International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249-8958 (Online), Volume-9 Issue-2, December, 2019

Influence of Parameters on Micro Structural and Mechanical Properties of Aluminium Based Alloy (A356) with Friction Stir Welding

Rakesh Kumar, Yogesh Kumar

Abstract: ***This study examines the influence of varied conditions of cooling and different rotations of tool on the accuracy of weld of aluminum samples taken out by friction stir welding process. The aim of this study was to check the effects on samples of aluminum alloy of A356 grades that were welded by friction stir welding under various conditions of cooling like cooling by water, cooling by air, cooling by nitrogen gas and cooling by lubrication oil at two varied rotating speed of tool at 900 revolution per minute and 1100 revolution per minute. These readings were being carried by experimental investigations. The influence of these different parameters on micro structural and mechanical properties of these joint are discussed. Cooling the different specimens by lubrication oil or liquid nitrogen showed to reduce the input heat in processing which reduce the improvement of grains in between the process. The reduction in input heat showed in decreasing the microscopic defects in the specimen found to gain in micro hardness and betterment of tensile properties. It was observed that best machining properties was found when the rotational speed is higher and no condition of cooling is used i.e. friction stir welding is applied in air. Also, the better findings found out from all the specimens when cooling by liquid nitrogen under rotating speed of tool at 1100 rpm as it represents higher tensile.***

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

I. INTRODUCTION

Friction stir welding (FSW) is a solid state method of joining discovered in 1991 by the Institute of Welding. Initially it was used for combining alloys like aluminum, copper, magnesium etc. which have very low melting point. In this process there are harmful gases and radiations are not developed and wastage of materials is also minimized. It is a solid state welding process that gives better results compared to fusion welding processes. In this type of welding, the different materials or different alloys are connected by visco-plastic deformation with the frictional heat lower than the melting point of the sample material.

Revised Manuscript Received on December 30, 2019.
* Correspondence Author
Dr. Rakesh Kumar,* Department of Mechanical Engineering, Ludhiana Group of Colleges, Chokimann, Ludhiana, Punjab, India.
Dr. Yogesh Kumar, Department of Electronics Engineering, CT Group of Institutions Jalandhar, Punjab, India.

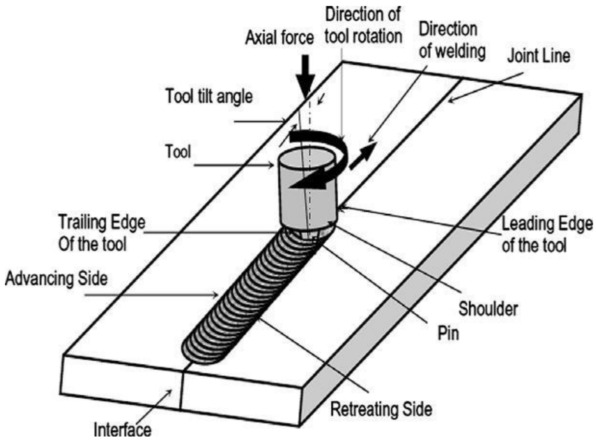


Fig. 1.1 Diagram of a Friction Stir Welding Process

This heat produced due to friction by a rotating non-consumable electrode, which penetrates the material joint to be welded, and traversed along the joint-line [7].

It uses a rotating tool which is non-consumable specifically designed pin and shoulder which is fitted into the adjacent edges of plates or sheets to be attached and traversed along the line of joint. This tool has two main functions: (a) to heat the work piece, and (b) material movement to produce the joint. The heat is produced by friction between work piece and the tool and plastic deformation of sample. The localized heating softens the specimen around the pin and tool consists of combination of translating and rotating motion leads to material move from the front to the back of the pin. Due to this process a joint is developed in solid state. During this process, at maximum temperature the material developed large plastic deformation, showed development of equated and fine re-crystallized grains. The adjoining of material do not use any kind of filler material and therefore any types of aluminum alloy can be met without concern for the compatibility of material composition, which is a problem in fusion welding [8].

II. PROBLEM FORMULATION

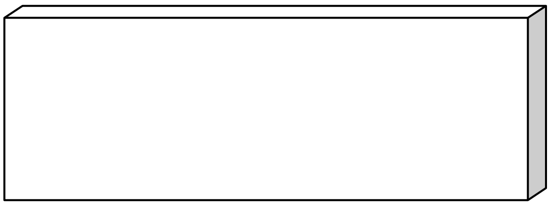
It was noted that mostly the work has been conducted by method of friction stir welding but very little amount of work was done

by varying conditions of cooling except air in friction stir welding. So there is a great need to investigate the technique of submerged friction stir welding. A very few researchers has taken into consideration the use of chilled water as a medium of cooling. So, there is need to determine the influence of various cooling conditions during friction stir. Very little research had done on A356 plates of aluminum alloy using as a base metal.

In this research, various conditions of cooling along with varying speeds of tool movement were considered to obtain their consequences on the welded samples of A356 specifically by the process of friction stir welding.

2.1 Geometry of Work Piece

Aluminum alloy plates of A356 grade had been cut at a very less speed in rectangular shapes, in order to minimize any gain in temperature, so there will be no damage in the structure of grains of the materials. After this, finishing of plates was done. The size of rectangular pieces was 150 mm x 100 mm x 6 mm.



2.2 Preparation of Tool

High carbon high chromium steel non-consumable tool which is specially prepared for this process. The shape of tool pin profile was of hexagonal. Geometry of profile of tool pin is discussed in Fig 2.2.

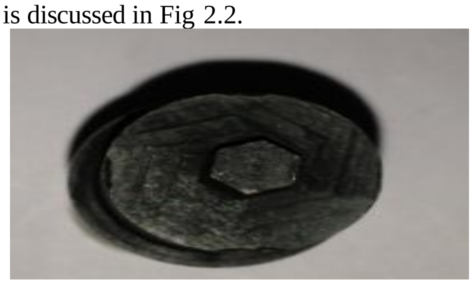


Fig 2.2: Friction stir processing Tool

The specifications of tool are given in Table 4.2. First of all on conventional lathe machine the tool had been turned to obtain the required diameter of pin and shoulder as given in the specification.

Table 2.2: Friction Stir Welding Tool Specifications

Length of tool	80 mm
Shoulder Diameter of tool (D)	18 mm
Pin Profile of tool	Hexagonal
Pin Diameter of tool (d)	6 mm
Pin Length of tool (L)	5.7 mm
Tool Tilt Angle	0 Degrees

Then the tool pin profile which is in hexagonal shape which was prepared by using vertical milling machine with the help of indexing head. After this machining the tools were heated up to temperature of 950 ^{0}C for 3-4 hours in a muffle furnace. After this the tool were quickly quenched in mobile oil of moderate viscosity.

2.3 Preparation of Fixture

A special fixture was made so that the samples can be hold. The size of fixture was 200 mm x 200 mm× 20 mm and was prepared by plates of mild steel. Then the fixture was held with the support 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

Two types of parameters were used in the processing of samples of aluminum alloys with friction stir welding, which are fixed parameters and variable parameters.

Fixed Parameters: - Some parameters were kept fixed throughout the process. These parameters are

a) Processing Speed = 50 mm/ min
b) Tilt Angle of tool = 0 degrees
c) Axial Load = Constant
d) Pin Profile of tool = Hexagonal
e) Shoulder Diameter of tool = 18 mm

- **Variable Parameters:** In this process the varying parameters were cooling conditions and speed of rotational tool. The varying speeds of rotational tool used in these experiments are shown in table 2.4.

Table 2.4: Tool Rotation Speed

Serial No	Tool Rotation Speed (RPM)
1	900
2	1100

The various conditions of cooling which were applied for these experiments are shown 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

III. WELDING OF SAMPLE

The varying conditions of cooling were used for welding of the samples by friction Stir welding on a vertical milling machine. In the milling machine welding tool was held in the collet of the vertical spindle that can move up and down. The feed was given automatically to the table of the vertical milling machine in different directions like X, Y and Z .The tool was then rotating to a required speed with respect to the normal of the work piece. The tool was then slowly inserted into the material of the work piece till the tool shoulder touched the material sample. A downward force was used to make the contact between the tool shoulder and work piece. Then a transverse force was used in the required direction by providing the automatic feed to the work table along the length.

The tool was withdrawn when reached at the end of the last round of path given. Fig 3.1 presents the welding of specimens held inside fixture on Computer Numerical Control machine with the help of specifically design of tool.

Fig 3.1: Welding of sample

IV. MECHANICAL PROPERTIES

1.1 Micro Hardness

The Vickers's hardness tester was used for the measurement of hardness at a dwell time of 10 seconds and at 200 grams load. Testing of micro hardness was done from the upper portion of the welded joints. The outcomes are presented in table. 4.1.

Table 4.1: Value of Micro Hardness at Different Conditions of Cooling

Sr.No	Condition of cooling	Rotational Speed (rpm)	Micro Hardness (Hv)
1	Air Cooling	1100	132
2	Air Cooling	900	131
3	Cooling in 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	ıbmerged Under Lubricant Oil	900	151

The materials hardness plays a main role in knowing the characteristics of wear. Generally wear is inversely proportional to the material hardness. It is because of less heat input in liquid nitrogen friction stir welding than the other friction stir welding samples. Maximum hardness value of 156 HV was found under liquid nitrogen cooling in friction stir welding at tool rotation speed of 1100 rpm; whereas the lowest value of hardness of 132 HV was obtained in air friction stir welding by rotating speed of tool at 900 rpm.

1.2 Tensile Strength

The effect on the tensile properties under different cooling conditions can be known from the observations that are shown in table.4.2.

Table 4.2: Value of Tensile Strength at Various Conditions of Cooling

Sr.No	Condition of Cooling	Speed of Rotation (rpm)	Maximum Tensile strength Value (MPa)
1	Air Cooling	1100	209
2	Air Cooling	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	ıbmerged Under Lubricant Oil	1100	222
8	ıbmerged Under Lubricant Oil	900	220

1.3 Impact Strength

A high strain-rate test which is known as "The Charpy impact test" that tells the quantity of energy stored by a specimen during rupture. The storage of energy gives us an idea of toughness of a given specimen.
The amount of Impact Strength found at varying speeds of rotation is presented in bar chart as shown in fig.4.3.

- The reduction in heat input was observed in different samples by cooling with lubrication oil and liquid nitrogen in processing that limits the growth of grain during the process. This helps in minimizing the microscopic defects in the material resulting to improvement of tensile properties and an increase in micro hardness.
- It was observed that better properties of machining can be obtained very high speed of rotation as no condition of cooling is used i.e. friction stir welding is applied in air.
- The better observations from all the pieces were found by cooling through liquid nitrogen under rotational speed of tool at 1100 revolution per minute as it produced maximum tensile strength of 228MPa, micro-structure of fine grains, improves micro hardness value of 156 Hv, impact strength 11, 3 Nm

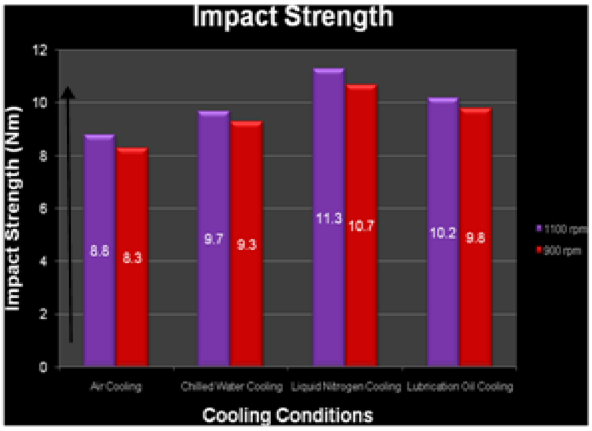


Fig 4.3: Comparison of impact Strength in different cooling conditions during friction Stir Welding

1.4 Microstructure

The behavior of micro structural of aluminum alloy welded by friction Stir Welding was noted at various 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 released 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 production of large amount of frictional heat in the stir zone, which produces proper plastic flow of material and may produce refinement of grains in the stir zone. Clearly better grain refinement was achieved under cooling conditions. FSW significantly modify the grain structure the material.

V. CONCLUSION

Friction stir welding is a relatively new process which can be easily applied to develop large 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 of rotation speeds of tool at 900 rpm and 1100 rpm using four cooling conditions air, chilled water, lubrication oil and liquid nitrogen was successfully applied. This improved the tensile and micro structural properties compared to parent material.

ACKNOWLEDGMENT

We are very thankful to Mr. Gurinder Singh Brar and Dr.M.K.Kushwaha for helpful discussions.

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. Arora K.S, Pandey,S .,Schaper, M., Kumar, R (2010), “Micro structural Evaluation during Friction Stir Welding of Aluminium Alloy AA2219 ”, Journal of Materials Science &Technology, Vol. 26, Issue 8, pp.747-753.
11. Weis Olea C A (2008), “Influence of Energy Input in Friction Stir Welding on Structure Evolution and Mechanical Behaviour of Precipitation-Hardening in Aluminium Alloys (AA2024-T351, AA6013-T6 and Al-Mg-Sc)”, Institute of Materials Research. International Journal of Machine Tools & Manufacture, Vol. 43, No. 13, pp. 1375-1382.
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.