASTM Standards Vol 03.03 (ASTM, Philadelphia, 2000), pp. 406-429