IOP Conference Series: Materials Science and Engineering

**PAPER** • **OPEN ACCESS**

# Investigations on friction stir welding of AA5083-H32 marine grade aluminium alloy by the effect of varying the process parameters

To cite this article: R Saravanakumar *et al* 2018 *IOP Conf. Ser.: Mater. Sci. Eng.* **402** 012187

IOP Conf. Series: Materials Science and Engineering **402** (2018) 012187 doi:10.1088/1757-899X/402/1/012187

# Investigations on friction stir welding of AA5083-H32 marine grade aluminium alloy by the effect of varying the process parameters

**R Saravanakumar*, K Krishna, T Rajasekaran, S Siranjeevi**

Department of Mechanical Engineering, SRM Institute of Science and Technology, Kattankulathur, Chennai, India

*Corresponding author: saravanakumar.r@ktr.srmuniv.ac.in

**Abstract.** Friction stir welding is a new technique for the complicated task for welding the aluminum alloys. The experimental work presents a complete study on friction stir welding of armour grade aluminium alloy. The input process parameters producing effects were completely analysed. The basic principles of FSW are illustrated; including thermal history and material flow before discussing how the process parameters affect the weld microstructure and related distribution of hardness are examined for AA5083-H32.

The Aluminium alloys such as H5083 called armour grade. Aluminium alloy 5083 exhibits the tremendous performance in the extreme environments. The material mostly applied in construction of ship building, vehicle bodies, mine skip and cages and pressure vessels. The effect of input parameters such as tool profile, rotational speed, and translational speed was investigated. The thermal histories, micro hardness and tensile strength were analysed. Dynamic polarization test was performed for measuring the pitting corrosion resistance. The parameters ranges from 700 to 1400rpm and feed rates from 20 to40 mm/min.The optimized input values which produced good tensile and harness values.

**Keywords.** Friction-stir welding, 5083-H32 Aluminium alloy, Tensile properties, Micro hardness.

## 1. Introduction

Mostly the Friction Stir Welding (FSW) is finding more uses in defence and aerospace applications. This is eco friendly technique and a relatively new welding technique, called solid state welding process invented in 1991. It has broad promise for joining similar and dissimilar materials, which are difficult or unattainable to weld conventionally. The rotating tool plunged with some axial force into the welding interface. The Tool consists of shoulder and pin is to produce the heat and its makes the initial deformation of material in a localized area. Controlling the temperature it makes defect free welding.

FSW can make a fine microstructure with smaller amount of defects, lower residual stresses, less distortion, better retained mechanical properties, and better dimensional stability as compared with conventional welding.FSW is also a candidate process for joining sheets of dissimilar thickness or composition to create tail or welded blanks that retain the capability for improved

ductility and strength via fine grain structure. Recent researcher has focuses on FSW in joining materials such as Armour grade alloys and steel. Commercialization of FSW, mainly for aluminum alloys, has occurred in the transportation industry, for many applications [3].
Such as automobiles, railway vehicles, ships, and rockets. Friction stir welding is extensively used by NASA to join large portions of aluminum for their space shuttle external fuel tank at the Michoud research facility. It is the preferred NASA welding technique for their moon rocket. As friction stir welding advances and is used in more applications, tool materials will need to be selected for optimal weld efficiency. This idea will determine the significance a tool material on the mechanical properties of a friction stir weld in 5083-H32 aluminum[4]. FSW process which can maintain constant heat input along the weld line. The heat conduction and dissipation during FSW controls the width of TMAZ and HAZ and also improves the joint properties.

## 2. Methodology

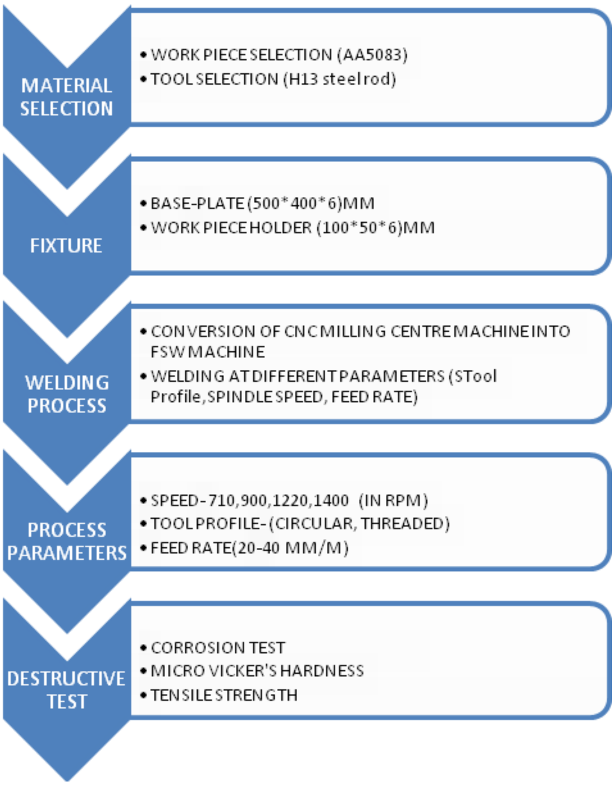


**Figure 1.** Methodology

## 3. Experimental details.

In this experimental works, the type of materials used for welding was AA5083-H32 marine grade aluminum alloy in plate form of thickness 6mm. Each specimen has 100mm long and 50mm wide. In this work the tool was used cylindrical and threaded profile with 15 mm shoulder diameter and pin diameter 5.9mm with a length of 5.9mm respectively. The experiment carried in vertical milling machine.

During FSW the temperature was measured at three different locations using K-type thermocouple. Normally the thermocouples were located in 3mm away from the stir zone and 1mm above from the top surface. For getting accurate tensile values the test were conducted in INSTRON UNIVERSEL machine at a speed of 2mm. The microhardness tester load of 500g and a dwell time of 10s.The microhardness of one FSW sample were measured along the transverse surface of the weld.

*3.1 Design of tool pins*

FSW pins which produces more effect in the weldments. The pin disrupts the faying surfaces or contracting the surface of the work piece. The different profile which exhibits the large amount of material and it's forged by sholders. Some commonly used tool profiles are:

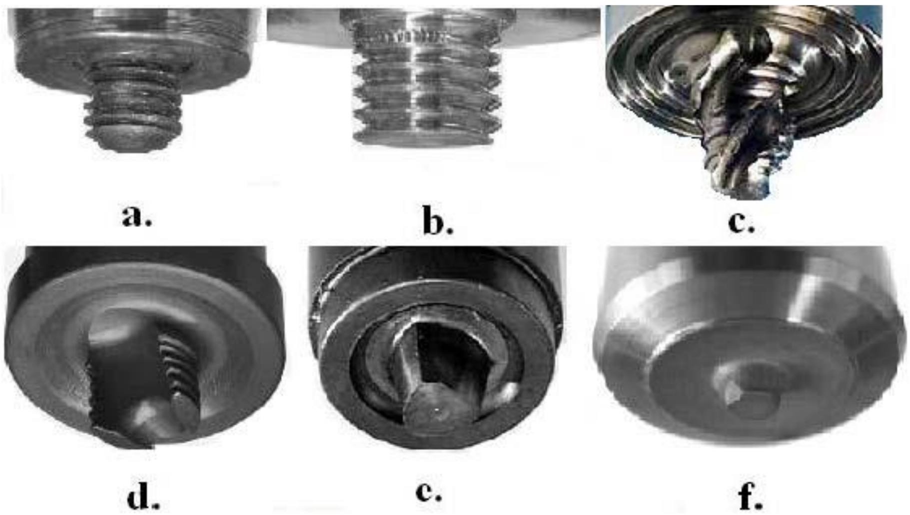


**Figure 2. a.** Round**, b.** Flat bottom, **c.** Mx Triflute**, d.** A-skew**, e.** Trivex**, f.** Thread less

**Table 1.** Friction Stir Welding Parameters

| Sample. no | Tool profile | Speed (rpm) | Feed rate (mm/min) |
|---|---|---|---|
| 1 | Circular | 710 | 20 |
| 2 | Circular | 900 | 20 |
| 3 | Circular | 1220 | 40 |
| 4 | Circular | 1400 | 40 |
| 5 | Threaded | 710 | 20 |
| 6 | Threaded | 900 | 20 |
| 7 | Threaded | 1220 | 40 |
| 8 | Threaded | 1400 | 40 |

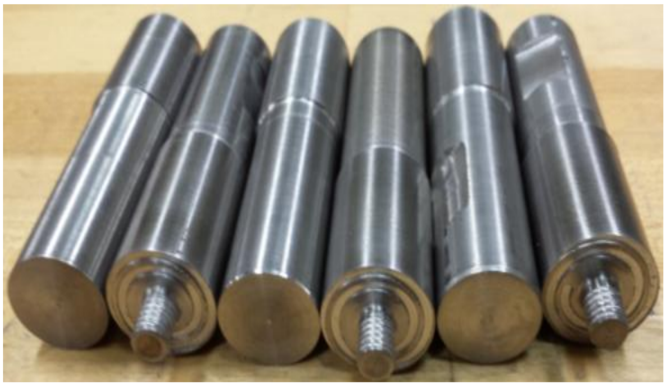

**Figure 3.** Friction Stir Welding Tools

**Figure 4.** H13-Friction Stir Tooling
Circular and Threaded profile

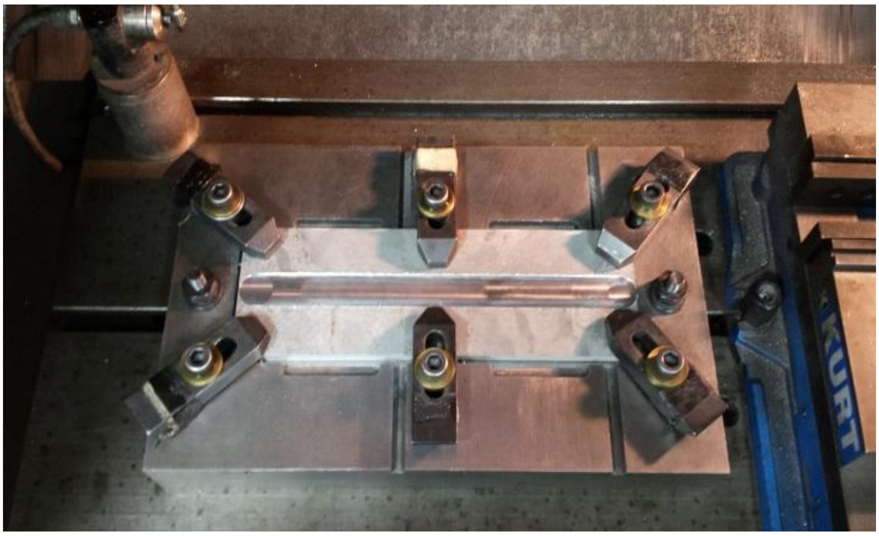


**Figure 5.** Work piece Holder

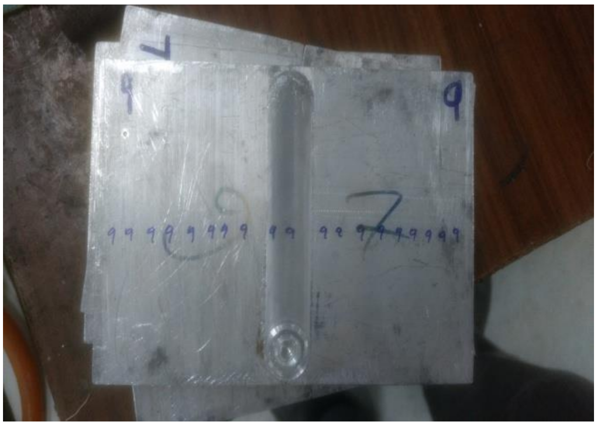

**Figure 6.** Friction Stir Welded specimens

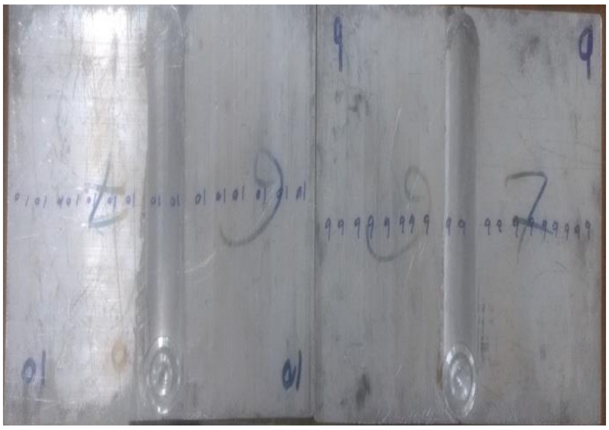

**Figure 7.** Friction Stir Welded specimens

## 4. Experimental Results

*4.1 Pitting Corrosion testing*

It is a type of corrosion takes place in a particular area. Corrosive attacks and form the small pits in that place. The large amount of materials remains unchanged the corrosion mainly forms where the passive films have out of order. Pitting can be one of the dangerous form, because it is not easily prevent and predictable, penetrates easily without any pre information of weight loss of materials. Potentio dynamic polarisation is probably the most commonly used polarisation testing method for measuring the corrosion resistance. At a selected rate of current, the Potential corrosion can be varying. Saturated calomel by adding the potassium hydroxide. The welded specimen may exhibits more positive or more negative potentials. Initially the welded specimens were surface cleaned by the help of acids than polished. Immersion takes place in NaCl solution using Plexiglas chamber which is shown in the figure-8. It is filled by 25 litres of salt water that contains 3.5% of NaCl,

**Steps involved in corrosion** are:

1. Initiation of pit

IOP Conf. Series: Materials Science and Engineering **402** (2018) 012187 doi:10.1088/1757-899X/402/1/012187

2. Propagation of pit
3. Termination of pit

Passivating metal in contact with sea water (Oxygen rich) anodic.
M—$M^{2+}$+$2e^-$----Anodic
$O_2$+$2H_2O$+$4e^-$----Cathodic
Initially the pits releases the $e^-$ and $M^{2+}$ form
Then the e- travels to the top of the pit and reaction with $O_2$ and $H_2O$ form.
$O_2$+$H_2o$+$4e^-$----($OH^-$)
Now the $M2^+$react with hydroxide (OH).
Then the ($OH^-$) react with $M^{2+}$
$OH^-$+$M^{2+}$---MOH is called rust.

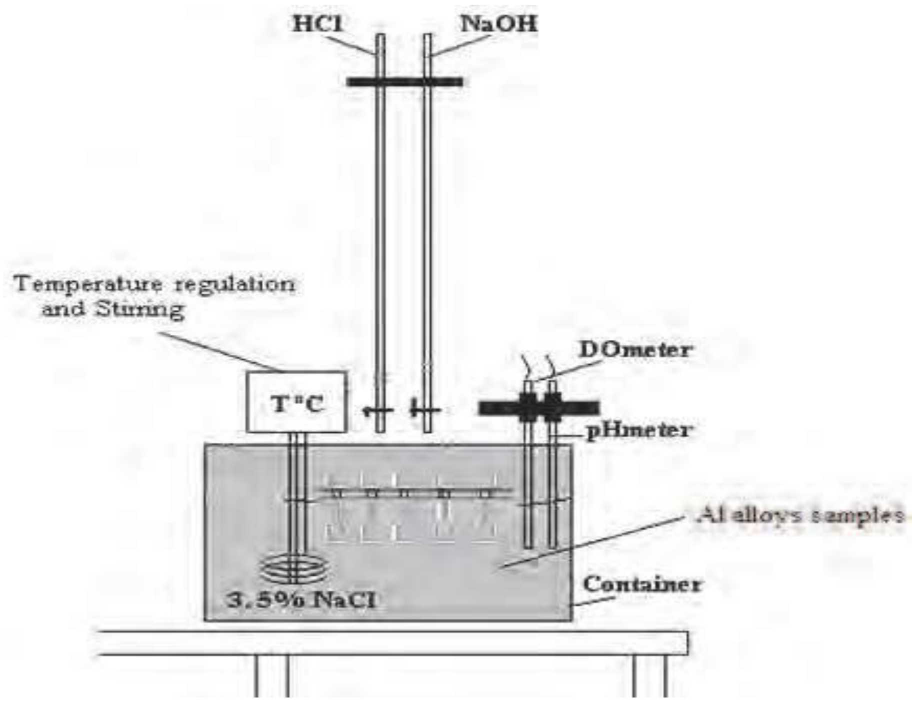


**Figure 8.** Schematic illustration of the immersion test in 3.5% NaCl solution


. **Figure 9.** Corrosion fatigue testing in a NaCl solution

IOP Conf. Series: Materials Science and Engineering **402** (2018) 012187 doi:10.1088/1757-899X/402/1/012187

*4.2 Corrosion behaviour of 5083-H32 in a 3.5% NaCl solution*

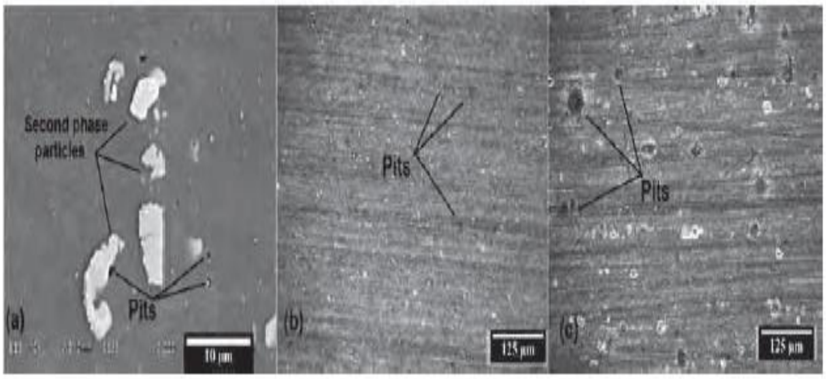


**Figure 10.** Corrosion observed

(a) a polished surface immersed for 24 hours; (b) a ground surfa immersed for 30 days; and (c) ground surface immersed for 90 days.

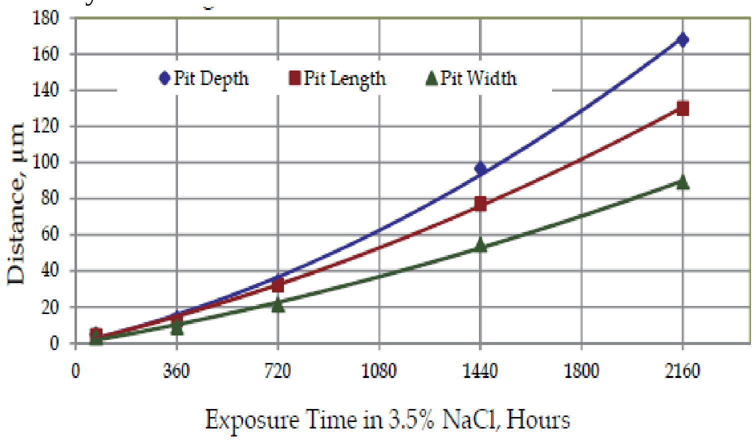


**Figure 11.** The pit dimensions observed on immersion of 5083-H32 in 3.5% NaCl solution are shown graphically as a function of exposure time. Longer exposure times increase the depth, length and width of the observed pits.

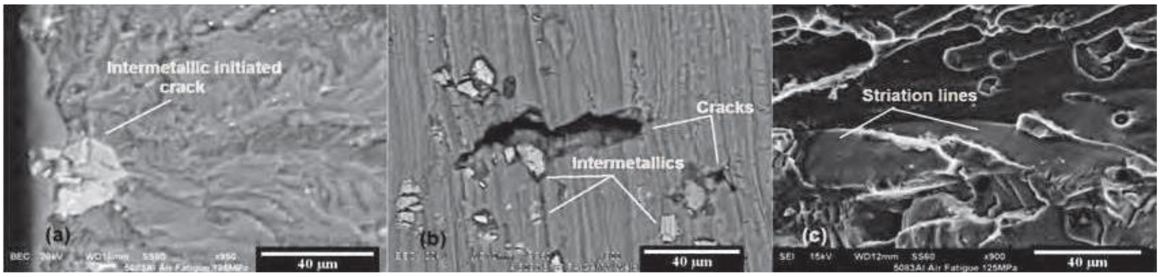


**Figure 12**. Mean dimensions of pits observed (b) crack initiation due to disbanding between precipitates and the matrix; and (c) crack propagation.

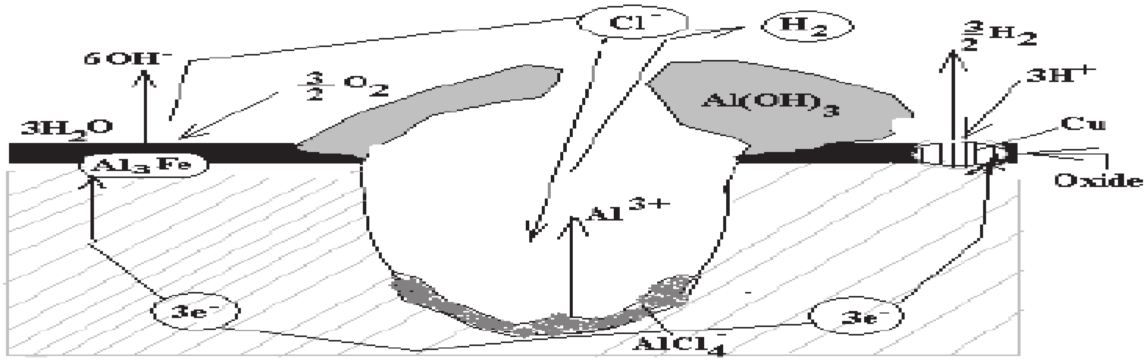


**Figure 13**. Pitting Corrosion

*4.3 Tensile Testing*

The tensile specimen is fixed between the fixed jaw and the movable jaw. Then the movable jaw is moved downwards opposite to the fixed jaw. The tensile specimen is extended at one stage the tensile specimen broken. The dimension of the tensile specimen is given below

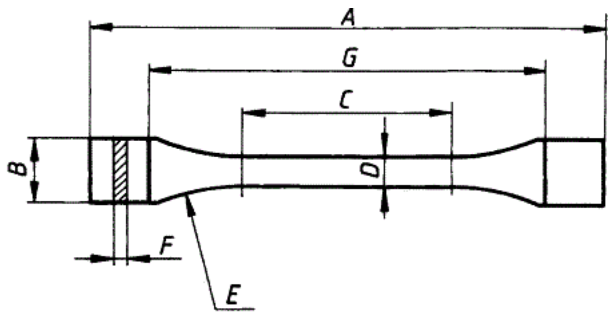


**Figure 14.** A - Overall length B-Width at ends - Length of narrow, parallel sided portion, D - Width of narrow, parallel sided portion, E-Radius, F-Thickness, G- Initial thickness between grips

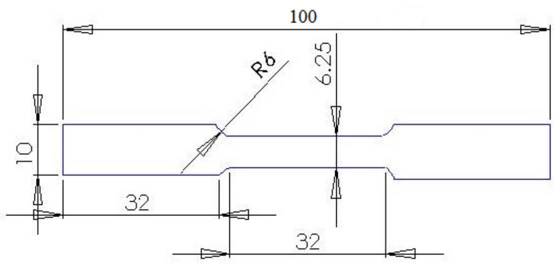


**Figure 15.** Tensile Test Specimen Standard


**Figure 16.** Welded Specimen for Tensile Test

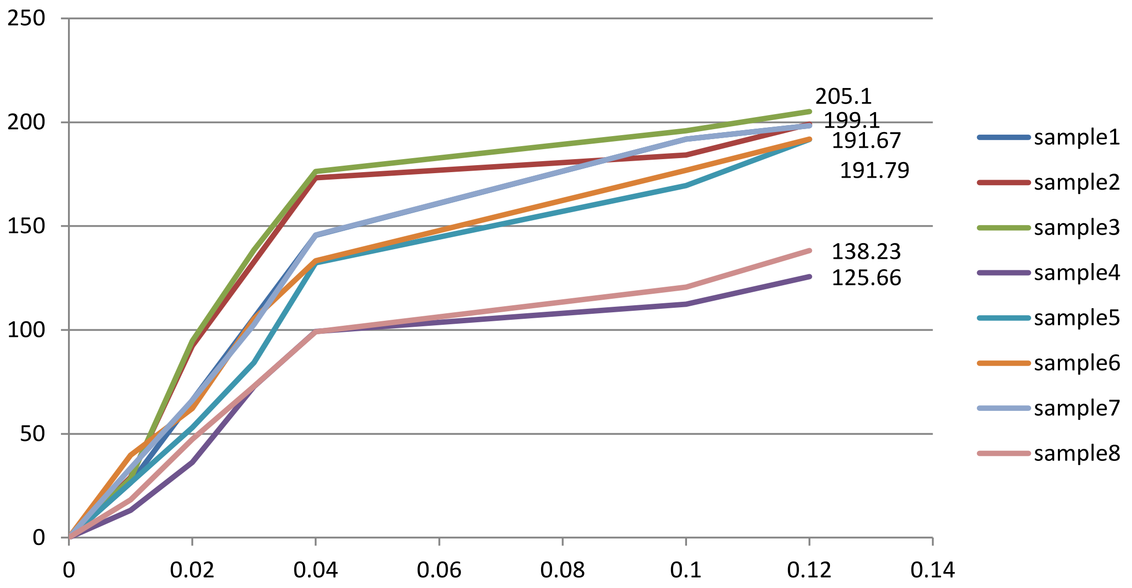


**Figure 17.** Graph of Tensile Strength

### *4.4 Vickers Hardness*

The Vickers hardness test was carried to measure the hardness of welded parts. The machine has a diamond indenter, a small load which produce an indentation on work piece which is subjected to the hardness test. The depth of indentation, to fix the hardness, likewise, if the indentation is large the material lacking in hardness, is it small the object has more. This test is utilized by more industries to determine the right type of material to use for many applications. A material with ultimate hardness according to its purpose, It should be selected.

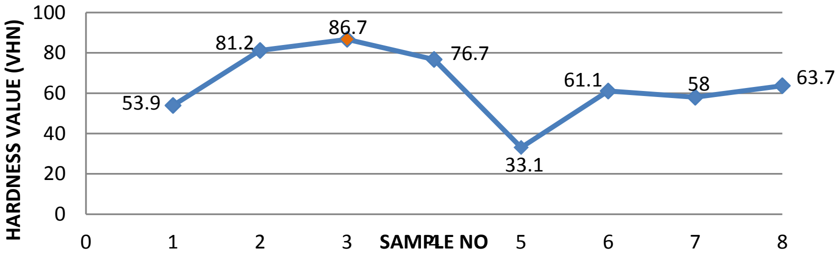


**Figure 18.** Vickers Hardness of Welded part

**Table 2.** Vickers Hardness of Welded part

| SAMPLE NO | PROFILE | RPM | FEEDRATE (MM/MIN) | HARDNESS VALUE (HV) |
|---|---|---|---|---|
| 1 | Circular | 710 | 20 | 53.9 |
| 2 | Circular | 900 | 20 | 81.2 |
| 3 | Circular | 1220 | 40 | 86.7 |
| 4 | Circular | 1400 | 40 | 76.7 |
| 5 | Threaded | 710 | 20 | 33.1 |
| 6 | Threaded | 900 | 20 | 61.1 |
| 7 | Threaded | 1220 | 40 | 58 |
| 8 | Threaded | 1400 | 40 | 63.7 |

## 5. Conclusion

In this work, The experimental investigation of a friction stir welding joints between aluminum AA5083 by changing the parameters, tool profiles, speed, feed rate then study influences of the friction stir welding on the microstructure and hardness of aluminum AA5083.

The results are summarized as follows.

1) As for the conditions the best speed is 1220 rpm and welding speed of 40 mm per minute and tensile strength 205.1N/mm$^2$

2) The maximum hardness of 86.7 VHN in spindle speed of 1220rpm, which resulted in a high tensile strength.

3) The weld zoned was divided into three regions (centre of weld, Advance side, Retreat side of AA5083) base on the microstructure the centre of weld had fine grain due to dynamic recrystallisation affect the tensile strength and hardness is higher.

4) Here by we conclude that at 1200 rpm at the feed rate of 40mm/min, the effective weld can be achieved.

5) Metal oxidation results in localized acidity is maintained continuously undergoing the cathodic and anodic reactions. The acidity breaks the passive layer which creates the potential gradient.

## 6. References

[1] Esther T, Akinlabi and Stephen 2012 Friction Stir Welding Process: A Green Technology, World Academy of Science, *Engineering and Technology*. **6**, 11.

[2] GAO Yefei, Tsumura Takuya, Nakata Kazuhiro 2012 Dissimilar Welding of Titanium Alloy and Steels Transactions of JWRI is published by Joining and Welding Research Institute, Osaka University, Ibaraki. **41**, 07-12.

[3] Galvão , D Verdera , D Gesto , A Loureiro , D. M. Rodrigues 2009 Analysing The Challenge of Aluminium to Copper FSW AIMEN, Relva 27A Torneiros.36410 Porriño, Spain.

[4] K Kimapong and T. Watanabe, 2004 Friction Stir Welding of Aluminium Alloy to Steel, *the Welding Journal*, 277 – 282.

[5] R S Mishra, Z Y Ma 2005 Friction stir welding and processing Materials Science and Engineering. **50**, 1–78.

[6] K D Bhatt, Bindu Pillai, A M Trivedi 2013 Effect of Size of Tool on Peak Temperature & Viscosity during Friction Stir Welding of AA6061-T6Aluminium Alloy Using Hyper Works *International Journal of Innovative Research in Science*, Engineering and Technology. **2,** 2347-6710.

[7] R Rai, a De, H K. D H.Bhadeshia and T DebRoy, 2011 Review: friction stir welding tools, *Science and Technology of Welding and Joining*. **16**, 325-341.

[8] Saad Ahmed Khodir and Toshiya Shibayanagi 2007 Dissimilar Friction Stir Welded Joints between 2024-T3 Aluminium Alloy and AZ31 Magnesium Alloy Materials Transactions, *The Japan Institute of Metals*. **48,** 2501 to 2505.

[9] Sajin G Sajan, Manish Meshram, Pankaj, Palli Srinivas, Suhash R. Dey, Friction Stir Welding of Aluminium 6082 with mild steel and its joint analyses, *Department of Materials Science and Engineering, Indian Institute of Technology.**3**,1-6.*

[10] V Firouzdor And S Kou 2009 Al-to-Mg Friction Stir Welding: Effect of Positions of Al and Mg with Respect to the Welding Tool, Supplement to The Welding Journal, *Sponsored by the American Welding Society and the Welding Research Council*.

[11] Woong-Seong Chang, S.R. Rajesh, Chang-Keun Chun and Heung-Ju Kim 2011 Microstructure and Mechanical Properties of Hybrid Laser-Friction Stir Welding between AA6061-T6 Al Alloy and AZ31 Mg Alloy science Direct J. Mater. Sci. Technol.**3**, 199-204.

[12] Yuhua Chen, Changhua Liu and Geping Liu 2011Study on the Joining of Titanium and Aluminium Dissimilar Alloys by Friction Stir Welding The Open Materials Science Journal. **5**, 256-261.