Effect of Tool Rotational Speed on Mechanical Properties of Friction Stir Welded Aluminium Alloys

Jagjeet Singh
Research Scholar, Department of Mechanical Engineering
Guru Jambheshwar University of Science and Technology,
Hisar,Haryana,India

Pankaj Sharma
Assistant Professor, Department of Mechanical Engineering
Guru Jambheshwar University of Science and Technology,
Hisar,Haryana,India

Abstract– In this research work, the effect of tool rotational speed on the mechanical properties of AA2014 and AA5083 welded by Friction Stir Welding (FSW) is studied. The influence of welding parameters has been presented in graphical form for better understanding. Result reveals that with the increase in tool rotational speed, coarse grain structure is produced, which lower ultimate tensile strength and impact strength. Further investigated that with the increase in tool rotational speed rate of heat input increases, which results in coarse micro structure that in turn decreases the hardness.

Keywords — Friction Stir Welding, AA 2014, AA 5083 Alloys, mechanical properties

I. INTRODUCTION

Friction Stir Welding (FSW) is a solid state welding process first discovered and patented by the Welding Institute of Cambridge U.K.in 1991 [1-2]. FSW technique is attractive for joining high strength aluminium alloys since there is far lower heat input during the process compared with conventional welding processes such as TIG, MIG[3-4], which include being a single step process, use of simple and inexpensive tool, less time consuming, no finishing process requirement, less processing time, use of existing and readily available machine tool technology, suitability to automation, flexibility to robot use, being energy efficient and environmental friendly [5]. This process is being used in wide variety of applications in the automotive, aerospace, ship building, and railroad industries [6]. In FSW the interaction of a non-consumable and rotating tool with the work pieces being welded, creates a welded joint through frictional heating and plastic deformation at temperatures below the melting temperature of the alloys being joined. Based on friction heating at the contacting surfaces of two sheets to be joined, a special tool with a properly designed rotating probe travels down the length of contacting metal plates, producing a highly plastically deformed zone through the associated stirring action [7]. The probe is typically slightly shorter than the thickness of the work piece and its diameter is typically slight larger than the thickness of the work pieces [8]. Interesting benefits of FSW compared to fusion processes are low distortion, excellent mechanical properties in the weld zone, execution without a shielding gas, and suitability to weld all aluminium alloys [9]. Fixture is used to hold the sample plates which are welded by FSW process on the bed of CNC milling machine. Sample plates have to be clamped because these plates are to undergo high mechanical forces during the process. Special fixture is design as per requirements [10-11].

II. EXPERIMENTAL DETAILS

A CNC universal milling machine was used to carry out the FSW experiments. The tool was mounted on the vertical spindle. Then two equipped aluminium pieces were clamped into the fixture. Then the rotating tool was made to insert into the butt joint. Then after some time, when there was adequate heating was achieved due to friction between tool and plates, the tool was given automatic feed, along the joint direction. Thus the welding was achieved. The schematic view of experimental setup is shown in Figure 1. After welding the pieces were cut into the samples of mandatory dimensions for performing the tensile tests, impact tests, and micro hardness tests.

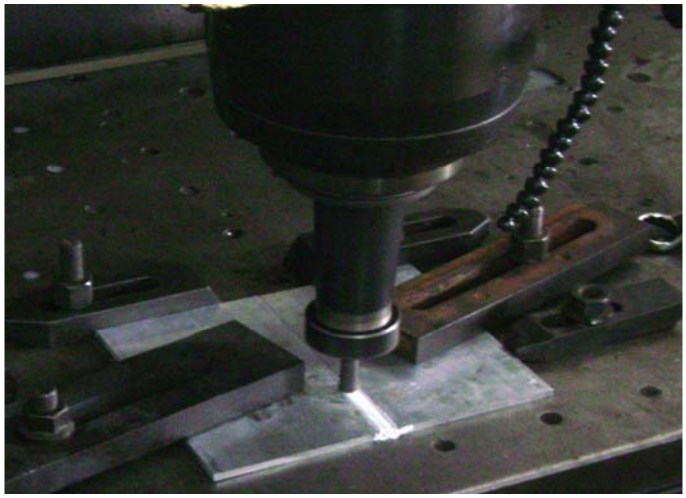


Figure1. Experimental Setup

The base material used in this study was AA-5083 and AA-2014 aluminium alloys whose chemical compositions are given in Table 1.

Table -1 Chemical Composition of AA 5083 alloy

Al	Si	Fe	Cu	Mn	Mg	Zn	Cr	Bi	Ti	Pb	Sn
94.17	0.046	0.119	0.086	0.005	4.780	0.032	0.062	0.042	0.058	0.029	0.008

Table -2 Chemical Composition of AA2014 alloy

Al	Si	Fe	Cu	Mn	Mg	Zn	Cr	Bi	Ti	Pb	Sn
93.18	0.843	0.189	4.255	0.690	0.560	0.083	0.018	0.038	0.047	0.001	0.017

The plates were prepared with 200*150*6 mm dimensions. Before FSW, the weld surface of the base material was cleaned. Plate edges to be weld were also prepared so that they are fully parallel to each other. This is to ensure that there is no bumpy gap between the plates which may not result in sound welding. In this work, the performance of FSW is done with straight threaded cylindrical tool.The length of probe/pin of tools is slightly less than thickness of plates and diameter of pin is slightly greater than thickness of plates. In this work, there are four rotational speeds (1900, 2000, 2100, & 2200 in rpm) and one transverse speed (42 mm/min).

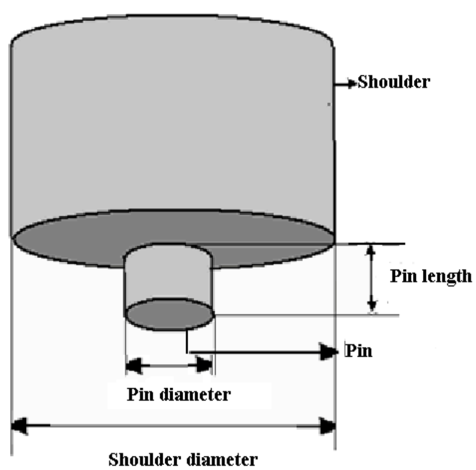


Figure 2. Tool Geometry

III. Results and Discussion

A. Tensile Test-

Tensile strength (in MPa) of samples is shown in following Figure 3:

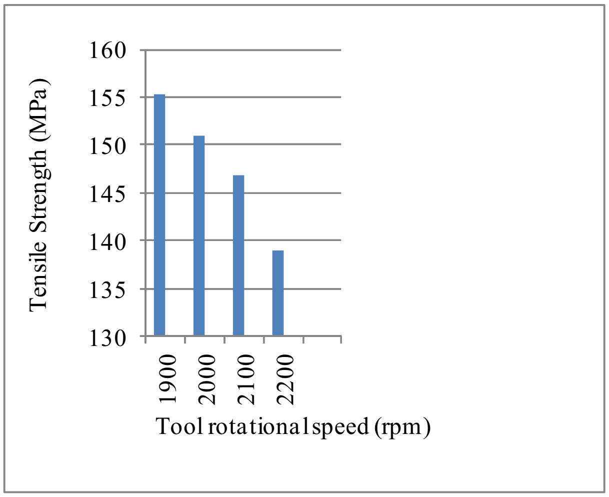


Figure 3. Variation of Tensile Strength

Results of tensile test shows that sample 1 which welded at lowest tool rotational speed had maximum tensile strength. This is due the fact that with increase in tool rotational speed coarse grain structure produced which results in low ultimate tensile strength.

B. Impact Test-

Impact test (in Joule) of samples is shown in Figure 4.

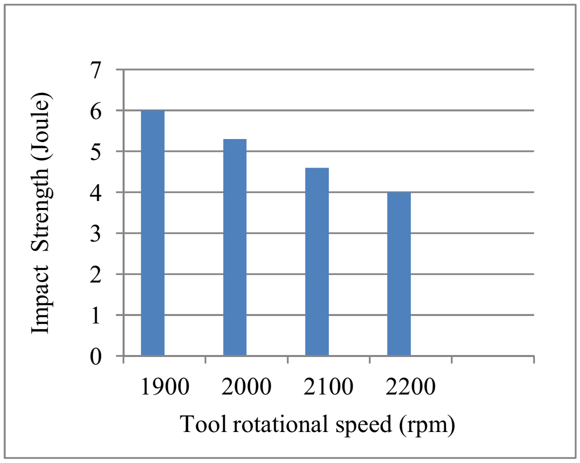
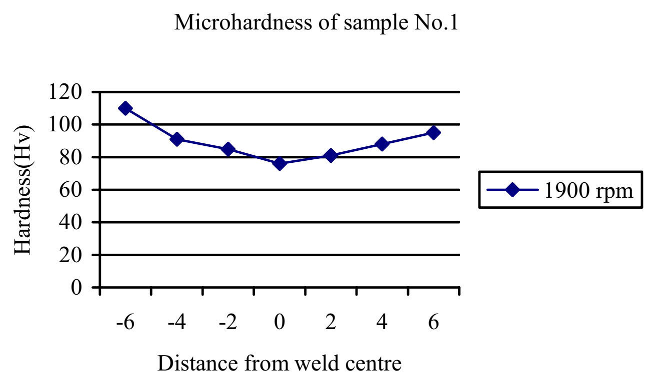


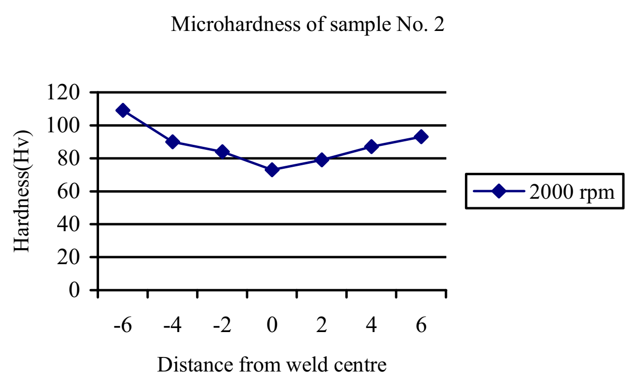
Figure 4. Variation of Impact Strength

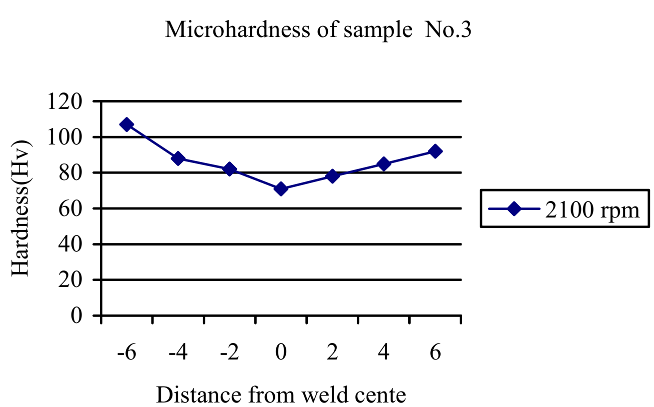
Results of impact test showed that samples welded at lowest rotational speed had maximum impact energy as compared with those welded at higher tool rotational speed.

C. Microhardness Test-

Microhardness of sample at different rpm are shown in following graphs


Microhardness of sample No.1
Hardness(Hv)
120
100
80
60
40
20
0
-6
-4
-2
0
2
4
6
Distance from weld centre
1900 rpm


Microhardness of sample No. 2
Hardness(Hv)
120
100
80
60
40
20
0
-6
-4
-2
0
2
4
6
Distance from weld centre
2000 rpm


Microhardness of sample No.3
Hardness(Hv)
120
100
80
60
40
20
0
-6
-4
-2
0
2
4
6
Distance from weld cente
2100 rpm

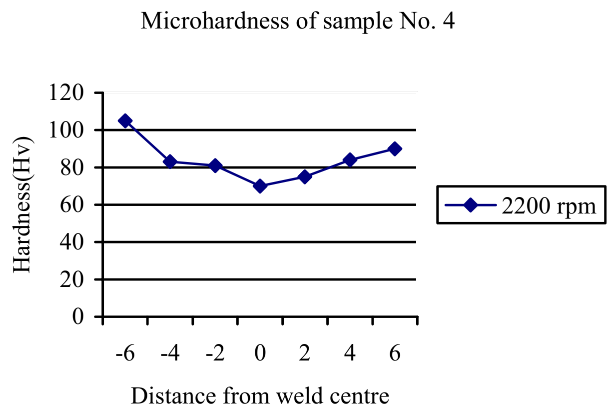


Figure 5.Variation of Hardness

Results of microhardness shows that samples welded at lowest tool rotational speed had maximum hardness value as compared to the sample welded at high tool rotational speed due to coarse microstructure.

IV. Conclusion and Future Scope

Following are the conclusions for the study:-

- With the increase in tool rotational speed, high heat is evolved, due to which coarse grain structure is produced, which resulted in low ultimate tensile strength as well as low impact strength.
- With the increase in rotational speed, rate of heat input increases, which results in coarse microstructure, which in turn decreases the hardness.
- Effects of welding parameters on the other mechanical properties like bending strength, fatigue behaviour, compressive strength can also be studied
- Effects of different types of tool materials can be studied on FSW process.
- FSW process can be studied for suitability for welding other materials like copper, magnesium, titanium, steel etc.

References

[1] C. J. Dawes and W. M. Thomas. “Friction stir process welds of aluminium alloys”, Welding Journal, pp. 41-45, 1996.

[2] W. M. Thomas, E. D. Nicholas, J. C. NeedHam, M. G. Murch, P. Templesmith and C. J. Dawes, “Improvements relating to Friction Stir Welding”, International patent application no. PCT/GB92/02203, 1992.

[3] M. Ericsson and R. Sandstro, “Influence of welding speed on the fatigue of friction stir welds, and comparison with MIG and TIG”, International Journal of Fatigue, pp. 1379-1387, 2003.

[4] W. M. Thomas, E. D. Nicholas, E. R. Watts and D. G. Staines, “Friction based welding technology for aluminium”, Material Science Forum, pp. 1543-1548, 2002

[5] K. Kumbhar, S. V. Kailas and T. S. Srivatsan, “Influence of tool geometry in Friction Stir Welding”, Material and Manufacturing Process, pp. 189-195, 2008

[6] K. H. Rendigs., “Aluminium structures used in aerospace-status and prospects”, Material Science Forum, pp. 11-24, 1997

[7] W. J. Arbegast. “Friction stir welding after a decade of development”, Welding Journal, pp. 28-35, 2007

[8] V. Soundararajan, E. Yarrapareddy and K. Radovan, “Investigation of the friction stir lap welding of aluminum alloys AA 5182 and AA 6022”, Journal Material science Engineering Perform, pp. 477-484, 2007

[9] L. Zhao, H. J. Liu and Q. W. Liu, “Effect of rotation speed on microstructure and mechanical properties of Ti–6Al–4V friction stir welded joints”, 2010.

[10] R. S. Mishra, Z. Y. Ma, “Friction stir welding and processing”, Material Science Engineering, pp. 1- 78, 2005

[11] R. M. Mishra and M. W. Mahoney, “Friction stir welding & processing”, ASM International, pp. 360, 2007

[12] A. Sidana, K. Sandhu and B. Singh, “Effect of tool rotation speed on microstructure properties of friction stir welded Al6061-T6 alloys”, International Journal of New Innovation, pp. 295-299, 2012

[13] S. Cam, A. Gucluer, A Cakan and H. T. Serindag, “Mechanical properties of Friction Stir butt-welded Al-5086 H32 plate”, Journal of Achievements in Materials and Manufacturing Engineering, pp. 151-156, 2008

[14] G. Singh, K. Singh and D. Jaiswal , “Mathematical modelling of process parameter in FSW of aluminium alloy.’ National conference on advancements & futuristic trends in mechanical and materials engineering, pp. 57, 2010