IARJSET
ISSN (Online) 2393-8021
ISSN (Print) 2394-1588
International Advanced Research Journal in Science, Engineering and Technology
ISO 3297:2007 Certified
Vol. 3, Issue 11, November 2016

Evalution of Mechanical Properties of Aluminium based Alloy (AA 6061) with Friction Stir Welding

Mr. Sukhdeep Singh Virk[1], Mr. Rakesh Kumar[2], Mr. Parvesh Dhingra[3]

Student, Mechanical, NWIET, Moga, India[1]

Professor, Mechanical, NWIET, Moga, India[2]

Assistant Professor, Mechanical, NWIET, Moga, India[3]

Abstract: This paper investigates the effect of different cooling conditions and varied tool rotations upon the weld quality of aluminium samples carried out by friction stir welding (FSW) process. In FSW parameters play an important role like tool design and material, tool rotational speed, welding speed and axial force. The processing is controlled by different parameters, such as tool rotational speed, feed rate and processing medium. Controlling these parameters helps to improve the mechanical and micro structural properties of the samples. Friction stir welding at tool rotation speeds of 600 rpm, 900 rpm and 1200 rpm using two cooling conditions normal water and nitrogen gas was successfully done. This improved the tensile and micro structural properties compared to parent material. Cooling the samples by nitrogen gas was found to decrease the heat input during welding which limits the grain growth during the process. The decrease in heat input resulted in reducing the microscopic voids in the material leading to an increase in micro hardness and improvement of tensile properties. It was found that good machining properties can be achieved at the relatively higher rotational speed when no cooling condition is applied i.e. FSW is done in normal water. The best results out of all the samples were produced by nitrogen gas cooling under tool rotational speed of 1200 rpm as it showed higher tensile strength of 260 MPa, fine grained micro-structure, better micro hardness value of 141 Hv and impact strength 14.6 Nm.

Keywords: Friction stir welding, microstructure, cooling conditions, rotational speeds.

1. INTRODUCTION

Friction stir welding process is a new welding technique which joins materials by plasticizing and then eventually consolidating the material around the joint line of the weld. First the base metal pieces which have to be joined are held suitable clamping force so that the work pieces do not fly away while welding. A rotating steel pin pierces a hole in the joint line between the work pieces to a predetermined depth and moves forward in the direction of the weld as shown in Fig.1.

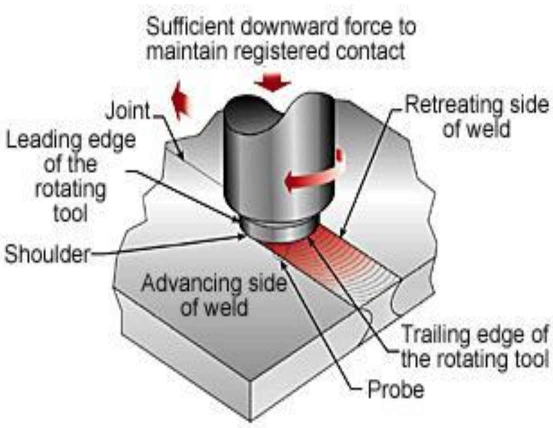


Fig. 1: Schematic of Friction Stir Welding process

As the pin moves forward it plasticizes the material due to the frictional heat generated by the rupture between the wear resistant steel pin and the workpiece. The force provided by the pin forces the plasticized material to the rare of the pin. This material cools and then consolidates to form a bond in the solid state of the material. There is no melting and the weld is in hot worked condition with no much entrapped gases and porosity and the weld nugget has fine grained microstructure.

Some of the attractive features which are forcing manufacturing firms to adopt friction stir welding are non-consumable tool, one tool can typically used for 1000m of weld length in 6000 series aluminium, no filler wire required, no gas shielding for welding aluminium, no welder certification required, no need for work piece preparations as small oxide layers are accepted, no need for grinding, brushing or pickling is required in mass production. The current industries which utilize FSW are the aerospace, railway, land transportation, ship building/ marine, and the construction industries.

2. PROBLEM FORMULATION

From the previous research studies, it was found that a lot of work has been done on friction stir welding technique

IARJSET
ISSN (Online) 2393-8021
ISSN (Print) 2394-1588
International Advanced Research Journal in Science, Engineering and Technology
ISO 3297:2007 Certified
Vol. 3, Issue 11, November 2016

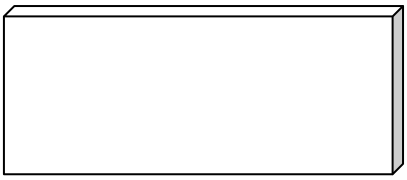
but very little work was done on submerged friction stir welding at variable tool rotation speed. So there is a great need to investigate the submerged friction stir welding technique at different tool rotational speed. The reasons of further investigation of friction stir welding technique are:

1. Very less research has been done on aluminium alloy 6061 as base metal.
2. In the previous researches, the main concentration of the researcher was only limited to friction stir welding in air. In their researches, there is no consideration of any cooling condition. A very few researchers considered the use of normal water as a cooling agent. So, there is need to investigate the effect of cooling conditions during friction stir welding.

In the present research, different cooling conditions were considered. To know the effect of cooling conditions different cooling conditions were taken at variable tool rotation speed (at 600 rpm, 900 rpm, 1200 rpm).

2.1 Preparation of Work Piece

Plates of aluminium alloy 6061 had been cut in rectangular shapes at slow speed, in order to avoid any temperature rise, so that the grain structure of the materials may not damage. After which, finishing of samples was done. The size of rectangular pieces was 120 mm x 80 mm x 6 mm.



2.2 Preparation of Tool

Specially designed Non-consumable tool of high carbon high chromium steel was used in this process. The tool pin profile was of hexagonal shape as shown in Fig 2.2.

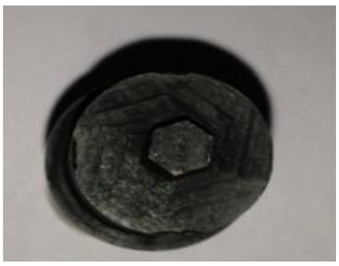


Fig 2.2: Friction stir welding Tool

Tool specifications are presented in Table 4.2. First of all the tool had been turned on conventional lathe machine to get the required pin diameter and shoulder diameter as mentioned in the specification.

Table 2.2: Friction Stir Welding Tool Specifications

Tool Length	75 mm
Tool Shoulder Diameter (D)	18 mm
Tool Pin Profile	Hexagonal
Tool Pin Diameter (d)	6 mm
Tool Pin Length (L)	5.7 mm
Tool Tilt Angle	0 Degrees

Then the hexagonal tool pin profiles had been made by using vertical milling machine with the help of indexing head. It had been found from the previous literature studies that the tool gets deformed during the process, so the heat treatment of tools had been done to increase the hardness. After machining the tools were heated in a muffle furnace up o a temperature of 1000 ^{0}C for 3-4 hours. After heating the tool were immediately quenched in mobile oil of moderate viscosity.

2.3 CNC Vertical milling machine

Fig2.3 : Vertical milling machine used for FSW

The machine on which FSW was done is a CNC vertical milling machine as shown in Fig. 4.3. The machine used for FSW is placed in Central Tool Room, Ludhiana. The tool holder and the table of the machine were pneumatically controlled. The detailed specifications of the CNC vertical milling machine are presented in Table 2.3.

Table 2.3: Specifications of CNC Vertical milling machine used for FSP

Model	DMU 50T
CNC Control	FANUC O-i MATE MD
Motor Power	15/18 KW Gear Head Spindle
Maximum Load	600 Nm
Tool RPM	20 - 4500 RPM
Table Size	800 mm x 600 mm
X, Y, Z Movements	58”, 27”, 24”

2.4 Process Parameters

For the processing of aluminum samples with FSW, two types of parameters were considered which are variable parameters and fixed parameters.

- **Fixed Parameters: -** The fixed parameters were kept constant throughout the study. The fixed parameters are

IARJSET
ISSN (Online) 2393-8021
ISSN (Print) 2394-1588
International Advanced Research Journal in Science, Engineering and Technology
ISO 3297:2007 Certified
Vol. 3, Issue 11, November 2016

a) Processing Speed = 65 mm/ min
b) Tool Tilt Angle = 0 degrees
c) Axial Load = Constant
d) Tool Pin Profile = Hexagonal
e) Tool Shoulder Diameter = 18 mm

- **Variable Parameters: -** In present study the variable parameters were tool rotational speed and cooling conditions. The different tool rotation speeds used in this study are shown in table 2.4.

Table 2.4: Tool Rotation Speed

Serial No	Tool Rotation Speed (RPM)
1	600
2	900
3	1200

The different cooling conditions which were used for this investigation are presented in Table 2.5.

Table 2.5: Types of Cooling Condition

Serial No.	Type of Cooling
1	Normal Water Cooling
2	Nitrogen Gas Cooling

3. Processing of Sample

The processing of the material by Friction Stir Welding had been done on a vertical milling machine by considering the different cooling conditions at different tool rotational speed. The processing tool was griped in the collets of the vertical spindle of the milling machine that can move up and down. The automatic feed can be given to the table of the vertical milling machine in X, Y, Z direction. The processing tool was then rotated to a prescribed speed with respect to the normal of the work piece. The tool was then slowly plunged into the work piece material, until the shoulder of the tool touched the surface of the material. A downward force was applied to maintain the contact between the work piece and the tool shoulder.

Fig 3.1: Processing of sample

Then a transverse force was applied in the processing direction by giving automatic feed to the work table along the length. Upon reaching the end of the last round of path defined, the tool was withdrawn. Fig 3.1 shows the processing of sample on CNC machine with the help of specially designed tool.

4. MECHANICAL PROPERTIES OBSERVATION

4.1 Micro Hardness

Hardness measurements were carried out using a Vickers's hardness tester at a load of 200 grams and dwell time of 10 seconds. Micro hardness testing had been done from the top of the welded portion. The results are shown in table. 4.1.

Table 4.1: Value of Micro Hardness at Different Cooling Conditions

Serial No.	Cooling Condition	Rotational Speed (rpm)	Micro Hardness (Hv)
1	Submerged Under Normal Water	600	124
2		900	128
3		1200	136
4	Submerged Under Nitrogen Gas	600	129
5		900	134
6		1200	141

The highest micro hardness value recorded in all of the studied samples was by nitrogen gas cooling as it had the lowest amount of heat input among all the FSWed samples at rotational speed 1200rpm.The rotational speed of the samples also plays an important role in the friction stir welding as the samples with higher rotational speed i.e. at 1200 rpm have higher micro hardness than the samples in which the welding was done at lower rotational speed i.e. at 600 rpm. Similar results were observed by **D. Muruganandam et al. (2011)** and indicated that defect concentration was maximum for the 600 rpm tool rotation. It was a little reduced for 800 rpm and even lesser for the 1000 rpm speed rotation. Least defects were found at the highest rpm (1200).

4.2 Tensile Strength

The effect of different cooling conditions on the tensile properties could be predicted from the results which are presented in table.4.2.

Table 4.2: Value of Tensile Strength at Different Cooling Conditions

Serial No	Cooling Condition	Rotational Speed (rpm)	Ultimate tensile strength Value (MPa)
1	Submerged Under Normal	600	223
2		900	236
3		1200	248

IARJSET

ISSN (Online) 2393-8021
ISSN (Print) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

ISO 3297:2007 Certified

Vol. 3, Issue 11, November 2016

	Water		
4	Submerged	600	228
5	Under	900	241
6	Nitrogen Gas	1200	260

4.3 Impact Strength

The Charpy impact test, also known as the Charpyv-notch test, is a standardized high strain-rate test which determines the amount of energy absorbed by a material during fracture. This absorbed energy is a measure of a given material's toughness. The values of Impact Strength measured at different rotational speeds are shown in bar chart fig.4.3.

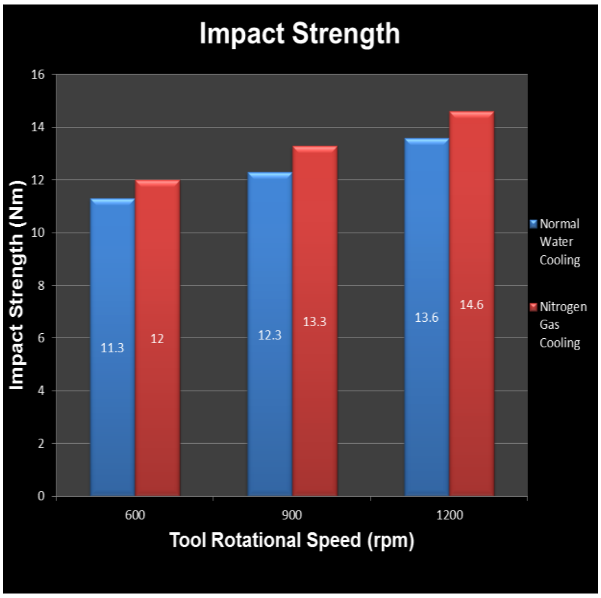


Fig 4.3: Impact Strength Comparison between in air, under chilled water, under lubrication oil cooling and under nitrogen Friction Stir Welding

4.4 Microstructure

The spinning bit refines the original grain structure down to the 50 nm scale, and the new recrystallized grain nuclei that form from this structure are at sizes between 25 and 40 nm. In normal water FSW fine grain structure was observed with the presence of some intermediate products because very less amount of heat was dissipated during in normal water FSW as normal water has low heat absorption properties and high heat is generated during welding, which slows down the cooling rate and causes grain growth. Hence the low value of tensile strength, impact strength and micro-hardness were obtained at this cooling condition at 600 rpm.A very fine grained microstructure was obtained of the welded zone under nitrogen gas cooling. This may be due to the generation of sufficient amount of frictional heat in the stir zone, which produces proper plastic flow of material and may lead to grain refinement in the stir zone. Clearly more grain refinement was achieved under cooling conditions. FSW significantly modify the grain structure of the material. Significant grain refinement was achieved.

5. CONCLUSION

Friction stir welding (FSW) is a relatively new solid-state joining process. This joining technique is energy efficient, environment friendly, and versatile. The principal advantages are low distortion, absence of melt related defects and high joint strength. In FSW parameters play an important role like tool design and material, tool rotational speed, welding speed and axial force. He processing is controlled by different parameters, such as tool rotational speed, feed rate and processing medium. Controlling these parameters helps to improve the mechanical and micro structural properties of the samples. The findings of this study can be summarized as follows:

1. Friction stir welding at tool rotation speeds of 600 rpm, 900 rpm and 1200 rpm using two cooling conditions normal water and nitrogen gas was successfully done. This improved the tensile and micro structural properties compared to parent material.
2. Cooling the samples by nitrogen gas was found to decrease the heat input during welding which limits the grain growth during the process. The decrease in heat input resulted in reducing the microscopic voids in the material leading to an increase in micro hardness and improvement of tensile properties.
3. It was found that good machining properties can be achieved at the relatively higher rotational speed when no cooling condition is applied i.e. FSW is done in normal water.
4. The best results out of all the samples were produced by nitrogen gas cooling under tool rotational speed of 1200 rpm as it showed higher tensile strength of 260 MPa, fine grained micro-structure, better micro hardness value of 141 Hv and impact strength 14.6 Nm.

ACKNOWLEDGMENT

The author sincerely would like to thank the following for helpful discussions: **Mr. Rakesh Kumar, Mr. Parvesh Dhingra, Mr. Harjeet Singh, Mr. Gurleen Singh, Mr. Karamjot Singh, Mr. Jaspreet Singh.**

REFERENCES

1. Timonthy J Minton (2008), PhD Thesis, "Friction Stir Welding of Commercially available Super plastic Aluminium", Department of Engineering and Design, Brunel University.
2. Pradhan Satya Prakash (2012), B-Tech Thesis, "An investigation into the friction stir welding of aluminium pipe with stainless steel plate", Department of Mechanical Engineering, Rurkela.
3. Weiyuan (2008), M-Tech Thesis, "Friction stir spot welding of aluminium alloys", Missouri University of Science and Technology, Missouri.
4. Akula Deepa Reddy (2007), M-Tech Thesis, "Characterization of mechanical properties and study of microstructures of friction stir welded joints fabricated from similar and dissimilar alloys of aluminium", University of Missouri, Columbia.
5. Robert E., Sanders Jr. (2001), "Technology Innovation in Aluminum Products", JOM35, Vol.2, 21–25.
6. Suresh babu. A &Devanathan.C. (2013), "An overview of friction stir welding", International Journal of Research in Mechanical Engineering & Technology, 259-265.

7. Cavaliere, P., Nobile, R., Panella, F. W., &Squillace, A. (2006), “Mechanical and microstructural behaviour of 2024–7075 aluminium alloy sheets joined by friction stir welding”, International Journal of Machine Tools and Manufacture, Vol. 46, 588-594.
8. Sivakumar, Bose Vignesh**,** Raguraman D., Muruganandam D. (2014), “Review Paper on Friction Stir Welding of various Aluminium Alloys”, IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE), 46-52.
9. Khourshid A. M., Sabry I (2013), “Friction stir welding study on aluminium”, International Journal of mechanical engineering and robotics research, Vol. 2, No. 3, 331-339.
10. Rodrigues D. M., Leita C., Louro R., Gouveia H. and Loureiro A. (2010), “High speed friction stir welding of aluminium alloys”, Science and Technology of Welding and Joining, Vol. 000, No.000, 1-7.
11. Tozaki, Yasunari, Yoshihiko Uematsu, and KeiroTokaji. (2007). "Effect of tool geometry on microstructure and static strength in friction stir spot welded aluminium alloys." International Journal of Machine Tools and Manufacture 47, no. 15: 2230-2236.
12. Cavaliere P., and F. Panella(2008), "Effect of tool position on the fatigue properties of dissimilar 2024-7075 sheets joined by friction stir welding," Journal of materials processing technology, Vol. 206, No. 1, 249-255.
13. Badarinarayan H, YangQ.,andZhu. S. (2009), "Effect of tool geometry on static strength of friction stir spot-welded aluminum alloy," International Journal of Machine Tools and Manufacture, Vol. 49, No. 2, 142-148.
14. ElangovanK., &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 & Design, Vol. 29, No.2, 362-373.
15. Liu H.J., Fujii H., Maeda M., Nogi K. (2003), “Tensile properties and fracture locations of friction-stir-welded joints of 2017-T351 aluminum alloy”, Journal of Materials Processing Technology, Vol. 142, 692-696.