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

Optimization of Mechanical Properties of Aluminium Based Alloy (A356) with Friction Stir Welding

Mr. Harjinder Singh Sekhon[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 this work, aluminum alloy A356 samples were friction stir welded under air cooling, water cooling, lubrication oil cooling and nitrogen gas cooling at two different tool rotation speeds of 900 rpm and 1100 rpm. The study carried out is through experimental investigations. The effect of these processing parameters on mechanical properties and micro structural properties of welded joint are studied. Cooling the samples by liquid nitrogen or by lubrication oil was found to decrease the heat input during processing 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 air. However, the best results out of all the samples were produced by liquid nitrogen cooling under tool rotational speed of 1100 rpm as it showed higher tensile.

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

1. INTRODUCTION

Friction stir welding (FSW) is a solid state joining technique invented by The Welding Institute (TWI) in 1991. Friction stir welding was initially used for joining low melting point alloys like Aluminium, copper, magnesium etc. During this process no harmful gases and radiations are produced and material wastages are also reduced to minimum. Friction Stir Welding is a solid state welding process, which offers all such benefits as compare with fusion welding processes. In friction stir welding, the materials or alloys are joined through visco-plastic deformation with the frictional heat, below the melting point of the materials.

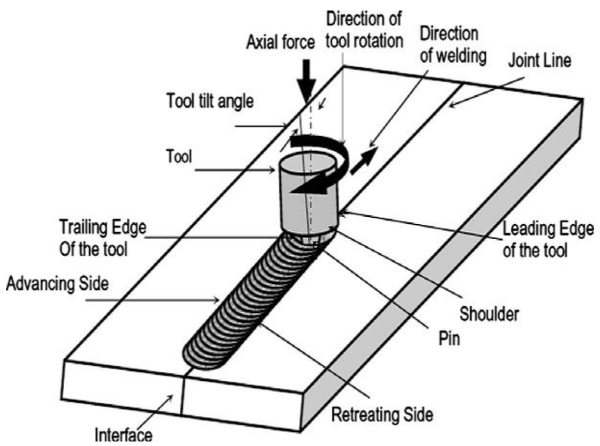


Fig. 1.1 Set up of a Friction Stir Welding Process

The frictional heat is created by a rotating non-consumable electrode, which penetrates the joint of the materials to be welded, and traverse along the joint-line [7].
Friction stir welding uses a non-consumable rotating tool with a specially designed pin and shoulder which is inserted into the abutting edges of sheets or plates to be joined and traversed along the line of joint. The tool serves two primary functions: (a) heating of work piece, and (b) movement of material to produce the joint. The heating is accomplished by friction between the tool and the work piece and plastic deformation of work piece. 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. During FSW process, the material undergoes intense plastic deformation at elevated temperature, resulting in generation of fine and equated re-crystallized grains. 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 [8].

2. PROBLEM FORMULATION

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

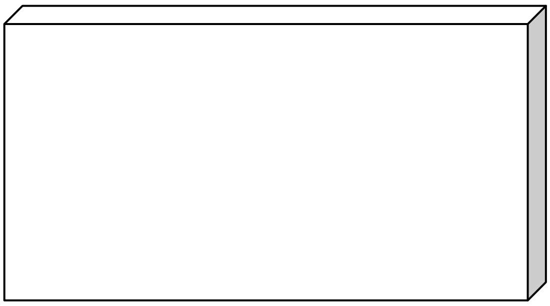
DOI 10.17148/IARJSET.2016.31106

under different cooling conditions except air. So there is a great need to investigate the submerged friction stir welding technique. A very few researchers considered the use of chilled water as a cooling agent. So, there is need to investigate the effect of different cooling conditions during friction stir. Very less research has been done on aluminum alloy A356 as base metal.

In the present research, different cooling conditions along with variable tool rotation speeds were considered to find out their effect upon the welded samples of A356 particularly by friction stir welding.

2.1 Preparation of Work Piece

Plates of aluminum alloy A356 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 150 mm x 100 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. Drawing of tool pin profile is shown in Fig 2.2.

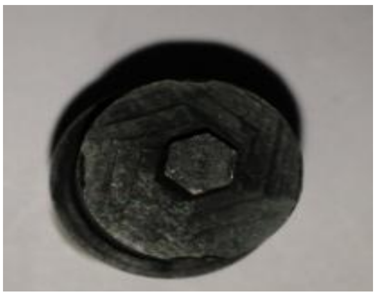


Fig 2.2: Friction stir processing Tool

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	80 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. After machining the tools were heated in a muffle furnace up to temperature of 950 ^{0}C for 3-4 hours. After heating the tool were immediately quenched in mobile oil of moderate viscosity.

2.3 Preparation of Fixture

A special fixture was designed to hold the samples. Fixture having dimensions 200 mm x 200 mm× 20 mm was made of mild steel plate. The prepared Fixture was clamped with the help of two clamps as shown in fig 2.3.

Fig 2.3: Fixture clamped on the bed of CNC vertical milling machine

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

a) Processing Speed = 50 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	900
2	1100

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	Air Cooling
2	Chilled Water Cooling
3	Lubrication Oil Cooling
4	Nitrogen Cooling

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

3. WELDING OF SAMPLE

The welding of the material by Friction Stir welding had been done on a vertical milling machine by considering the different cooling conditions. The welding tool was griped in the collet 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. 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 welding of sample clamped inside fixture on CNC machine with the help of specially designed tool.

Fig 3.1: Welding of sample

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	In Air	1100	132
2	In Air	900	131
3	Submerged Chilled Water	1100	141
4	Submerged Chilled Water	900	139
5	Submerged Under Liquid Nitrogen	1100	156
6	Submerged Under Liquid Nitrogen	900	155
7	Submerged Under Lubricant Oil	1100	152
8	Submerged Under Lubricant Oil	900	151

The hardness of the materials plays an important role in determining the wear characteristics. Generally wear is inversely proportional to the hardness of material. This is due to the lower heat input in liquid nitrogen FSW than the other FSW samples. Highest hardness value 156 HV was obtained at tool rotation speed of 1100 rpm under liquid nitrogen cooling FSW, whereas the lowest hardness value of 132 HV was obtained at tool rotation speed of 900 rpm in air FSW.

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	In Air	1100	209
2	In Air	900	205
3	Submerged Chilled Water	1100	215
4	Submerged Chilled Water	900	212
5	Submerged Under Liquid Nitrogen	1100	228
6	Submerged Under Liquid Nitrogen	900	225
7	Submerged Under Lubricant Oil	1100	222
8	Submerged Under Lubricant Oil	900	220

4.3 Impact Strength

The Charpy impact test, also known as the Charpy v-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.

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

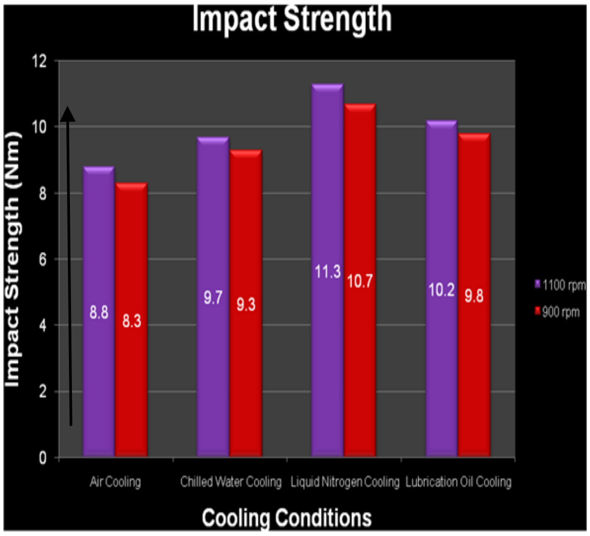


Fig 4.3: Impact Strength Comparison between in air, under chilled water, under lubrication oil cooling and under nitrogen Friction Stir Welding

4.4 Microstructure

The micro structural behavior of aluminum alloy welded by Friction Stir Welding was studied at different conditions of cooling. 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 air FSW fine grain structure was observed with the presence of some intermediate products because very less amount of heat was dissipated during in air FSW as air 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 900 rpm. A very fine grained microstructure was obtained of the welded zone under liquid nitrogen 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 the material.

5. CONCLUSION

Friction stir welding is a relatively new technique which can be easily used to produce bulk samples of fine-grained welding joints. The quality of joint can be 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:

- Friction stir welding at tool rotation speeds of 900 rpm and 1100 rpm using four cooling conditions air, chilled water, lubrication oil and liquid nitrogen was successfully done. This improved the tensile and micro structural properties compared to parent material.
- Cooling the samples by liquid nitrogen or by lubrication oil was found to decrease the heat input during processing 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 air.
- The best results out of all the samples were produced by liquid nitrogen cooling under tool rotational speed of 1100 rpm as it showed higher tensile strength of 228 MPa, fine grained micro-structure, better micro hardness value of 156 Hv, impact strength 11, 3 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] RanjanSahoo and PinakiSamantaray (2007), B-Tech Thesis, "STUDY OF FRICTION WELDING", National Institute of Technology, Rurkela.
[2] Deepa Reddy Akula (2007), M-Tech Thesis, "Charaterization of mechanical properties and study of microstructures of friction stir welded joints fabricated from similar and dissimilar alloys of aluminium", University of Missouri, Columbia.
[3] D. Scott MacKenzie and George E. Totten, 2006, "Analytical characterization of Aluminum, Steel and Superalloys", Atlas of Aluminum microstructures, Chapter 2, PP 55-156.
[4] ASM Handbook (1993), "Welding, Brazing and Soldering", Vol. 6, pp. 297-324.
[5] Mishra, R. S., & Ma, Z. Y. (2005), "Friction stir welding and processing", Materials Science and Engineering: R: Reports, Vol. 50, No.1, 1-78.
[6] Mofid, M. A., Abdollah-Zadeh, A., Ghaini, F. M., &Gür, C. H. (2012), "Submerged friction-stir welding (SFSW) underwater and under liquid nitrogen: an improved method to join Al alloys to Mg alloys", Metallurgical and Materials Transactions A, Vol. 43, No.13, 5106-5114.
[7] Amancio- Filho, S. T., Sheikhi, S., Dos Santos, J. F., &Bolfarini, C. (2008), " Preliminary study on the microstructure and mechanical properties of dissimilar friction stir welds in aircraft aluminium alloys 2024-T351 and 6056-T4", Journal of Materials Processing Technology, Vol. 206, No. 1, 132-142.
[8] Suresh babu. A &Devanathan.C. (2013), "An overview of friction stir welding", International Journal of Research in Mechanical Engineering & Technology: 259-265.
[9] 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.
[10] . Liu H.J, Fujii H., Maeda M., Nogi K (2003), "Tensile properties and fracture locations of friction-stir-welded joints of 2017-T351 aluminium alloy", Journal of Materials Processing Technology, Vol. 142, 692–696.
[11] Jannet S., Mathews P.K., Raja R. (2013), "Comparative investigation of friction stir welding and fusion welding of 6061-T6 and 5083-O aluminum alloy based on mechanical properties and microstructure", Journal of Achievements in Materials and Manufacturing Engineering, Vol. 61, 181-186.
[12] Khourshid A. M., Sabry I (2013), "Friction stir welding study of aluminium pipe", International Journal of mechanical engineering and robotics research, Vol. 2, No. 3, 331-339.