

Effects of Friction Stir Welding Parameters on Butt Joint Properties of Aluminium Alloy 5083

B. Ravindar¹, Dr. K. Gururaj²

Department of Mechanical Engineering, Vaageswari college of Engineering, Thimmapur, Karimnager, Telangana state, India¹

Department of Mechanical Engineering, Kakatiya Institute of Technology & Science, Yerragattu Hillock, Hasanparthy, Warangal, Telangana state, India²

ABSTRACT: The purpose of the present study was to determine the effects of friction stir welding (FSW) parameters, which are the tool rotation speed, Welding speed, Angle of the tool. The microstructure and mechanical properties of butt joint Aluminum Alloy (Al 5083) sheets of thickness 4mm. The macroscopic and microstructure examinations and tensile test results indicated that the joint properties were significantly affected by FSW parameters. Due to high strength, good welding properties, increased wear and corrosion resistance and high strength-to weight ratio, Aluminium 5083 is widely used in Ship building, Rail cars, Vehicle bodies, Tip truck bodies, Pressure vessels. Friction Stir Welding is an emerging solid state joining process in which the material that is being welded does not melt and recast. This process uses a non- consumable tool to generate frictional heat in the abutting surfaces. The welding parameters and tool profile play major roles in deciding the weld quality. In this investigation, an attempt has been made to understand the effect to tool rotational speed (rpm), welding speed (mm/min) and Tool tilt angle (degrees) on 5083 Aluminium Alloy Plates of thickness 4mm. A sound and defect-free weld was achieved with a tool rotation speed of 1100 rpm, welding speed of 100mm/min and tool tilt angle of 91°. From this investigation it has been found that the tool rotational speed had little effect a heat input and tensile properties, weld properties were dominated by thermal input rather than the mechanical deformation by tool tilt angle for the plate thickness 4mm. In our Investigation we are using straight cylindrical pin profiled tool produces mechanically sound. The effect of welding process on mechanical properties of welded joints was analyzed on tensile test and microstructures. The mechanical properties of weld joint is affected greatly with the variation of welding parameters i.e. Tool rotational speed, Welding speed and Tool tilt angle

KEYWORDS: AA 5083 plates, Tensile strength, Yield strength, Percentage of elongation & Micro structural Properties, Butt Joint.

I. INTRODUCTION

Friction stir welding is a solid state joining process in-vented in TWI in Cambridge, England in 1991 firstly for joining aluminium alloys [1]. It has made low cost welded joints due to low power consumption, absence of gas shielding, no need of joint edge preparations before welding application and low distortion because of lower welding temperature and specially high joint strength compared with conventional welding methods, i.e. TIG or laser welding, that had been widely used for this purpose before, obviously because of decreasing in metallurgical defects. It is able to join all of the aluminum alloys from 2XXX to 7XXX series that had been considered as not weld able alloys by conventional welding methods due to excessive joint strength de-crease in compared with the base material. FSW can produce many kinds of joints, i.e. butt joints, lap joints and T joints. Lap joints are widely used in assemblies of parts in air craft and automotive industries. In the last years, FSW has been one of the most interests for aluminum alloys lap joints. In aircraft and automotive structures friction stir welded lap joints have been widely used with the aim to replace riveted lap joints. Rivet holes are often potential sites for crack initiation or corrosion problems; moreover, the elimination of fasteners leads to considerable weight and cost savings. A few examples of FSW joints applied in automotive industries are some applications include engines, wheel rims and lap joints in car back supports [2-3]. In FSW process, the joint is produced by penetrating a specially designed inconsumable rotating shouldered tool pin into the interface of two pieces

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 7, July 2015

of sheets and moving it along the weld line to heat and stir the sheets' materials by producing friction between the shoulder and the sheet sur-face and also the material flow by the pin movement. As the tool moves through the weld line, the heated materials of two sheets flow and mix together without melting and make the welded joint[4]. Because in FSW the joining process is accomplished by material flow below the melting temperature, many joint defects caused by joint material melting such as porosity, grain boundary cracks and alloys segregation can be eliminated or adequately reduced. These process specialties have made FSW very practical for joining dissimilar alloys. Lately some researchers have been performed on friction stir welding of dissimilar aluminum lap joints [5-7]. AA5083 is a strain hardening structural alloy that is widely used in aerospace, marine and military industries mostly because of its light weight, admissible weld ability and elite corrosion resistance [8]. Some recent researches have studied friction stir welding of this aluminum alloy in similar or dissimilar joints [9-12].

In this study, similar sheets of 5083 Al alloy were butt jointed by friction stir welding method with various tool rotational, welding speeds and angle of the tool. Microstructure and Tensile test properties are studied.

Introduction to Aluminium Alloy 5083

Aluminium is a chemical element in the boron group with symbol Al and atomic number 13. It is silvery white, and is not soluble in water under normal circumstances. Aluminium is the third most abundant element (after oxygen and silicon), and the most abundant metal, in the Earth's crust. It makes up about 8% by weight of the Earth's solid surface. Aluminium metal is so chemically reactive that native specimens are rare and limited to extreme reducing environments. Instead, it is found combined in over 250 different minerals. The main ore of aluminum is bauxite. Aluminium is remarkable for its low density and ability to resist corrosion due to the phenomenon of passivation. Structural components made from aluminum and its alloys are vital to the aerospace industry and are important in other areas of transportation and structural materials. The most useful compounds of aluminium, at least on a weight basis, are the oxides and sulphates. Aluminium 5083 is a high strength non-heat treatable alloy in commercial use. The major additive in the alloy is Magnesium. It has good formability and weldability and retains excellent tensile strength in the weld zone. It has excellent resistance to corrosion and high strength-to-weight ratio. The experimental material is selected as 5083 Al alloy sheets of 4 mm thickness, which is welded by Friction Stir Welding after surface preparation.

Table 1: Chemical Composition AA 5083

Element	Si	Fe	Cu	Mn	Mg	Zn	Cr	Ti	Al
% present	0.4	0.4	0.1	0.4-1.0	4.0-4.9	0.25	0.05-0.25	0.15	Remaining

The base metal employed is AA 5083 of chemical composition is shown in Table 1. Mechanical properties and Physical properties are shown in Table 2 and 3.

Table 2: Mechanical Properties of AA 5083

Property(Mpa)	Value
Tensile Strength(MPa)	330
Shear Strength(MPa)	185
Elongation (%)	17
Hardness Vickers(HV)	95

Table 3: Physical Properties of AA 5083

Property	Value
Density	2650 kg/m ³
Melting Point	570°C
Modulus Resistivity	72 Gpa
Electrical Resistivity	0.058x10 ⁻⁶
Thermal Conductivity	121 W/m.K
Thermal Expansion	25x10 ⁻⁶ m/k

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 7, July 2015

Table 4: Material composition H13

Metal	Content (%)
Cromium, Cr	4.75-5.50
Molibdenum, Mo	1.10-1.75
Silicon, Si	0.8-1.2
Vanadium, V	0.8-1.2
Carbon, C	0.32-0.45
Nikel, Ni	0.3
Copper Cu	0.25
Maganese, Mn	0.2-0.5
Phosphours, P	0.03
Sulfur ,S	0.03

Table 5: Mechanical properties H13

Properties	Content (%)
Ultimate Tensile Strength(@ 20 ⁰ c)	1200-1590 Mpa
Yield Strength (@ 20 ⁰ c)	1000-1380 Mpa
Reduction of Area (@ 20 ⁰ c)	
Modulus of Elasticity (@ 20 ⁰ c)	
Poisson's Ratio	0.27-0.3

Table 7 : Base Metal

	Tensile strength (N/mm ²)	Yield strength ((N/mm ²)	% Elongation
1	296.154	170.093	20.78

II. WELDING VARIABLES

Friction Stir Welding involves complex material movement and plastic deformation. Welding parameters, Tool geometry and joint design exert significant effect on the material flow pattern and temperature distribution, thereby influencing the microstructure and mechanical properties. Moreover, no systematic study has been reported so far to analyze the mechanical & micro structural properties of AA 5083 with H13 welding tool.

Aluminium Alloy 5083 was selected as the base metal as it has gathered wide acceptance in the fabrication of light weight structures requiring a high strength-to-weight ratio and excellent weldability, such as transportable bridge girders, military vehicles, road tankers and ship building. For FSW, two parameters are very important: tool rotational speed and Traverse speed along the line of joint. Another important process parameter Tool.

III. EXPERIMENTAL WORK

In this analysis friction stir welding is used. The studied material is AA 5053 sheets, 4 mm thickness for butt joint. A vertical semiautomatic milling machine was used for this process. The tool used for this process was made of H13 steel 18mm diameter with the length of the pin is 4.7mm. Firstly material cut by shear machine as required dimensions of 100 x 100 x 4 mm are prepared and weld was made by joining two pieces. The process of welding is FSW completed by one pass by using H13 steel and weld samples of weld at different conditions by changing the Tool rotational speed, Welding speed, and Angle of the tool. Total number of samples is 27.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 7, July 2015

Table 6: Welding process parameters

Specimen	Tool Rotational speed(rpm)	Welding Speed (mm/min)	Angle of the Tool (degrees)
1	700	60	90
2	700	60	90.5
3	700	60	91
4	700	80	90
5	700	80	90.5
6	700	80	91
7	700	100	90
8	700	100	90.5
9	700	100	91
10	900	60	90
11	900	60	90.5
12	900	60	91
13	900	80	90
14	900	80	90.5
15	900	80	91
16	900	100	90
17	900	100	90.5
18	900	100	91
19	1100	60	90
20	1100	60	90.5
21	1100	60	91
22	1100	80	90
23	1100	80	90.5
24	1100	80	91
25	1100	100	90
26	1100	100	90.5
27	1100	100	91

Table8: Results of Experiment

Specimen Id	Average values of mechanical properties		
	Tensile strength (N/mm ²)	Yield strength (N/mm ²)	% Elongation (N/mm ²)
1	192.193	149.820	3.27
2	240.461	155.405	5.26
3	264.573	158.843	6.72
4	178.700	135.534	2.86
5	235.200	151.916	5.70
6	250.151	152.332	6.32
7	224.618	155.205	4.97
8	209.345	140.642	4.08
9	226.509	139.139	4.02
10	203.629	133.467	3.98
11	229.719	161.105	5.25
12	243.900	154.183	4.52
13	193.265	137.137	3.94
14	183.264	137.625	3.74
15	256.547	153.344	4.96
16	174.612	140.991	4.16
17	181.339	145.075	3.85
18	166.470	129.525	3.75
19	175.186	137.502	3.13
20	224.837	157.558	3.65
21	192.571	158.895	3.74
22	153.910	123.136	1.76
23	210.726	154.618	3.94
24	195.753	151.186	4.59
25	140.799	109.860	1.81
26	194.767	153.465	3.12
27	255.464	184.539	8.28

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 7, July 2015



Figure 1: Friction stir welding Tool H13



Figure 2: Experimental setup for FSW process



Figure 3: Welding Process



Figure 4: FSW welded samples



Figure 5: TS Welded samples cut by EDM



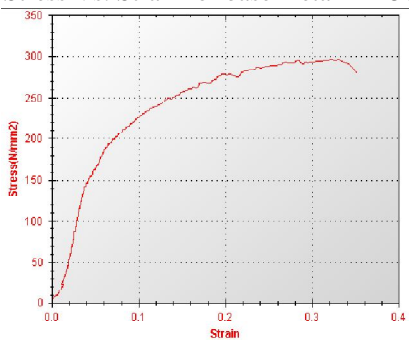
Figure 6: Samples after test

Table 6: Welding process parameters

The tensile test specimens are cut by Electro Discharge machine at the required dimension. Tensile test has been carried out in 600kN. Electro-mechanical controlled Universal Testing machine (Fine Spavy). Specimen is loaded at the stain rate of 2mm/min and extensometer is attached to specimen, so that tensile specimen undergoes deformation. The specimen finally fails after necking and the load versus displacement has been recorded and stress-strain curve generates automatically. The Ultimate Tensile strength, Yield strength and percentage of elongation have been evaluated

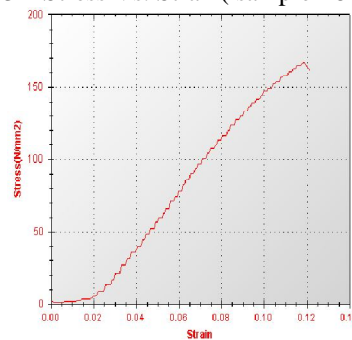
IV. RESULTS AND DISCUSSION

Stress Vs. Strain for base metal AA 5083



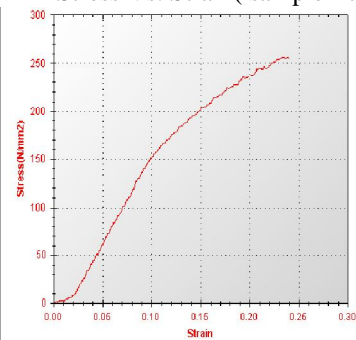
Graph3: Stress Vs. Strain curve (a) 900 rpm, rotational speed rpm, rotational speed

Stress Vs. Strain(sample-18)



Graph4: Stress Vs. Strain curve (a) 1100 rpm, rotational speed

Stress Vs. Strain(sample-27)



(b) 100 mm/min, Welding speed, (c) 91° Angle of the too (b) 100mm/min Wleding speed,(c) 91° Angle of the tool

International Journal of Innovative Research in Science, Engineering and Technology

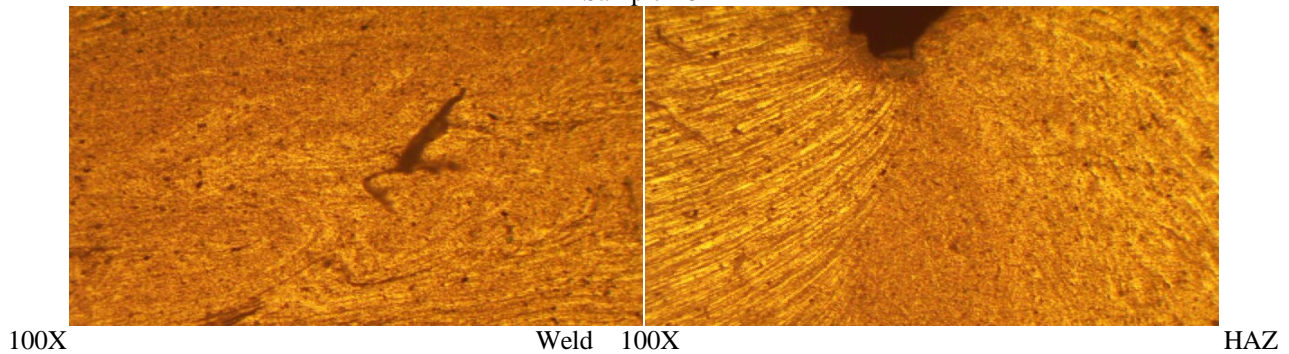
(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 7, July 2015

Transverse tensile properties of FSW joints such as yield strength, ultimate tensile strength, and percentage of elongation have been evaluated. Three specimens were tested at each condition and average of the results of three specimens is presented. Here we are using cylindrical tool. By changing the different process parameters i.e. Tool rotational speed, Traverse speed and Tool tilt angle .here keeping two parameter constant and varying one parameter such that total we went for total 27 samples. From that some of the results presenting here. Graph 1 shows the stress Vs strain curve of base metal AA5083. From graph2, welding speed 700 rpm, welding speed 60 mm/min and Angle of the tool is 91° , here tensile strength is 264.573 N/mm^2 Yield strength is 158.843 N/mm^2 and Percentage of elongation is 6.72. From graph4 welding speed 1100 rpm, welding speed 100 mm/min and Angle of the tool is 91° , here tensile strength is 255.464 N/mm^2 Yield strength is 184.539 N/mm^2 and Percentage of elongation is 8.2

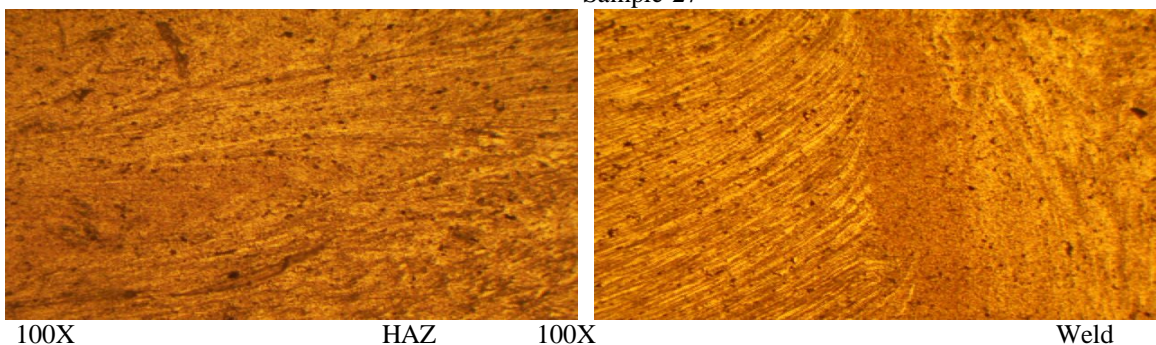
Micro structures

Sample-18



From the above micro structures observed that dendrites of Aluminium solid solution with fine inter metallic particles. Cracks observed and blowholes observed and lack of fusion. Heat affected zone shows fine intermetallic particles in Aluminium solid solution, cracks observed along weld joint.

Sample-27



From the above figure result shows that dendrites of Aluminium solid solution with fine intermetallic particles, no cracks observed and no lack of fusion at the root. Heat affected zone shows fine intermetallic particles in aluminium solid solution, no cracks observed and no coarsening.

V. CONCLUSION

From analysis of all experimental trials, it is found the great effect of welding parameters such as Tool rotational speed, Welding speed and Angle of the tool on mechanical properties and Microstructures. At Tool rotational speed 900 rpm , Welding speed is 100 mm/min & Angle of the tool is 91° here tensile strength ,yield strength, % elongation are very low and from micro structures absorbed that, lack of fusion and cracks absorbed and coarsening. But at Tool rotational speed 1100 rpm , Welding speed is 100 mm/min & Angle of the tool is 91° here Tensile strength is 255.464 N/mm^2 , Yield strength is 184.539 N/mm^2 and percentage of elongation is 8.28 and

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 7, July 2015

from MS at HAZ shows that fine intermetallic particles in Al. solid solution, No cracks are absorbed and no coarsening. It can be concluded that as the mechanical and micro structural prosperities are high at Tool rotational speed 1100 rpm, Welding speed is 100 mm/min & Angle of the tool is 91° .

REFERENCES

- [1] W.M. Thomas, E.D. Nicholas, J.C. Needam, M.G.Murch, P. Templesmith, C.J. Dawes. GB Patent
- [2] D. Fersini, A. Pironi, Fatigue behaviour of Al2024-T3 friction stir welded lap joints, Engineering Fracture Mechanics 74 (2007) 468–480
- [3] Mats Ericsson, Lai-Zhe Jin, Rolf Sandström, Fatigue properties of friction stir overlap welds, International Journal of Fatigue 29 (2007) 57–68
- [4] S, Li Y, Murr LE, Brown D, McClure JC (1999) Low temperature friction-stir welding of 2024 aluminium, Scr Mater 41.(8):809–815
- [5] L. Dubourg, A. Merati, M. Jahazi, Process optimisation and mechanical properties of friction stir lap welds of 7075-T6 stringers on 2024-T3 skin, Materials and Design 31 (2010) 3324–3330
- [6] Chang-Yong Lee, Won-Bae Lee, Jong-Woong Kim, Don-Hyun Choi, Yun-Mo Yeon, Seung-Boo Jung, Lap joint properties of FSWed dissimilar formed 5052 Al and 6061 Al alloys with different thickness, J Mater Sci (2008) 43:3296–3304
- [7] Vijay Soundararajan, Eswar Yarrapareddy, and Radovan Kovacevic, Investigation of the Friction Stir Lap Welding of Aluminum Alloys AA 5182 and AA 6022, JMEPEG (2007) 16:477–484
- [8] M. Grujicic, G. Arakere, B. Pandurangan, A. Hariharan, C.-F. Yen, B.A. Cheeseman, and C.Fountzoulas, Statistical Analysis of High-Cycle Fatigue Behavior of Friction Stir Welded AA5083-H321, JMEPEG (2011) 20:855–864
- [9] CAIZHI ZHOU, XINQI YANG, GUOHONG LUAN, Effect of kissing bond on fatigue behavior of friction stir welds on Al 5083 alloy, J MATER SCI 41 (2006) 2771–2777
- [10] Min-Su HAN, Seung-Jun LEE, Jae-Cheul PARK, Seok-Cheol KO, Yong-Bin WOO, Seong-Jong KIM, Optimum condition by mechanical characteristic evaluation in friction stir welding for 5083-O Al alloy, Trans. Nonferrous Met. Soc. China 19(2009) s17-s22
- [11] J.J.S. Dilip, M.Koilraj, V.Sundareswaran, G.D. Janaki Ram and S.R. Koteswara Rao, Microstructural characterization of dissimilar friction stir welds between AA2219 and AA5083, Transactions of The Indian Institute of Metals, Vol. 63, Issue 4, August 2010, pp. 757- 764
- [12] M. Movahedi, A.H. Kokabi, S.M. Seyed Reihani and H. Najafi, Mechanical and Microstructural Characterization of Al-5083/St-12 lap joints made by friction stir welding, Pro-cedia Engineering 10 (2011) 3297-3303