International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 5 **Issue:** XII **Month of publication:** December 2017

DOI:

Effect of Tool Pin Profile on Mechanical Strength on Friction Stir Welded AA 6063 Joint

Deepti Jaiswal[1], Sunil Pandey[2]
[1, 2] *First-second Department of mechanical engineering, First-second IIT Delhi*

Abstract: AA-6063 T5 aluminum alloy (Al-Mg-Si alloy) is widely used in the fabrication of light weight structures requiring a high strength-to-weight ratio and good corrosion resistance. Friction stir welded joints of aluminum alloys are extensively employed in marine frames, pipelines, storage tanks and aircraft applications. In this research work an attempt has been made to understand the effect of tool profiles, tool dimensions and process parameters on mechanical properties and microstructure of friction stir welded AA6063 T5 joints. Square tool profile with shoulder diameter to pindiameter ratio 3: 1found best for higher tensile and impact strength. Rotation per minute (rpm) found the most significant parameter for welding followed by welding speed, shoulder-diameter, pin-diameter and tool geometry. Beyond 1000 rpm, strength of joint start decreasing due to stresses and higher heat generation.
Keywords: friction stir welding, aluminium alloy, tool design, parametric optimization, tool shape

I. INTRODUCTION

Friction stir welding (FSW) is latest development in solid state joining processes and extensively used for welding aluminum alloys. FSW becomes more popular due to its energy efficiency, environmental friendly nature and versatility**[1]**. FSW tool heat the work piece and stir/intermix the material for joining metals together. Friction stir welding tool is critical component for successful welding. Rotating round shoulder and cylindrical pin of FSW tool heat the work piece by frictional heat and moves the soften alloy to produce sound weld. Tool shape and material is critically important due to stress and higher temperature faced by it**[2]**. Tool should be designed for higher strength and longer life span.

Recently many recercher worked on parametric optimization and tool design of friction stir welding **[3-10]**. Combination of tool design and parametric optimization for higher mechanical strength was not found in literature for AA 6063 T5 alloy joints. This paper provides detailed study of optimization and effect of various parameters (rpm, pin diameter, shoulder diameter, welding speed) along with tool profile for friction stir welding of aluminum alloy.

II. EXPERIMENTATION

A. Consumables

The rolled plates of 6 mm thickness, AA6063 T5 aluminum alloy, have been cut into required size (300 mm x 100 mm) by power hacksaw cutting and milling. Butt joint configuration has been prepared to fabricate FSW joints. The initial joint configuration is obtained by securing the plates in position by clamping in the fixture. The direction of welding is normal to the rolling direction. Single pass welding procedure has been used to fabricate the joints. The chemical composition and mechanical properties of base metal are presented in Table 1 and Table 2.

TABLE 1 ALLOYING ELEMENT IN THE BASE METAL OBTAINED BY OPTICAL EMISSION SPECTROSCOPY

Element	Weight %
Mg	0.65
Cr	0.053
Cu	0.043
Fe	0.254
Mn	0.042
Si	0.35
Zn	0.0257
Al	Balance

TABLE 2 MECHANICAL PROPERTIES OF BASE METAL

Mechanical Properties	Values Tested
Tensile Strength. UTS (MPa)	140
% Elongation	18% @ 24°C
Vicker hardness (HV_{100})	73

B. *Equipment*

Vertical milling machine (VMM: model VF-3.5, Bharat Fritz Werner Limited make with 11 kW main spindle power, 1.3 kW power feed and digital position display along three axes) available in the machine shop of central workshop, IIT-Delhi, was used for the experimentation. Pre-weld cleaning was done in two steps: oil/grease removal and oxide removal. Oils and greases were removed first, then removed the oxide.

C. *Tool material and tool geometry*

The primary function of the non-consumable rotating tool pin is to stir the plasticized metal and move the same behind it to have good joint. Pin profile plays a crucial role in material flow and in turn regulates the soundness of the welded joint produced. Pin profiles with flat faces (square and triangular) are associated with eccentricity. This eccentricity allows incompressible material to pass around the pin profile **[11,12]**. Thus, in the present study three different tool pin profiles viz., (a) threaded cylindrical, (b) triangular, and (c) square are used to examine the effect of pin profile on the welded joint. Non-consumable tool made of high speed steel(H-13) has been used to fabricate the joints. Three different tool pin profiles as shown in Fig. 2 have been used to fabricate the joints.

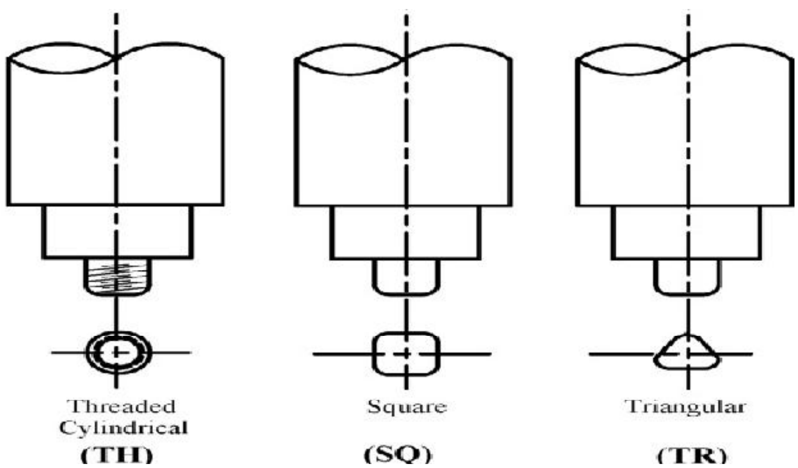


Figure 1 FSW tool pin profiles

D. *Process Parameters and their ranges*

It was observed during trial runs that mechanical strength of joint has been increasing continuously till 1000 rpm and beyond that it starts decreasing. High stresses and temperatures may be the reason for this decrement. Hence to observe the effect of process parameters accurately, experiments were performed in two sets (SET-I and SET-II) as shown in Table 3 and Table 4. Taguchi Design L9 was selected for the study. To observe the effect of variable accurately experiments were performed in random manner. Set-up for friction stir welding is shown in Figure 2. Welded plates are shown in Figure 3.

TABLE 3 PARAMETERS FOR SET-I

Input parameters	Levels		
	1	2	3
Tool geometry	Triangular	Square	Cylinder
RPM	500	750	1000
Welding speed (m/min)	50	75	100
Shoulder diameter (mm)	14	16	18

TABLE 4 PARAMETERS SET-II

Input parameters	Type of parameter	Levels		
		1	2	3
Atmosphere	Categorical	Air	Water	_
Tool geometry	Categorical	Triangular	Square	Cylinder
RPM	Numerical	1000	1500	2000
Welding speed (m/min)	Numerical	100	125	150
Shoulder dia (mm)	Numerical	18	20	22

Figure 2 Setup for underwater friction stir welding


Figure 3 Welded specimen

III. RESULTS AND DISCUSSION

A. *Mechanical Testing of the Weld specimens*

American Society for Testing of Materials (ASTM E8M) guidelines are followed for preparing test specimens. Tensile test has been carried out in 100 KN, electro-mechanical controlled Universal Testing Machine**[13]**. The specimen was loaded at the rate of 1.5 KN/min as per ASTM E8M specifications, so that tensile specimen undergoes deformation. The specimen finally fails after necking and load versus displacement has been recorded.

Impact tests were performed on standard notched test specimens (ASTM E 23-04) machined on wire-EDM. The impact energy absorbed by each sample was calculated and analyzed for effect of process parameters and their interactions. Impact testing was conducted at room temperature using a pendulum-type impact testing machine (ENKAY, India) with a maximum capacity of 300 J.

The amount of energy absorbed in fracture was recorded, and the absorbed energy is defined as the impact toughness of the material. ASTM E23-04 specifications were followed for preparing and testing the impact specimens [14].Three specimens are tested at each condition for tensile and impact test and average of the results of three specimens is presented in Table 5 and Table 6.

TABLE 5 WELDING RUNS AND THEIR DETAILS FOR SET-I.

Run No.	Tool Pin Profile	RPM	Welding Speed(m/min)	Shoulder dia (mm)	Pin dia (mm)	Impact Strength (J)	Tensile Strength (MPa)
1	Trinagular	500	50	14	4	30	120
2	Trinagular	750	75	16	5	48	146
3	Trinagular	1000	100	18	6	70	165
4	Square	500	50	16	5	37	131
5	Square	750	75	18	6	58	156
6	Square	1000	100	14	4	54	155
7	T.Cylinder	500	75	14	6	32	130
8	T.Cylinder	750	100	16	4	44	138
9	T.Cylinder	1000	50	18	5	51	146

T Cylinder = Threaded Cylinder

TABLE 5 WELDING RUNS AND THEIR DETAILS FOR SET-II.

RunNo.	Tool Pin Profile	RPM	Welding Speed(m/min)	Shoulder dia (mm)	Pin dia (mm)	Impact Strength (J)	Tensile Strength (MPa)
1	Trinagular	1000	100	18	6	70	165
2	Trinagular	1500	125	20	7	49	143
3	Trinagular	2000	150	22	8	30	124
4	Square	1000	100	20	7	64	160
5	Square	1500	125	22	8	44	139
6	Square	2000	150	18	6	42	137
7	T.Cylinder	1000	125	18	8	50	146
8	T.Cylinder	1500	150	20	6	46	141
9	T.Cylinder	2000	100	22	7	44	135
10	Trinagular	1000	150	22	7	51	146
11	Trinagular	1500	100	18	8	61	153
12	Trinagular	2000	125	20	6	47	143
13	Square	1000	125	22	6	61	158
14	Square	1500	150	18	7	53	146
15	Square	2000	100	20	8	51	144
16	T.Cylinder	1000	150	20	8	47	145
17	T.Cylinder	1500	100	22	6	51	152
18	T.Cylinder	2000	125	18	7	43	138

T Cylinder = Threaded Cylinder

B. *Effect of tool pin profile*

The primary function of the non-consumable rotating tool pin is to stir the plasticized metal and move the same behind it to have a good joint. Pin profile plays a crucial role in material flow of the FSW process. The details of static area and dynamic area for each tool pin profile is presented in the following Table 7. The relationship between the static volume and dynamic volume decides the flow of plasticized material from the leading edge to the trailing edge of the rotating tool. This ratio is equal to 1.35 for triangular, 1.57 for square and 1.01 for threaded cylindrical pin profiles. In addition, the triangular and square pin profiles produce a pulsating action in the flowing material due to flat surfaces. Figure 4 and Figure 5 shows that maximum tensile strength and impact strength observed with square tool due to highest static to dynamic volume ratio with optimum shoulder diameter to pin diameter (D/d) ratio.

TABLE 7 STATIC AND DYNAMIC AREA FOR DIFFERENT TOOL PROFILES.

Pin Profile	Static Area (mm^2)	Pin Diameter	Dynamic Area (mm^2)	Dynamic Vol/ Static Vol
Triangular	20.78	6	28.26	1.35
Triangular	28.29	7	38.465	1.35
Triangular	36.95	8	50.24	1.35
Square	18.00	6	28.26	1.57
Square	24.50	7	38.465	1.57
Square	32.00	8	50.24	1.57
T.Cylinder	27.88	6	28.26	1.01
T.Cylinder	38.03	7	38.465	1.01
T.Cylinder	49.74	8	50.24	1.01

Note: The static and dynamic volume is calculated for the pin height of 5.7 mm.

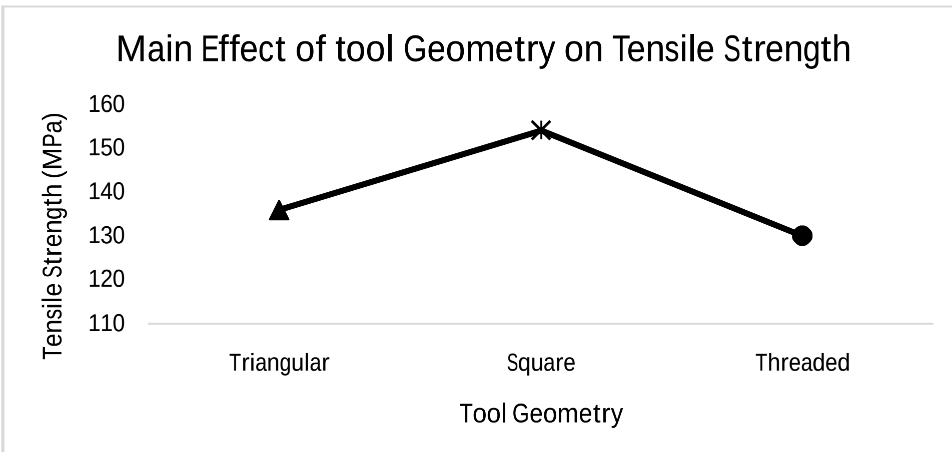


Figure 4 Main Effect of tool Geometry on Tensile Strength

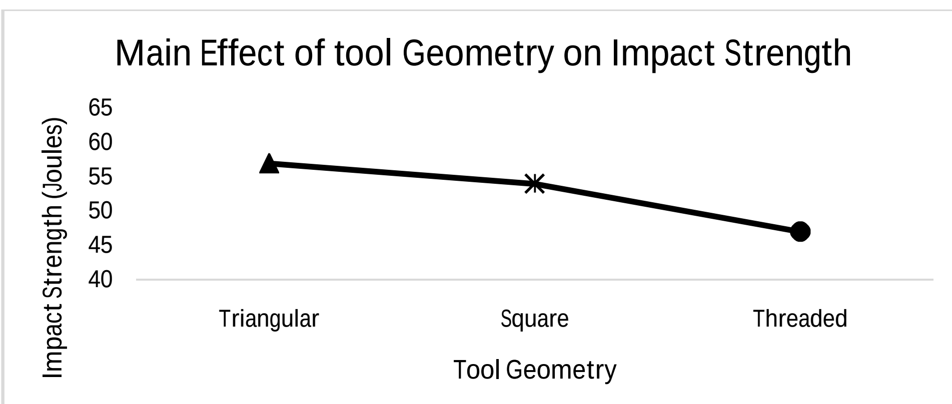


Figure 5 Main Effect of tool Geometry on Impact Strength

C. Effect of Process parameters on Mechanical properties

The joints fabricated by square pin profiled tool exhibited superior tensile properties compared to the other joints irrespective of other parameters. Figure 6 and Figure 10 shows that the joints fabricated at 1000 rpm have shown higher tensile and impact strength compared to joints fabricated at 500 rpm and 2000 rpm and this trend is common for all tool profiles.Figure 7 and Figure 11 shows the joints fabricated at a welding speed of 100 mm/min have also shown higher tensile and impact strength compared to joints

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor :6.887
Volume 5 Issue XII December 2017- Available at www.ijraset.com

fabricated at a welding speed of 50 mm/min and 150 mm/min. The joints fabricated by the tools with shoulder diameter 18 mm and tool pin diameter 6 mm (D/d=3) have shown higher tensile strength and elongation compared to joints fabricated by the tools with shoulder diameter 20 mm and 22 mm and this trend is common for all the tool profiles and shown by Figure 8. The interaction effect of welding and tool pin profile is shown in Fig 9. Welds produced using square tool pin profile at welding speed of 100 mm/min exhibit higher tensile strength than the other counterparts. It can be concluded that the joints fabricated by square pin profiled tool exhibited superior Tensile and impact properties compared to the other joints irrespective of other parameters.

The rotation per minute (rpm) has been found most significant parameter followed by welding speed, shoulder-diameter, pin-diameter and tool geometry.The maximum Tensile and impact strength is obtained at 1000 rpm, 100 m/min of welding speed and square tool with 18 mm of shoulder diameter and 6 mm of pin diameter.

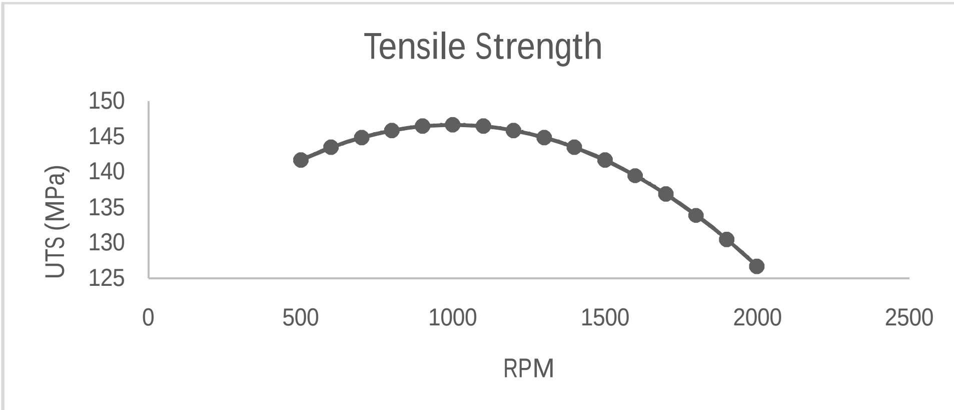


Figure 6 Main Effect of rpm on Tensile Strength

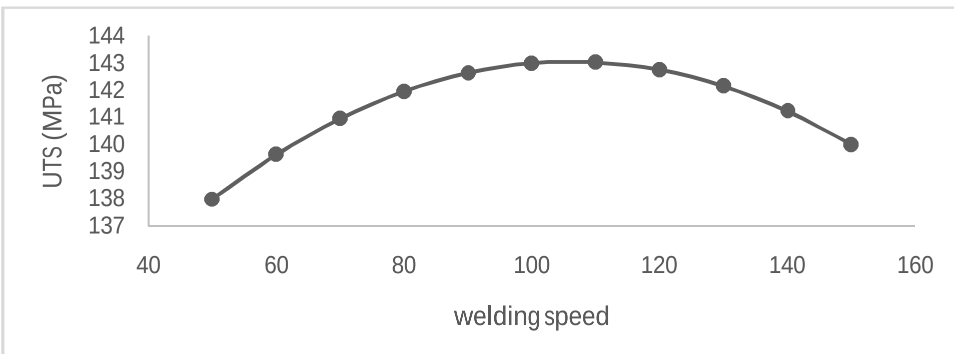


Figure 7 Main effect of welding Speed on Tensile Strength

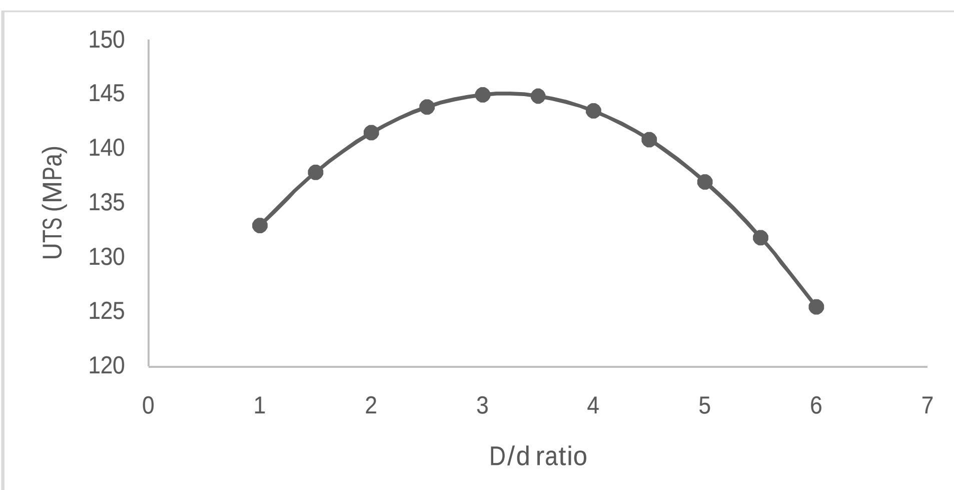


Figure 8 Main effect of (D/d) ratio on tensile strength

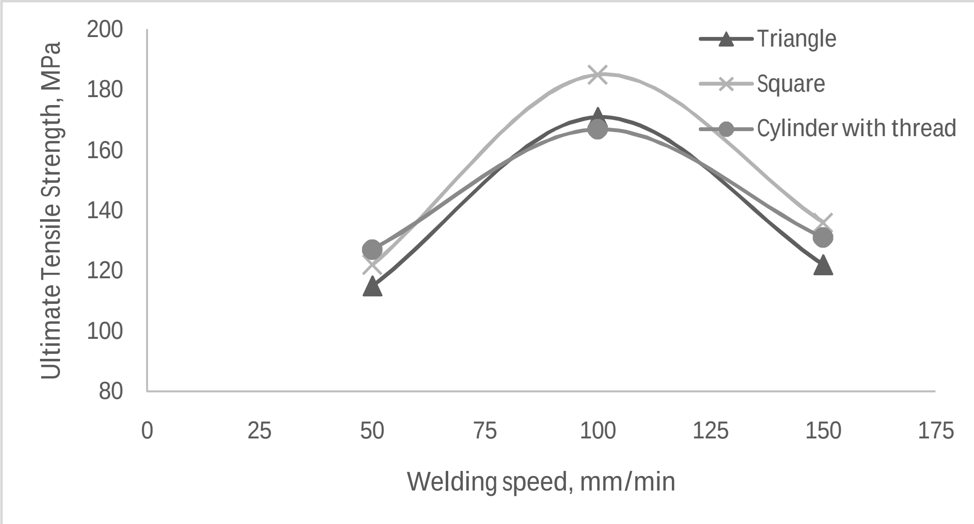


Figure 9 Interaction effect of welding speed and tool pin profile on UTS

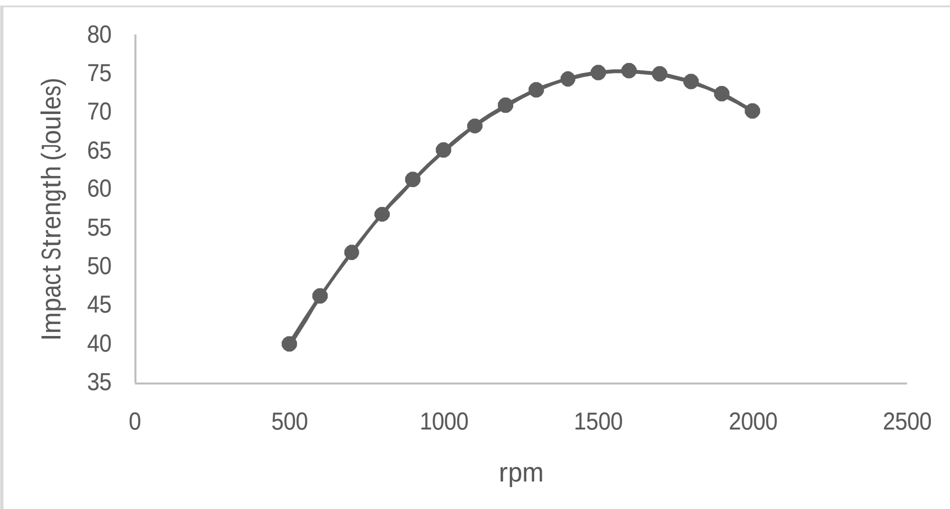


Figure 10 Main Effect of RPM on Impact Strength

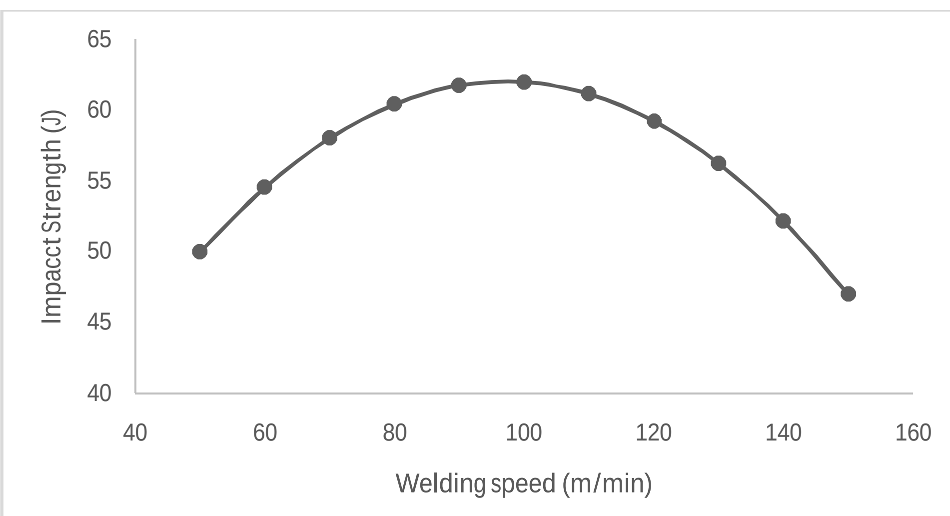


Figure 11 Main effect of welding speed on Impact Strength

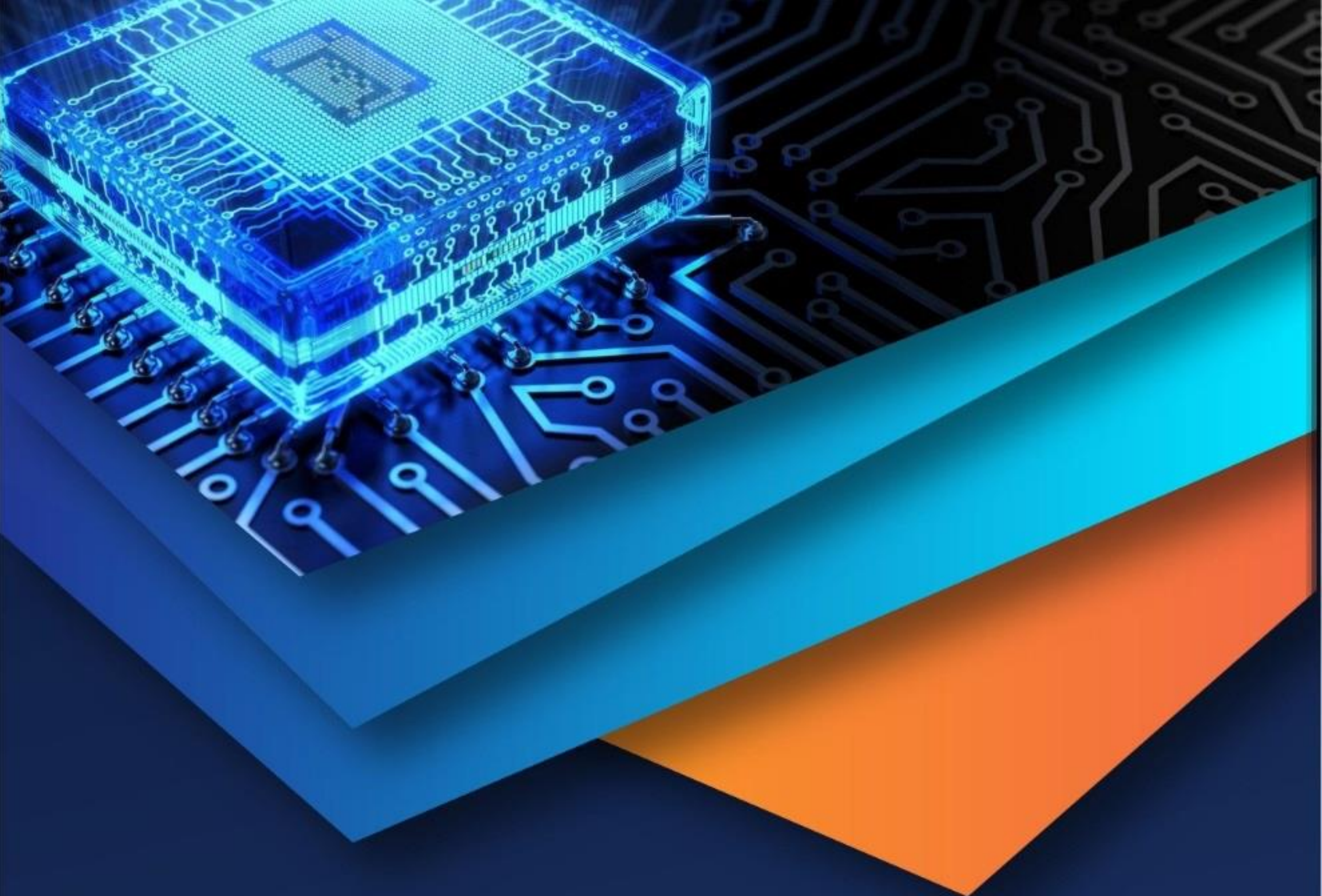
IV. CONCLUSION

Friction stir welding was successfully performed on 6 mm thick AA-6063 T5 Aluminum alloy. A new fixture was designed and fabricated for friction stir welding of aluminum alloy. Following specific conclusions may be drawn from this research:

1) Process Parameters were optimized for welding of AA-6063 T5alloy friction stir welding. Optimum process parameters were proposed for sound weld.
2) The effect of process parameters along with tool geometry represented. Beyond 1000 rpm, due to high temperature generated mechanical properties start decreasing.
3) Best welds found with square tool pin and 1000 rpm,100 m/min welding speed, 18 mm shoulder diameter andpin diameter of 6 mm. Square tool pin provides maximum swirl of weld metal which is necessary for sound weld.
4) The rotation per minute (rpm) has been found most significant parameter followed by welding speed, shoulder-diameter, pin-diameter and tool geometry.
5) Shoulder diameter to pin diameter ratio is equal to 1.35 for triangular, 1.57 for square and 1.01 for threaded cylindrical pin profiles. Triangular and square pin profiles produce a pulsating action in the flowing material due to flat surfaces.

REFERENCES

[1] Cavaliere, P, A De Santis, F Panella, and A Squillace, 'Effect of Welding Parameters on Mechanical and Microstructural Properties of Dissimilar AA6082 – AA2024 Joints Produced by Friction Stir Welding', Materials and Design, 30 (2009), 609–616.
[2] Liu, H J, H J Zhang, and L Yu, 'Effect of Welding Speed on Microstructures and Mechanical Properties of Underwater Friction Stir Welded 2219 Aluminum Alloy', 32 (2011), 1548–1553.
[3] Shen, J J, H J Liu, and F Cui, 'Effect of Welding Speed on Microstructure and Mechanical Properties of Friction Stir Welded Copper', Materials and Design, 31 (2010), 3937–3942.
[4] Rajakumar, S, C Muralidharan, and V Balasubramanian, 'Influence of Friction Stir Welding Process and Tool Parameters on Strength Properties of AA7075-T 6 Aluminium Alloy Joints', Materials and Design, 32 (2011), 535–549.
[5] Simoncini, M, and A Forcellese, 'Effect of the Welding Parameters and Tool Configuration on Micro- and Macro-Mechanical Properties of Similar and Dissimilar FSW Joints in AA5754 and AZ31 Thin Sheets', Materials and Design, 41 (2012), 50–60.
[6] Fujii, Hidetoshi, Yufeng Sun, Hideaki Kato, and Kazuhiro Nakata, 'Investigation of Welding Parameter Dependent Microstructure and Mechanical Properties in Friction Stir Welded Pure Ti Joints', Materials Science & Engineering A, 527 (2010), 3386–3391.
[7] Al-jarrah, Jawdat A, SallamehSwalha, Talal Abu, Masoud Ibrahim, Maen Al-rashdan, and Deya A Al-qahsi, 'Welding Equality and Mechanical Properties of Aluminum Alloys Joints Prepared by Friction Stir Welding', Journal of Materials & Design, 56 (2014), 929–936.
[8] James, M N, D G Hattingh, and G R Bradley, 'Weld Tool Travel Speed Effects on Fatigue Life of Friction Stir Welds in 5083 Aluminium', 25 (2003), 1389–1398.
[9] Rajakumar, S, and V Balasubramanian, 'Correlation between Weld Nugget Grain Size , Weld Nugget Hardness and Tensile Strength of Friction Stir Welded Commercial Grade Aluminium Alloy Joints', Journal of Materials & Design, 34 (2012), 242–251.
[10] Imam, Murshid, KajalBiswas, and VikranthRacherla, 'Effect of Weld Morphology on Mechanical Response and Failure of Friction Stir Welds in a Naturally Aged Aluminium Alloy', Materials and Design, 44 (2013), 23–34.
[11] K. Elangovan and V. Balasubramanian, "Influences of tool pin profile and welding speed on the formation of friction stir processing zone in AA2219 aluminium alloy," J. Mater. Process. Technol., vol. 200, no. 1–3, pp. 163–175, 2008.
[12] K. Elangovan, V. Balasubramanian, and M. Valliappan, "Influences of tool pin profile and axial force on the formation of friction stir processing zone in AA6061 aluminium alloy," Int. J. Adv. Manuf. Technol., vol. 38, no. 3–4, pp. 285–295, 2008.
[13] ASTM, Standard test methods for tension testing of metallic materials [Metric], in E8M, 2004. ASTM International: West Conshohocken, USA.
[14] ASTM, Standard test methods for notched bar impact testing of metallic materials, in E-23- 2007a, 2007. ASTM International: West Conshohocken, USA.



10.22214/IJRASET

INDEX COPERNICUS
45.98

IMPACT FACTOR:
7.129

TOGETHER WE REACH THE GOAL

IMPACT FACTOR:
7.429

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY