International Journal of Engineering Science Invention (IJESI)
ISSN (Online): 2319-6734, ISSN (Print): 2319-6726
www.ijesi.org ||Volume 10 Issue 1 Series II || January 2021 || PP 14-20

Hardness Testing of Friction Stir Welded Aluminium 6061 Materials

M. Yashwanth Kumar[1], S.N.Sarveswara Reddy[2], M.V. Ramana Reddy[3]
[1,2,3] (Mechanical Department, G. Narayanamma Institute of Technology & Science, JNTUH, INDIA)

ABSTRACT : *Friction stir welding is one of the most advanced types of solid state welding process and it involves moving one component relative to other component to generate required amount of heat and then applying lateral force (called upsetting force) to plastically displace and fuse materials. Technically, because no melt occurs, friction welding is not an actually a welding process in the traditional sense, but a forging technique. However, due to the similarities between these techniques and traditional welding, the term has become common. Friction stir welding requires no filler material. Hence, the properties won't be altered to a great extent and the weld does not suffer from any inclusions and gas porosity as compare to any other type of welding. Also, it is a very fast process because of which heat affected zone in the base metal is much less when compared to other welding process. The weld obtain will also have greater strength than that of the other welding process. Generally, friction stir welding is carried out on a deducted friction stir welding machines which is cost effective for small or medium scale industries. In the present work an attempt has been made to retrofit an attachment to heavy duty lathe. After successful welding and characterisation of attachment, an experiment was conducted for routinely used material like Aluminium and Aluminium the welded pieces were tested mechanically to find the hardness, microstructure and heat affected zone etc. In this paper, an investigations are carried out on Al (6061) materials the mechanical properties obtained at different spindle speeds are recorded and hardness test are conducted at the HAZ is measured. With previous experimentations it is identified that a heavy duty lathe can perform friction stir welding up to any 5mm thickness. In the present paper the influence of speed, feed on the performance of FSW such as hardness is determined at different experimental conditions*

KEYWORDS:- *Aluminium 6061, friction Stir Welding, hardness, Heat affected zone(HAZ), Weldment*

Date of Submission: 15-01-2021 Date of Acceptance: 31-01-2021

I. INTRODUCTION

Friction stir welding also produces a plasticized region of material, but in a different manner. A non-consumable rotating tool is pushed into the materials to be welded and then the central pin, or probe, followed by the shoulder, is brought into contact with the two parts to be joined. The rotation of the tool heats up and plasticizes the materials it is in contact with and as the tool moves along the joint line, material from the front of the tool is swept around this plasticized annulus to the rear, so eliminating the interface.

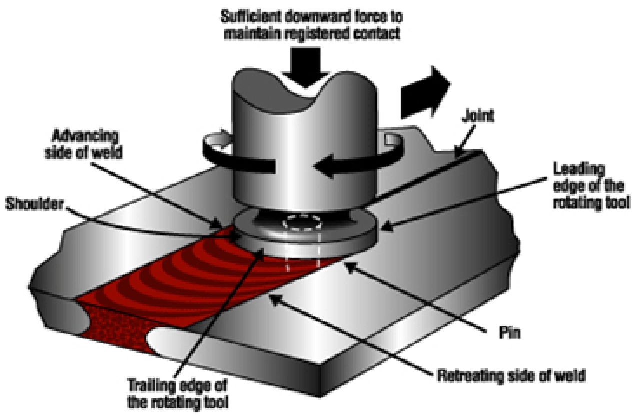


Fig 1 : Friction stir welding process

Friction stir welding (FSW) is a novel welding technique invented by The Welding Institute (TWI) in 1991. FSW is actually a solid-state joining process that is a combination of extruding and forging and is not a true welding process. Since the process occurs at a temperature below the melting point of the work piece material, FSW has several advantages over fusion welding. The process uses a rotating, non-consumable weld tool that plunges into the base material and moves forward. Friction heat caused by the rotating pin creates a plasticized tubular shaft around the pin. Pressure provided by the weld tool forces the plasticized material to the back of the pin, cooling and consolidation. This welding technique involves the joining of metals without fusion or filler materials. It is used already in routine, as well as critical applications, for the joining of structural components made of Al and its alloys.

1.1 VARIABLES IN FRICTION STIR WELDING: A few major factors affecting FSW/FSP process, such as tool geometry, welding parameters, joint design is addressed. The strength of friction stir welding depends on the following three parameters. They are

Spindle speed:

The spindle speed is the rotational frequency of the spindle of the machine, measured in revolutions per minute (RPM). The preferred speed is determined based on the material being cut. Excessive spindle speed will cause premature tool wear, breakages, and can cause tool chatter, all of which can lead to potentially dangerous conditions. Using the correct spindle speed for the material and tools will greatly affect tool life and the quality the surface finish.

Feed rate:

Feed rate is the velocity at which the cutter is fed, that is, advanced against the work piece. It is expressed in units of distance per revolution for turning and boring (typically inches per revolution (ipr) or millimetres per revolution). It can be expressed thus for milling also, but it is often expressed in units of distance per time for milling (typically inches per minute (ipm) or millimetres per minute).

Depth of penetration:

Depth of penetration depends upon the thickness of the material to be welded. It is expressed in units of millimetres (mm).

In this present paper, an investigations are carried out on Al (6061) materials, the mechanical properties obtained at different spindle speeds are recorded and hardness at the HAZ is measured. Thus for the experimentations to conduct a heavy duty lathe is used to perform friction stir welding up to any 5mm thickness.

II. EXPERIMENTAL PROCEDURE

2.1 SELECTION OF MATERIAL

Aluminium6061 known for exceptional performance in extreme environments. It is a ductile metal. It is highly resistant to attach by both sea and industrial chemical environment. It also retains experimental strength after welding. It has highest strength of the non-heat treatable metals.

2.2 DESIGN OF TOOL

Tool dimensions:

The High speed steel is used as tool which is non-consumable tool has a circular section except at the end where there is a threaded probe or more complicated flute. The junction between the cylindrical portion and the probe is known as the shoulder. The probe penetrates the work piece whereas the shoulder rubs with the top surface. The tool has an end tap of 5mm diameter and a height of 5mm the welding direction. The design of the pin and shoulder assembly plays a major role on how the material moves during the process.

Fig 2: Tool and tool tip

Tool specification:

Parameter	Length(mm)
Total tool length	100
Tool diameter	20
Shoulder length	75
Shoulder diameter	16
Pin length	4.7
Pin diameter	5

Table 1: Tool specifications

2.3 SAMPLE PREPARATION

Rolled plates of 5mm in thickness were cut into the required size (120mm×100mm×5mm) by power hacksaw cutting, milling, and manually also. The experiments were conducted on the aluminium 6061 (2 no's). Before the friction stir welding, the weld surface of the base material was cleaned. Plate edges to be weld were also prepared so that they are fully parallel to each other. This is ensuring that there is no uneven gap between the plates which may not result in sound welding. Secondly surface preparation was also done so that the surfaces of both the plates are of equal level and footing.

Fig 3(a): Sample Al plates **Fig 3(b):** FSW Tool

2.4 SETUP FOR WELDING

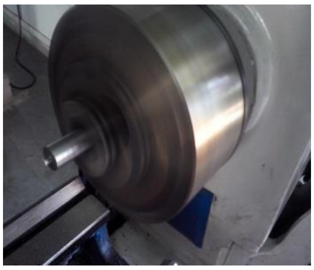


Fig 4 (a) Al 6061 plates **Fig 4(b)** Tool

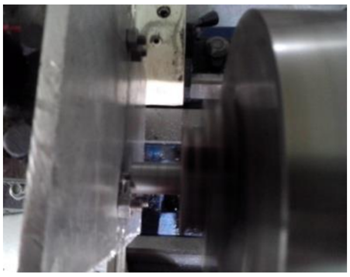


Fig 4 (c) During welding Process **Fig 4 (d)** specimens after FSW

A heavy duty lathe machine was used for friction stir welding (FSW) of aluminium 6061, aluminium 6061 and their combination. The machine used has a maximum speed of 800 rpm and manual power. Test piece was clamped in the fixture tightly. Initially the rotating pin was inserted into a predrilled hole, which will facilitate the start-up of welding. Processing began at spindle speed of 750 rpm and travel rate 350 mm/min. The speed was increased to 800 rpm and feed rate to 500 mm/min. Since tool plunge was to extent of 15 mm and plate thickness being 5mm, the result was one side welded plates. The plates where then subjected to mechanical testing.

III. HARDNESS TEST:

A hardness test can be conducted on Brinell testing machine & Rockwell hardness testing machine, the specimen may be a cylinder, cube, thick or thin metallic sheet. Specifications of a Brinell cum Rockwell hardness testing machine are as follows

1. Diameter of ball (as indenter) used D=2.5mm, 5mm, 10mm.
2. Maximum application Load + 2000kgf
3. Method of application = Lever type
4. Capability of testing the lower hardness range=1BHN on application of 0.5D2 Load.

Brinell Hardness Testing Machine:

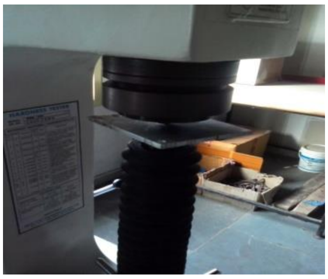


Fig 5(a) Before welding

Fig 5(b) After welding

Brinell hardness (before welding)

S.I	d1	d2	d=(d1+d2)/2	F in kg	D in mm	HB kg/mm^2
1	2.9	2.9	2.9	250kg	5mm	34.22

Table 2 (a) before welding

Calculations:

$$BHN = \frac{2F}{\pi D(D - \sqrt{D^2 - d^2}}$$

$$BHN = \frac{2*250}{5\pi(5 - \sqrt{5^2 - 2.9^2}} = \frac{500}{5\pi(5 - 4.07)} = 34.22$$

Brinell hardness (after welding)

S.I	d1	d2	d=(d1+d2)/2	F in kg	D in mm	HB kg/mm^2
1	2.1	2.2	2.15	250kg	5mm	64.96

Table 2 (b) after welding

Calculations:

$$BHN = \frac{2F}{\pi D(D - \sqrt{D^2 - d^2}}$$

$$BHN = \frac{2*250}{5\pi(5 - \sqrt{5^2 - 2.15^2}}$$

$$BHN = \frac{500}{5\pi(5-4.51)} = 64.96$$

Rockwell Testing Machine:

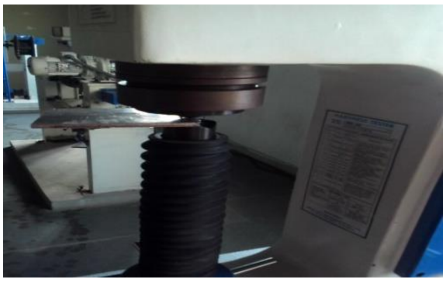


Fig 6(a): Before welding

Fig 6(b) After welding

Rockwell hardness (before welding or parent metal)

S.No	Scale used	Indenter used	Minor load(Kg)	Major load(Kg)	RHN			
					Loc1	Loc2	Loc3	Loc4
1	B	1/16" ball	10	90	42	41	43	42

Table 3(a) before welding

Calculations:

$$RHN = \frac{Loc_1 + Loc_2 + Loc_3 + Loc_4}{4}$$

$$RHN = \frac{42+41+43+42}{4} \Rightarrow RHN = \frac{168}{4} = 42$$

Rockwell hardness (on weld)

S.No	Scale used	Indenter used	Minor load(Kg)	Major load(Kg)	RHN			
					Loc1	Loc2	Loc3	Loc4
1	B	1/16" ball	10	90	88	87.1	86.3	92.2

Table 3 (b) after welding

Calculations:

$$RHN = \frac{Loc_1 + Loc_2 + Loc_3 + Loc_4}{4}$$

$$RHN = \frac{88+87.1+86.3+92.2}{4}$$

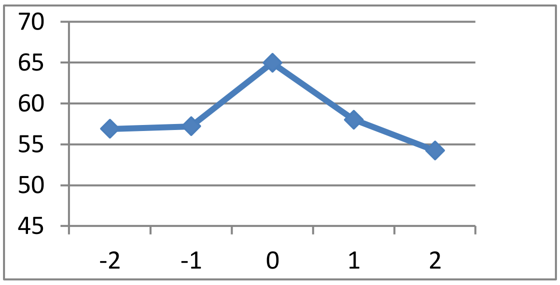
$$RHN = \frac{353.6}{4} = 88.4$$

IV. RESULTS & DISCUSSIONS:

GRAPHS

1. Distance Vs Hardness for Brinell Hardness

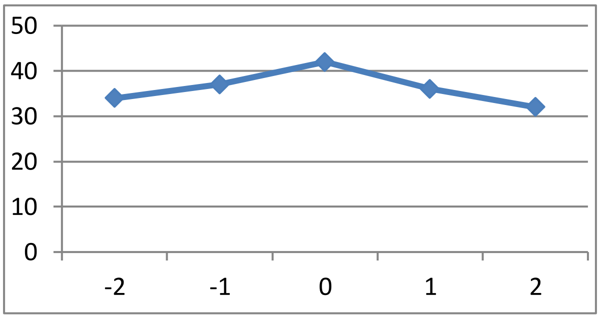
Distance (X- axis)	Hardness (Y-axis)
-2	56.90
-1	57.20
0	64.96
+1	58.01
+2	54.23



Graph 1: Brinell hardness

2. Distance Vs Hardness for Rockwell Hardness

Distance (X- axis)	Hardness (Y-axis)
-2	34
-1	37
0	42
+1	36
+2	32



Graph 2: Rockwell hardness

The quality of weld is being affected by Tool for friction stir welding. The good tool for making a good quality welding can be identified by conducting experiments with different weld parameters. The different tool rotations at speeds produced pre-eminence welds it is concluded that Aluminium has increase in hardness in the welded region.

V. CONCLUSIONS:

In this investigation an attempt has been made to study the effect of hardness on the formation of friction stir processing zone in Aluminium6061. From this investigation, we conclude that the welded specimens show an increase in micro hardness in the welded region.

REFERENCES

[1]. X.K. Zhu, Y.J. Chao, (2003) "Numerical simulation of transient temperature and residual stresses in friction stir welding of 3041 stainless steel" materials processing technology,146,263-272.
[2]. Akos Meilinger, Imre Torok, (2013), "The important of friction stir welding tool", production processes and systems, vol. 16. (2013) No. 1, pp-25-34.
[3]. M.A. Abdelrahman, M.M. Ghoneim, M.E. Abdelazim, M M. R. EI-Kouss, N.A. Abdelrahman, (2012), "The effect of FSW tool geometry on AA6061-T6 weldments", 45(2), 407-418.
[4]. Deepak Sharma, Dr. Rajesh Kumar Bhushan, "Thermo mechanical modelling of FSW", International journal of engineering technology and advanced engineering, volume 3, special issue 2, January 2013.
[5]. M. Vural, A. Ogur, G. Cam, C. Ozarpa. 2007. "On the friction stir welding of aluminium alloys EN AW 2024-0 and EN AW 5754-H22". Archives of materials science and engineering. 28: 49-54.
[6]. N. Rajamanickam, V. Balusamy, (2008), "The influence of pun geometry on bonding and mechanical properties in friction stir weld 2014 aluminium alloy", Indian journal of engineering and material sciences, Vol 15, Aug 2008, pp.293-299.
[7]. J.C. McClure, E. Coronado, S. Aloor, B. Nowak, L.M. Murr, A.C. Nunes, Jr., "Effect of Pin tool Shape on Metal Flow During Friction Stir Welding" , Metallurgical and Materials Engineering Department, University of Texas El Paso, NASA, Marshall Space Flight Centre, Huntsville, AL.
[8]. T. J. Lienert, W. L. Stellwag, Jr., B. B. Grimmett, and R. W. Warke, "Friction Stir Welding Studies on Mild Steel", supplement to the welding journal, January 2003.
[9]. Yong-Jai Kwon, Seong-Beom Shim, Dong-Hwan Park, Friction stir welding of 5052 aluminum alloy plates, Trans. Nonferrous Met. Soc. China 19(2009) s23−s27.

[10]. H. J. LIU, H. FUJII, K. NOGI, Friction stir welding characteristics of 2017-T351 aluminum alloy sheet, JOURNAL OF MATERIALS SCIENCE **40** (2005) 3297 – 3299.
[11]. D.Muruganandam, K.S.Sreenivasan, S.Ravi Kumar, Sushilal Das, V.Seshagiri Rao, Study of process parameters in friction stir welding of dissimilar Aluminium alloys, International 26 Conference on Industrial Engineering and Operations Management Kuala Lumpur, Malaysia, January 22 – 24, 2011.

M. Yashwanth Kumar, et. al. "Hardness Testing Of Friction Stir Welded Aluminium 6061 Materials." *International Journal of Engineering Science Invention (IJESI)*, Vol. 10(01), 2021, PP 14-20. Journal DOI- 10.35629/6734