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THE INFLUENCE OF PROCESS PARAMETERS ON MICROHARDNESS AND MECHANICAL PROPERTIES OF FSW ALUMINIUM 5083 ALLOY BUTT JOINT

B. Ravindar, Dr. K. Gururaj, Dr.A.Somi Reddy
*Department of Mechanical Engineering, Vaageswari college of Engineering, Karimnager, Telangana state, India
Department of Mechanical Engineering, Kakatiya Institute of Technology & Science, Telangana state, India
Department of Mechanical Engineering, Vivekananda Institute of Technology & Science, Karimnager, Telangana state, India

ABSTRACT
Recently the air craft and military industries widely have been using aluminium alloys particularly because of their fine strength to weight ratio. However in compare with steels they represent welding difficulties and also lower ductility. 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, Too tilt angle. The Micro hardness and mechanical properties of butt joint Aluminum Alloy (Al 5083) sheets of thickness 4mm. The microstructure examinations and mechanical 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 910. 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, Impact, Micro hardness properties and Scanning Image Microscope. The mechanical properties of weld joint are affected greatly with the variation of welding parameters i.e. Tool rotational speed, Welding speed and Tool tilt angle.

KEYWORDS: AA 5083 plates, Impact test, Micro hardness Properties, Scanning Image Microscope, straight cylindrical pin, Butt Joint..

INTRODUCTION
Friction-stir welding (**FSW**) is a solid-state joining process (meaning the metal is not melted during the process) and is used for applications where the original metal characteristics must remain unchanged as far as possible. This process is primarily used on aluminium, and most often on large pieces which cannot be easily heat treated post weld to recover temper characteristics. Friction Stir Welding (FSW) is a solid state joining process that involves joining of metals without fusion or filler materials. The frictional heat is produced from a rapidly rotating non-consumable high strength tool pin that extends from a cylindrical shoulder. The process is particularly applicable for aluminium alloys but can be extended to other products also. Plates, sheets and hollow pipes can be welded by this method. The process is also suitable for automation. The weld produced is of finer microstructure and superior in characteristics to that parent metal. FSW finds application in shipbuilding, aerospace, railway, electrical and automotive industry. The limitations of FSW are reduced by intensive research and development. Its cost effectiveness and ability to weld dissimilar metals makes it a commonly used welding process in recent times. 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 process es 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].

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

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
Manganese,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)	50%
Modulus of Elasticity (@ 20^0 c)	31200 ksi
Poisson's Ratio	0.27-0.3

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 impact tests, micro hardness tests and SEM results.

WELDING VARIABLS

Friction Stir Welding involves complex material movement and plastic deformation. Welding parameters, Tool geometry and joint design expert 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 is Tool.

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.

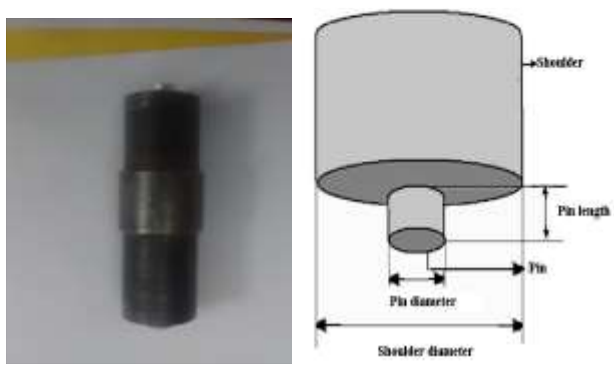

Figure 1: Friction stir welding Tool H13 and Tool geometry

Figure 2: Experimental setup

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

Figure 3: FSW welded samples

Figure 4: Impact Test Welded samples cut by EDM

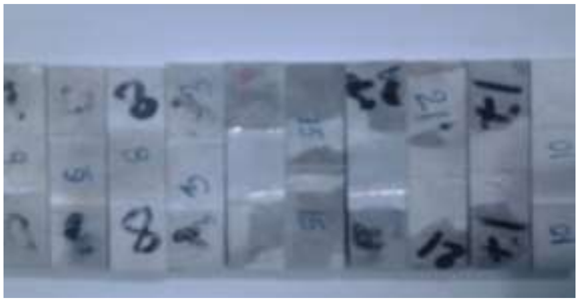

Figure 5: Impact testing machine

Figure6: Samples after test

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Base Metal AA 5083

Sample ID.	Impact Energy - Joules
BASE METAL	14 - J

Table9: Result of Impact energy(Joules)

Sample ID	1	2	3	4	5	6	7	8	9
Average Values	8	10	12	10	8	12	8	4	8

Sample ID	10	11	12	13	14	15	16	17	18
Average Values	6	10	8	6	6	12	8	6	4

Sample ID	19	20	21	22	23	24	25	26	27
Average Values	6	10	10	10	8	4	8	8	10

Figure 7: Micro hardness curves

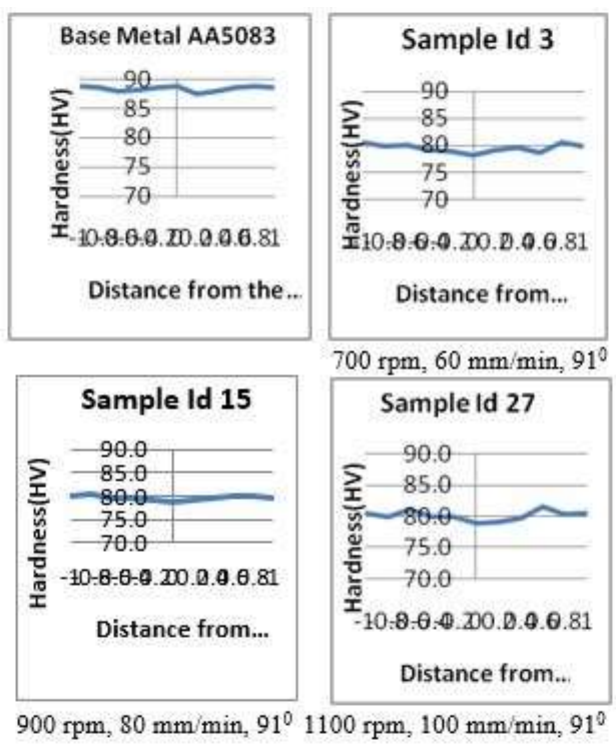

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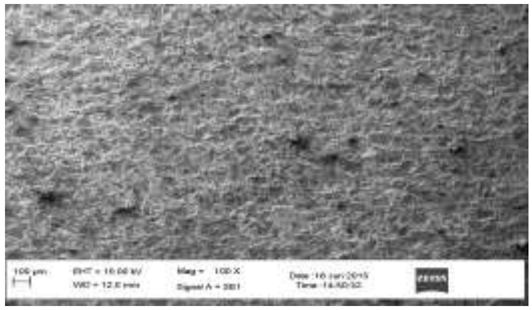
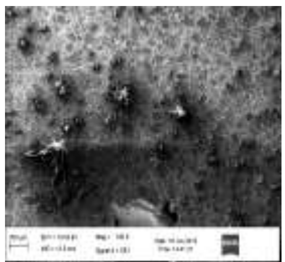
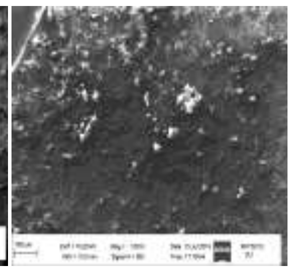
FIGURE 8: SEM IMAGES

Base Metal AA 5083



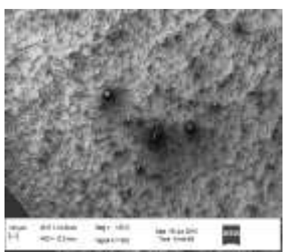
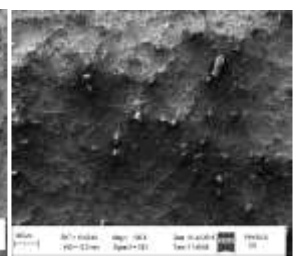
100X

FSW SAMPLE 3

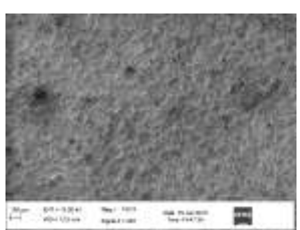
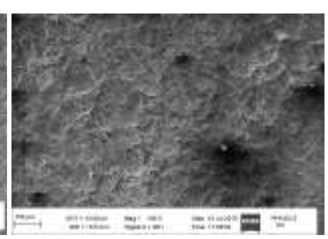
100X WELD 100 HAZ

FSW SAMPLE 15

100X WELD 100X HAZ

FSW SAMPLE 27

100X WELD 100X HAZ

CONCLUTIONS

For optimizing the joint properties different parameters including different rotational and welding speed have been experimented. The following conclusions may be drawn from the friction stir welded 5083 aluminium alloy. At all the rotational speeds experimented the nugget area showed lower hardness valued compare to the base metal. The nugget of the weld as the finest grain size and lowest hardness among the other welding areas. At both the speeds experimented the HAZ (Heat Affected Zone) as the highest grain size. The reasons for the lowest strength compare to the base material would be the in sufficient stirred joint area. At higher rotational speeds large amount of material defects on the joint.

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