IJSRD - International Journal for Scientific Research & Development| Vol. 4, Issue 09, 2016 | ISSN (online): 2321-0613

To Study the Effect of Process Parameters on Mechanical Properties of Friction Stir Welded AA 6063 Aluminium Alloy

Gurpreet Singh[1] Gurlal Singh[2]
[2]Assistant Professor
[1,2]Department of Mechanical Engineering
[1,2]Desh Bhagat University Mandi Gobindgarh

Abstract— Friction stir welding is widely used in joining aluminium alloys in industries, especially, the shipbuilding, aerospace, mass transportation and automotive and other commercial importance. This process is considered as "green technology" due to its energy efficiency, environmental friendly and versatility. Friction stir welding was carried out using a vertical milling machine on aluminium 6063 alloy. The tool material and geometry were carefully chosen and prepared using lathe machine. Important process parameters that control the quality of the weld and rotation speed (rpm), transverse speed (mm/min), tool depth (mm) and tool tilt angle and these process parameters were optimized to obtain defect free welding joints. it is observed that, during the friction stir welding, extensive deformation takes place at the nugget zone and the evolved microstructure properties of the joint. The aim of present study is to understand the mechanical properties and study wear test of Friction Stir Welding of AA 6063. In order to study the mechanical properties, we applied Micro Vickers hardness test and tensile test on FSW AA 6063 Aluminium alloy.

Key words: Al 6063 aluminium Alloy, friction Stir Welding, Micro Vickers Hardness test, Tensile Test and Wear Test, Orthogonal L9 method

I. INTRODUCTION

Friction Stir Welding (FSW) was invented by The Welding Institute (TWI) of the United Kingdom in 1991 as a solid-state joining technique, was initially applied to Aluminium alloys, and is extensively used in joining of Al, Mg, Cu, Ti and their alloys. The basic concept of FSW is that a non-consumable rotating tool with especially designed pin and shoulder is inserted into the abutting edges of sheets or plates to be joined and subsequently traversed along the joint line. In FSW, a cylindrical-shouldered tool, with a profiled threaded/unthreaded probe or pin is rotated at a constant speed and fed at a constant traverse rate into the joint line between two pieces of sheet or plate material, which are butted together as shown in Figure 1(Thomas, W.M. et al.)(1)

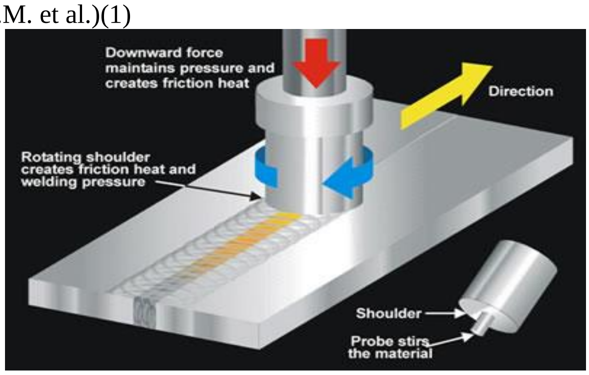


Fig.1 Schematic of Friction Stir Welding Process (www.friction stir welding.com)(2)

The tool serves primary functions: (a) Heating of workpiece, (b) deform the material to produce the joint. The heating is accomplished by friction between the rotating 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. Friction Stir Welding is considered to be the most significant development in metal joining in a decade. In Friction Stir Welding no cover gas or flux is used, thereby making the process environmentally friendly, energy efficiency and versatility or it is a "green technology‟. The joining does not involve any use of filler metal and therefore any aluminium alloy can be joined without concern for the compatibility of composition, which is an issue in fusion welding. (Sabarisarathkumar. et al)(3)

Elangovan, K. et al. (2008)(4) fabricated "the joints, square pin profiled tool produced defect free FSP region, irrespective of shoulder diameter of the tools". Of the three tool shoulder diameters used in this investigation to fabricate the joints, a tool with 18 mm shoulder diameter produced defect free FSP region, irrespective of tool pin profiles. Of the 15 joints fabricated in this investigation, the joint fabricated using has worked on the Influences of tool pin profile and tool shoulder diameter on the formation of friction stir processing zone in AA6061 aluminium alloy. Babu, G.R. et al. (2008)(5) studied the effect of processing parameters on mechanical and microstructural properties of aluminium alloy 6082-T6 FSW joints. Different welded specimen was produced by using processing parameters such as rotational speed (rpm) and welding speed. Tensile strength of produced joint was tested at room temperature and the correlation with process parameters was assessed. Arora, A. et al. (2011)(6)experimentally and theoretically explained that a criterion that balances the need for low flow stress for good material flow and the contrasting requirement for the tool to have a good grip on the plasticized material can be used to identify an optimum shoulder diameter. Performed FSW experiments on AA7075-T6 for a number of tool shoulder diameters and tool rotational speeds and used a three-dimensional, heat transfer and viscoelastic flow model to simulate these welding experiments. Biswajit Parida et al. (2011) (7) studied on the development of FSW of commercial grade Al-Alloy to study the mechanical and microstructural properties. The proposed research will include experiments related to the effect of FSW optimum process parameter on weldebility of Al Alloy. The paper has been subdivided in to two different sections 1. Studied mechanical properties and 2. Studied of microstructural properties. In this investigation the test was performed tensile test, microhardness test microstructure test.

Jayaraman, M. et al. (2012) (8) studied on effect process parameters on tensile strength of FSW cast A 356 aluminium alloy joints. Attempt was made to study the effect of FSW process parameters on the tensile strength of cast A356 aluminium alloy. Joints were made using different combinations of tool rotation speed, welding speed and axial force. The quality of weld zone was analysed by macrostructure and microstructure analyses. Ram Niwas Bishno et al. (2013)(9) an investigation has been carried out on friction stir welding (FSW) in 6mm thick plates of AA19000 aluminium alloy using high carbon high chromium alloy steel tool. Three different tool pin profiles namely straight cylindrical threaded and square have been used to fabricate the joint at constant tool rotational speed of 1400 rpm and traverse speed of 20mm/min.

Cavalierea et al. (2008)(10) Studied the “effect of processing parameters on mechanical and micro structural properties of AA6082 joints produced by friction stir welding”. Result showed that a strong variation in the nugget mean grain size was observed by increasing the advancing speed from 40 to 165mm/min. corresponding to no further variations by increasing the speed up to 460 mm/min. The yield strength was recorded to increase strongly from the lower speeds to 115mm/min and after starts to decrease by increasing the advancing speed; the ductility of the material followed the same behavior but restarted to increase after 165 mm/min.

II. Experimental Procedure

The chemical composition of AA6063 aluminium alloys is given in Tables 1 respectively.

Elements	% Percentage
Copper	0.047
Magnesium	0.032
silicon	0.525
Iron	2.008
Manganese	0.180
Nickel	0.01
Zinc	0.315
Tin	0.004
Titanium	0.004
Aluminium	96.550

Table 1: Chemical composition of aluminium alloy Al 6063

AA 6063 Aluminium Alloy plates (100mm X 50mm X 6mm) are used for this experiment tool is designed. The material of the tool is HSS steel is used. The profile of this tool is having outer shoulder diameter of 16mm, pin diameter 5mm is use for friction stir welding for AA6063 Aluminium Alloy plates. The tool used in FSW process was simple cylindrical tool. The FSW is carried out on Universal Milling Machine at CTR (central machine tool), Ludhiana. The plates are positioned in the fixture, which is prepared for fabricating FSW joints by using mechanical clamps so that the plate will not be separated during welding illustrated in Figure2. The tool is fixed in the tool holder of the milling machine

Fig. 2: FSW process in CNC Milling Machine


Fig. 3: HSSFSW Tool

Tool geometry play an important role during friction stir welding. By reviewing the various research papers, the tool dimensions, material and hardness are selected. For performing the experiment, a special type of FSW tool is manufactured from Super Capital Tool, Patiala.

The parts produced in FSW of aluminium alloys have been becoming increasingly significant in industrial applications because of their technical and economic benefits. The article contains mainly the selection of tool material and process parameters with experimentation trials of FSW of AA6063. Also this contains the large overview on tool material selection which depends on the operational parameters such as temperature of the operation, wear resistance, geometry and load bearing ability also the tool degradation process. (Bhasale, S.R. et al. (2015) (11)

The various tests were performed on the welded part that includes the tensile strength, Vickers hardness test and wear test In the results proved that the highest tensile strength and Vickers hardness value of welded joint (Ali Akbar Nadim et al. (2014)(12)

A. Selection of Orthogonal Array

According to the L9 orthogonal array, there experiments in each set of process parameters have been performed on AA 6063 alloy plates. The three factors used in this experiment are the rotational speed (rpm), feed rate (mm/min), axial force (KN). The factors and levels of the process parameters are present in the table no.2 and these parameters are taken based on the trials to weld the FSW of AA 6063 alloy plates.

Fig. 4: Formation of pin using disc grinder for wear test

Fig. 5: Sample after Tensile Testing FSW AA 6063 samples

B. Micro Vickers hardness test

Hardness is the property of a material that enable it to resist plastic deformation; mainly by penetration. Hardness can also be termed as resistance to scratching, abrasion or cutting and bending. This method consists of indenting the test material having a diamond indenter. The indenter is in the form of right pyramid having a square base. The angle between opposite face is 136. The load is applied 10 to 500 gm.

C. Tensile test

Tensile property expresses how the materials will react to forces being applied in tension. A tensile test issued fundamental mechanical test where a carefully prepared is loaded in very controlled manner while measuring the applied load and elongation of the specimen over some distance. Tensile test is used to determine the modulus of elasticity, elastic limit, elongation, proportional limit, tensile strength, yield point, yield strength and other tensile properties.

D. Wear test

In a pin on disc wear test, there is a circular wear path, which is described by machine in which, pin is loaded against a flat rotating disc specimen under pure sliding condition. Both wear and friction property of material can be measured using machine. Wear measurement is carried out to determine the amount of material removed after a wear test.

III. Results and Discussions

The study of effect of process parameters on mechanical properties of FSW AA6063 has been performed by using Orthogonal L9 method and Qulaitek4 software. In this experiment the three factors are used rotational speed (rpm), feed rate (mm/min), axial force (mm).The factors and the levels of the process parameters are presents in the table no.2. In experiments, three parameters and three levels were used with the help of L9 orthogonal array method.

Exp.	Rotational speed(rpm)	Feed rate(mm/min)	Axial force(mm)
1.	900	15	4
2.	900	20	5
3.	900	25	6
4.	1200	15	5
5.	1200	20	6
6.	1200	25	4
7.	1500	15	6
8.	1500	20	4
9.	1500	25	5

Table 2: DOE using orthogonal array L9

A. Micro Vickers Hardness Testing Results

The hardness of friction stir welded AA 6063 aluminium alloy is performed on Microhardness testing machine. Vickers testing machine is used instead of Rockwell testing machine. The reason was that Vickers hardness test gives extremely accurate reading. Using orthogonal array L9 method is adopted in which there are three parameters, three factors and three levels have been taken. The hardness of 9 samples was measured with the help of the Micro Vickers hardness testing machine.

The mean hardness values are shown in table 3. The applied load was taken 300 g. for all 9 experiments. The Micro Vickers Hardness test was performed in Research and Development Centre for Bicycle and Sewing Machine in Ludhiana.

Exp.	Rotational speed	feed rate	Axial force	Hardness (HV)	Mean Hardness
1.	900	15	4	56	51
2.	900	20	5	56	52
3.	900	25	6	56	51
4.	1200	15	5	46	45
5.	1200	20	6	56	49
6.	1200	25	4	56	50
7.	1500	15	6	56	54
8.	1500	20	4	54	53
9.	1500	25	5	54	52

Table 3: Micro Vickers Hardness Test Results using OA L9

The values of hardness depend on the presence and uniform distribution of material. It has been concluded that the value of hardness in FSW is increases with increase in tool rotational speed (rpm). The maximum hardness value during FSW is 56 HV. The minimum value of Hardness is 46 HV.

Parameters	Level 1	level 2	level 3
Rotational speed	51.333	48	53
Feed rate	50	51.333	51
Axial force	51.333	49.666	51.333

Table 4: Mean hardness value (HV) for each parameter

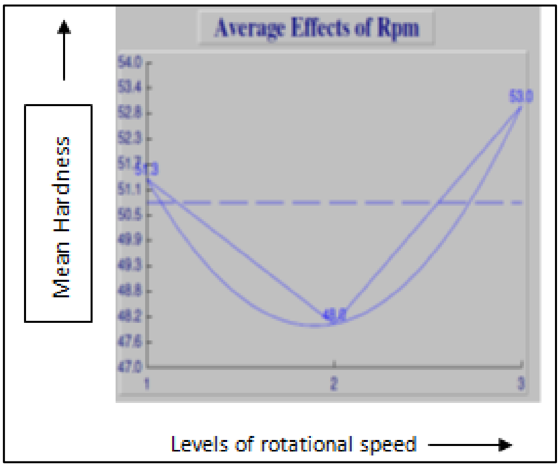


Fig. 6: Change in hardness value with variation of RPM

The maximum value of hardness can be obtained at 1500 rpm.

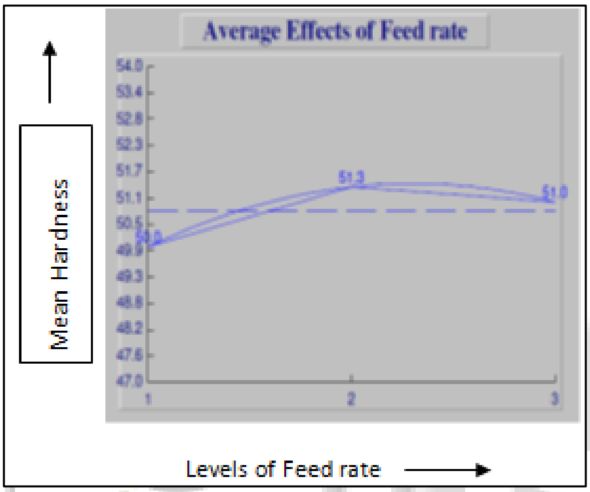


Fig. 7: Change in hardness value with variation of feed rate

The maximum value of hardness is obtained at 20 mm/min feed rate (mm/min).

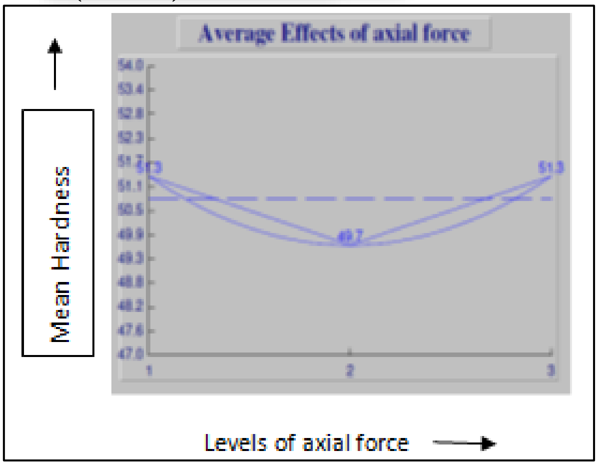


Fig. 8: Change in hardness value with variation of feed rate

It is clear from the graph that the mean value of hardness is 51.333 HV at 4KN, at 5KN the mean value of hardness is 49.666 HV and at 6KN there is increase in mean value of hardness which is 51.333 HV.

B. Tensile Test Results

In tensile test, the Ultimate Tensile strength (UTS) has been determined in all 9 experiments. In this orthogonal array L9 has been applied.

The observation table for (UTS) is given below. All values are in N/mm2.

Tensile property expresses how the materials will react to forces being applied in tension. A tensile test issued fundamental mechanical test where a carefully prepared is loaded in very controlled manner while measuring the applied load and elongation of the specimen over some distance.

This tensile test is performed in research and development Centre for bicycle and sewing machine in Ludhiana. Only the value of tensile strength has been analysed from all 9 experiments.

Exp.	Rotational speed	Feed rate	Axial force	UTS (N/mm^2)	UTS Mean
1.	900	15	4	52.40	52.40
2.	900	20	5	51.30	51.30
3.	900	25	6	21.10	21.10
4.	1200	15	5	47.10	47.10
5.	1200	20	6	4.70	4.70
6.	1200	25	4	66.90	66.90
7.	1500	15	6	4.10	4.10
8.	1500	20	4	10.50	10.50
9.	1500	25	5	10.40	10.40

Table 5: Value of Tensile Strength using OA L9

In the above results the maximum value of tensile strength is 66.90 N/mm^2 at 1200 rpm and 25 mm/min feed rate. Table 5 the rank importance of the various factors in terms of their relative significance has been shown. The table 6 shows the effect of each parameter on the UTS of the FSW AA 6063.

Parameters	Level 1	Level 2	Level 3
Rotational speed(rpm)	41.599	39.566	8.333
Feed rate(mm/min)	34.533	22.166	32.799
Axial force(mm)	43.266	36.266	9.966

Table 6: Mean of Ultimate Tensile Strength for Each parameter

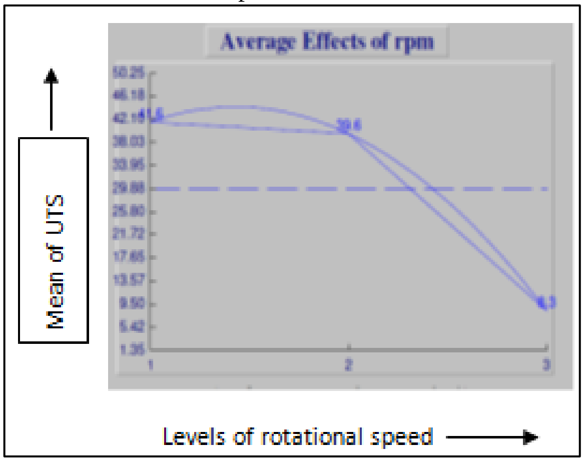


Fig. 8 : Change in tensile strength value with variation of RPM

The maximum value of tensile strength can be achieved at 900 rpm.

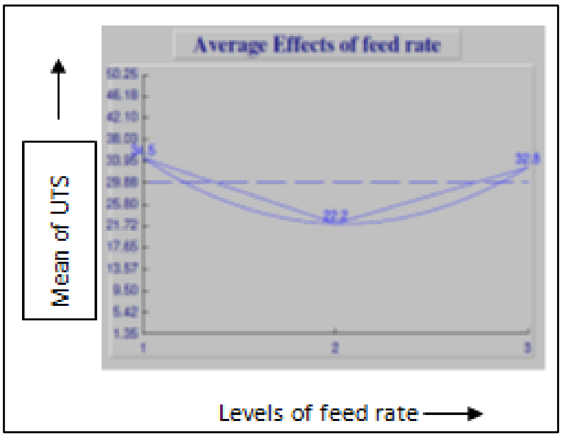


Fig. 9: Change in tensile strength value with variation of feed rate

The maximum value of tensile strength is obtained at 15 mm/min feed rate (mm/min).

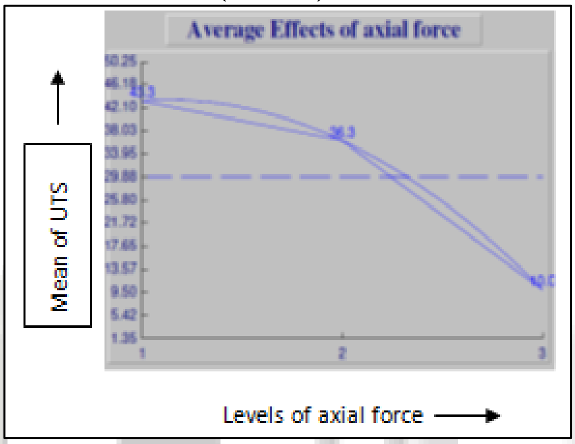


Fig. 10: Change in tensile strength value with variation of axial force

It is clear from the graph that the mean value of tensile strength is 43.266 N/mm^2 at 4KN, at 5KN the mean value of tensile strength is 36.266 N/mm^2 and at 6KN there is decrease in mean value of tensile strength which is 9.966 N/mm^2.

C. Wear Test Results

This wear test was performed on pin on disc machine. For all 9 specimens, the load was 29.43N, speed was 170 rpm at 10 min of time. In a pin on disc wear test, there is a circular wear path which is described by machine in which pin is loaded against a flat rotating disc specimen under pure sliding condition. Both wear and friction property of material can be measured using machine. Wear measurement is carried out to determine the amount of material removed after a wear test. The initial and final weight of all specimens in gm. was given below: -

Sr. No.	Initial weight(gm.)	Final weight (gm.)	Weight loss
1.	6.404	6.391	0.013
2.	7.203	7.188	0.015
3.	6.152	6.133	0.019
4.	6.465	6.457	0.008
5.	4.978	4.958	0.02
6.	6.970	6.954	0.012
7.	6.023	5.991	0.032
8.	5.655	5.648	0.007
9.	5.501	5.648	0.094

Table 7: Weight loss of all nine specimens

Specimen No.	Rotational speed	Feed rate	Axial force	wear rate(μm)	Mean of wear rate
1.	900	15	4	124.97	124.97
2.	900	20	5	286.58	286.58
3.	900	25	6	129.33	129.33
4.	1200	15	5	136.79	136.79
5.	1200	20	6	281.24	281.24
6.	1200	25	4	338.14	338.14
7.	1500	15	6	252.29	252.29
8.	1500	20	4	234.86	234.86
9.	1500	25	5	911.37	911.37

Table 8: Wear rate of nine specimens using OA

Parameters	Level 1	Level 2	level 3
Rotational speed	180.273	249.389	499.506
Feed rate	204.663	267.559	256.946
Axial force	229.97	444.913	254.286

Table 9: Mean Wear rate (micrometre) for each Parameter

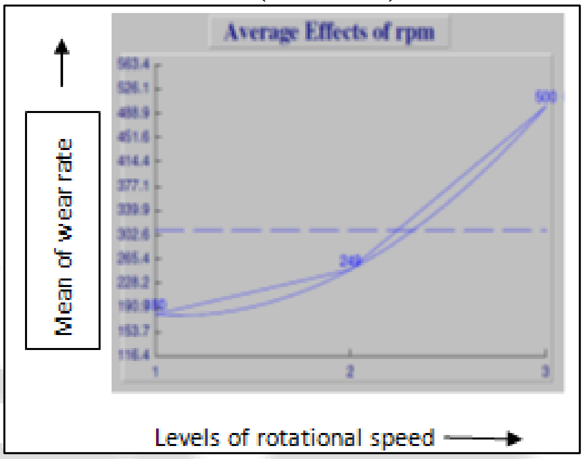


Fig. 11: Change in Wear rate value with variation of rotational speed

It has been observed that with increase in tool rotational speed from 900 rpm to 1500 rpm, there is an increase in wear rate values of the specimen.

So the minimum value of wear rate is achieved at 900 rpm is 180.273.

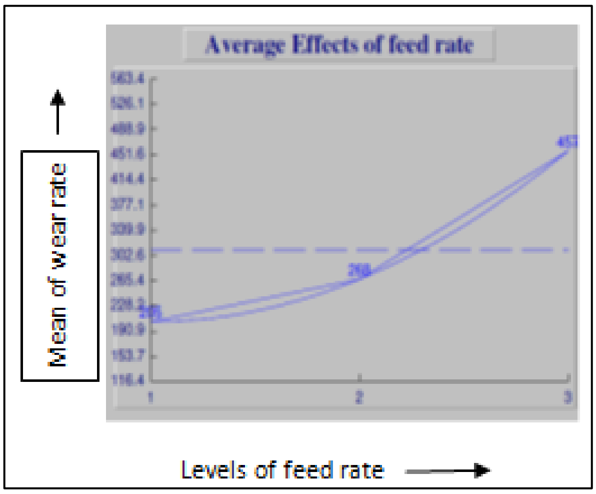


Fig.12: Change in Wear rate value with variation of feed rate

The minimum value of wear rate is achieved at 15 mm/min is 204.663

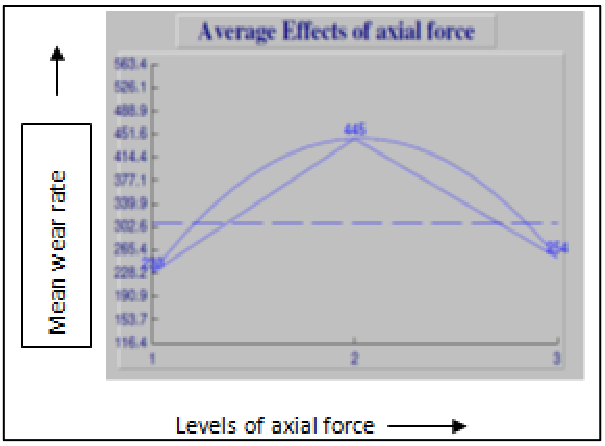


Fig. 13: Change in Wear rate value with variation of axial force

It has been concluded from the graphs the minimum values of wear rate achieved at rotational speed 900 rpm, feed rate 15 mm/min and axial force 4KN. The minimum value of wear rate is achieved at 4KN is 229.97.

D. Wear Rate Graphs

Following 9 graphs showing the variation of wear rate with variation of time, rpm and and load is remaining constant.29.43 N

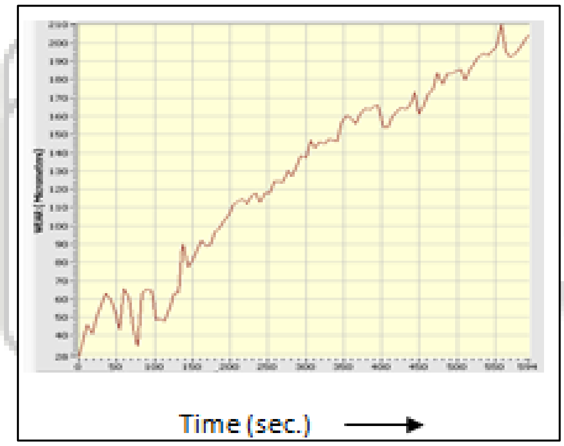


Fig. 14: Wear Rate curve for specimen no.1 (At 900 rpm, 15 mm/min and 4 KN)

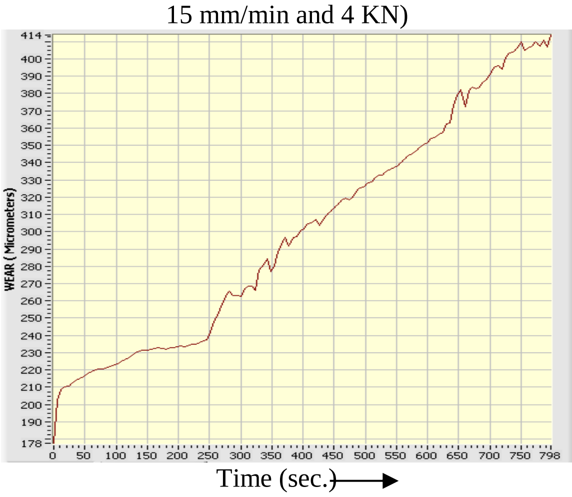


Fig. 15: Wear Rate curve for specimen no.2 (At 900 rpm, 20 mm/min and 5 KN)

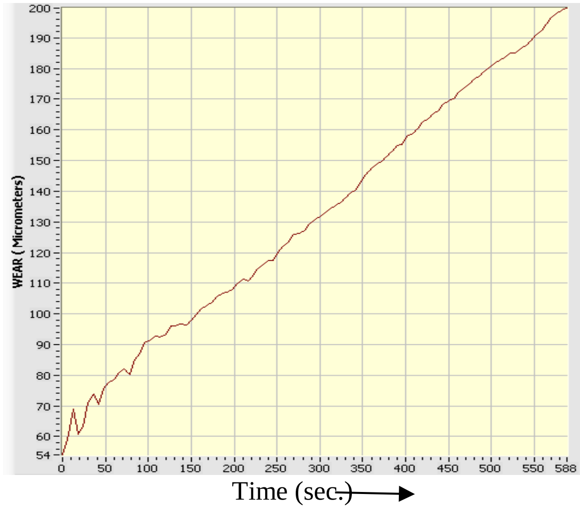


Fig. 16: Wear Rate curve for specimen no.3 (At 900 rpm, 25 mm/min and 6 KN)

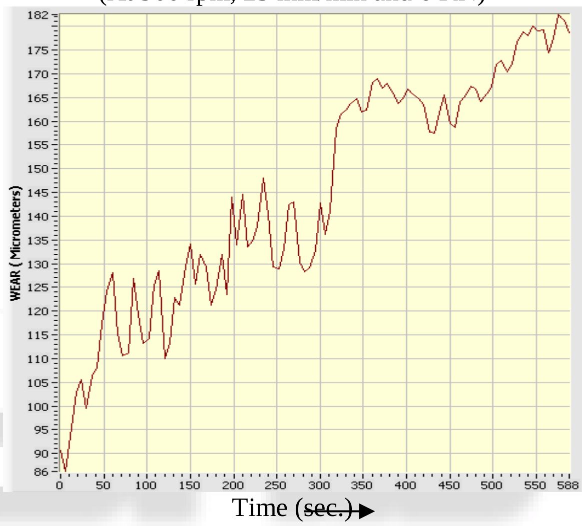


Fig. 17: Wear Rate curve for specimen no.4 (At 1200 rpm, 15 mm/min and 5 KN)

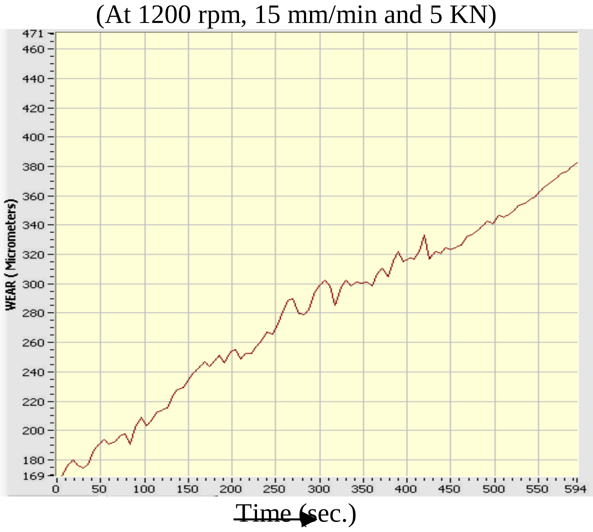
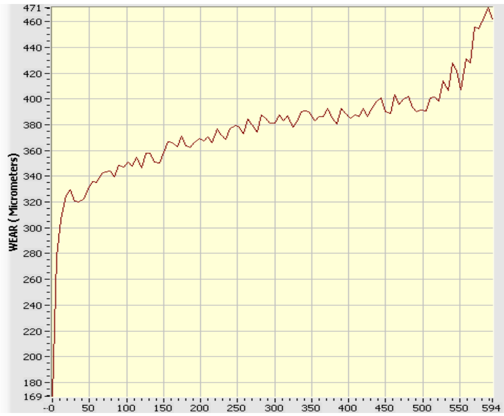
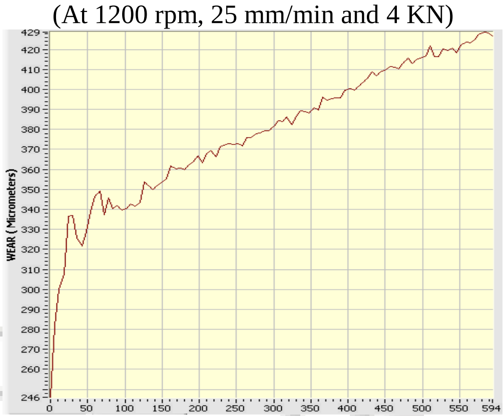


Fig. 18: Wear Rate curve for specimen no.5 (At 1200 rpm, 20 mm/min and 6 KN)



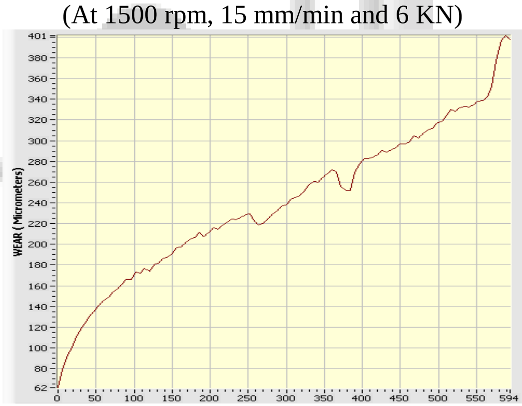
Time (sec.) ⟶

Fig. 19: Wear Rate curve for specimen no.6
(At 1200 rpm, 25 mm/min and 4 KN)



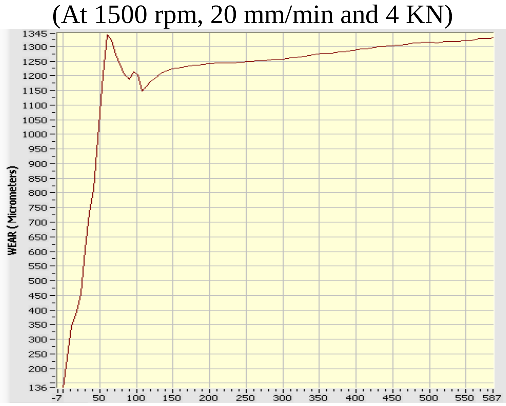
Time (sec.) ⟶

Fig.20: Wear Rate curve for specimen no.7
(At 1500 rpm, 15 mm/min and 6 KN)



Time (sec.) ⟶

Fig. 21: Wear Rate curve for specimen no.8
(At 1500 rpm, 20 mm/min and 4 KN)



Time (sec.) ⟶

Fig. 22: Wear Rate curve for specimen no.9
(At 1500 rpm, 25 mm/min and 5 KN)

IV. Conclusion

1) The maximum value of hardness can be achieved at rotational speed of tool is 1500 rpm and feed rate of tool is 15 mm/min and axial force is 6KN. The maximum value of hardness is 54 HV.
2) ii) The maximum value of tensile strength is obtained 66.90 N/mm2 when tool rotational speed is 1200 rpm, feed rate of tool is 25 mm/min and axial force is 4 KN.
3) iii) Wear properties are improved at 900 rpm, 15 mm/min feed rate of tool and the axial force of the tool is 4KN.In the wear test result the wear rate increases with increase in rpm. In the wear, result the minimum value of wear rate is achieved 124.97 Micrometre.

V. Future Scope

The research could be taken further by applying the same technique too other aluminium alloys as 5XXX and 7XXX which are the alloys used in automotive industry. This could help the increase of use of the friction stir welding in the automotive industry.

Further studies may be done, considering most of welding parameters, on a wider range of values. Fatigue analysis, Izard chirpy test can be conducted.

Welding of material like copper, titanium and magnesium by using friction stir welding with different process parameters is another area of interest.

Higher thickness aluminium plates can be welded by employing double sided FSW. One can try to use tools made of different materials to improve the quality of joints.

References

[1] Thomas, W.M., Nicholas, E.D., Needham, J.C., Murch, MG. Templesmith, P., Dawes, CJ., (2003), “Friction Stir Welding Aluminium Process and Applications”, Journal of Material Science, vol. 419, pp 251-262.
[2] Www.en wikipedia.org / wiki/Frictions stir welding.
[3] Sabarisarathkumar,S., Dr. M. Muthu Krishnan (2015), “A study of process parameters of fsw of AA 6063 aluminium alloys”, International Journal of Advances in Engineering Research, (IJAER) 2015, Vol. No. 10, Issue No. VI, December,pp.145-154.
[4] 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 and Design, Vol. 29, pp 362–373.
[5] Babu, G.R., Murti, H.G.K. and G. Ranga. Janardhana (2008), “An experimental study on effect on welding parameters on mechanical and microstructural properties of AA 6082-T6 FSW”, Journal of Engineering and applied science, vol.3.
[6] Arora, A. Deand, A., DebRoy,T., (2011), “ Toward Optimum Friction Stir Welding Tool Shoulder Diameter”,Scriptamaterialia,Vol. 64, pp 9–12.
[7] Biswajit Parida, Sukhomay Pal, Pankaj Biswas, Mohapatra, M.M., Sujoy Tikader(2011), “ Mechanical and Microstructure Study of Friction Stir Welding of Al –Alloy”, International Journal of Applied Research in Mechanical engineering , Volume -1, Issue -2.
[8] Jayaraman, M., Balasubrmaniam,V. (2012),“Effect of process parameters on tensile strength of friction stir

welded cast A356 aluminium alloy joints" , Elsevier, pp. 605-615.

[9] Ram Niwas Bishnoia, Pawan Kumar Saprab and Raman Bhambhu (2013), "Effect of Tool Pin Profile on Mechanical Properties of Single and Double Sided Friction Stir Welded Aluminium Alloy AA19000", International Journal of Current Engineering and Technology, Vol.3, No.4 , pp. 1338-1341.

[10] Cavalierea, P., Squillaceb, A., Panellaa, F., (2008), "Effect of Welding Parameters on Mechanical and microstructural Properties of AA6082 Joints Produced By Friction Stir Welding", Journal of Materials Processing Technology, Vol. 2 0 0 , pp 364–372.

[11] Bhasale,S.R., Prof. M. K. Wasekar (2015), " Friction stir welding of AA 6063 aluminium alloy experimentation and testing", International Journal of Innovative Research in Science, Engineering and Technology , vol. 2.

[12] Ali Akbar nadim, Hakeemuddin Ahmed (2014), "Design, Fabrication and Testing of FSW welded joints," International journal of innovative research in science, Engineering and Technology, Vol.3, Issue 11, pp. 17261-17268.