ISSN 2348 – 7968

Mechanical and Microstructure properties of Pulsed Tungsten Inert Gas and FS Welding of AA5083 Butt joint

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Abstract

This study has been conducted to investigate the effect of welding process parameter on the mechanical properties and microstructure of aluminum alloy 5083, using Pulsed Tungsten inert gas welding (P/TIG) and friction stir welding (FSW). In this study, Pulse TIG welding parameter's on weldability of 5083 alloy specifications. The welding parameters such as welding current, Gas flow rate, and different filler diameters are taken into account which influences the properties of material at welded area. Aluminium 5083 sheets were welded by Pulse Tig welding with 5356. To determine the effects of friction stir welding (FSW) parameters, which are the tool rotation speed, Welding speed, Tool tilt angle for the same material. The effect of welding process parameters is analyzed by conducting of mechanical properties and micro structure tests on weld joint for TIG welded samples as well as FSW samples. The experimental results indicate that the welding process parameters have significant effect on mechanical properties of the joints, compare with Pulsed Tig welding we got fsw best results at Tool Rotational speed 900 rpm, welding speed 80 mm/min and angle of the tool is 91^0. The mechanical properties and micro hastucture results shows that FSW joint is better than Pulsed Tig welding.

Keywords: *AA 5083 plates, Tensile test, Impact test, Micro structure Properties, straight cylindrical pin, Butt Joint.*

1. Introduction

Tig welding is an arc welding process that uses a non – consumable tungsten electrode to produce the weld. The weld area is protected from atmosphere by an inert shielding gas (argon or helium) and a filler metal is normally used. The power is supplied from the power source (rectifier), through a hand piece or welding torch and is delivered to a tungsten electrode which is fitted into the hand piece. An electric arc is then created between the tungsten electrode and the work piece using a constant currant welding power supply that produces energy and conducted across the arc through a column of highly ionized gas and metal vapors. The tungsten electrode and the welding zone are protected from the surrounding air by inert gas.. The welding came into existence from "Bronze Age" about 2000 years ago. But Egyptian people learned to weld iron pieces together during Iron Age. TIG Welding is preferred only for aluminium alloys because it starts to spread out from weld pool during the welding operation in other processes.TIG welding was demonstrated first by Russell Meredith in 1930 during Second World War for welding aluminum and magnesium in aircraft industry. Tig welding with Pulsating current has been known for many years. The welding current weaves periodically between a high (pulse current) and low (basic current) values. In the basic current phase, the low temperature causes a decrease in the volume of the molten pool. The welding has applications in manufacturing field such as ships, boats, cyclic, automotive industry, aircraft industry and pipelines. The weld quality was strongly characterized by weld bead geometry because the weld pool geometry plays an important role in determining mechanical properties of weld. Maximum quality can be achieved with control of welding parameters and material and material used must be cleaned. The heat affected zone influenced with the increment of heat input due to increased welding current. The width of heat affected zone increases due to low heat input. The weld bead geometry of weld repaired aluminium alloy was similar as cast aluminium alloy in appearance but different in micro-structure.

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].

1.1Introduction 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

ISSN 2348 – 7968

Table 3: Physical Properties of AA 5083

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

Table 4: Chemical Composition of Filler rod ER 5356

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

Table 5: Material composition H13

Metal	Cr	Mo	Si	V	C	Ni	Cu	Mn	P	S
Content (%)	4.75 - 5.50	1.10 - 1.75	0.8 - 1.2	0.8 - 1.2	0.32 - 0.45	0.3	0.25	0.2 - 0.5	0.03	0.03

Table 6: 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

2.EXPERIMENTAL WORK

Pulsed current gas tungsten arc welding, developed in 1950's, is a variation of gas tungsten arc welding which involves cycling of the welding current from a high level to a low level at a selected regular frequency. The high level of peak current (Ip) is generally selected to give adequate penetration and bead contour, while the low level of background current (Ib) is set at a level sufficient to maintain a stable arc. This permits arc energy to be used efficiently to fuse a spot of controlled dimensions in a short time producing the weld as a series of over lapping nuggets and limits the wastage of heat by conduction into the adjacent parent material as in normal constant current welding, the fact that heat energy required to melt the base material is supplied only during peak current pulses for brief intervals of time allows the heat affected zone (HAZ). The technique has secured a niche for itself in specific applications such as in welding of root passes of tubes and in welding thin sheets, where precise control over penetration and heat input are required to avoid burn through.

For friction stir welding and tig welding same metal i.e AA 5083 sheets, 4 mm thickness for butt joint is used. For tig welding different diameters of electrodes are use and the material is 5356 i.e same composition as base metal. For tig welding a vertical semiautomatic milling machine was used. 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 one parameters and keeping two parameter constant such that total number of samples are 27 from each welding.

Table 7. TIG welding process parameters

Specimen Id	Welding current (Amps)	Gas Flow Rate (Lt/min)	Filler rod dia.(mm)
3	180	8	3.2
15	210	10	3.2
27	240	12	3.2

Table 8. FSW Process parameter

Specimen	Tool Rotational speed(rpm)	Welding Speed (mm/min)	Angle of the Tool (degrees)
3	700	60	91
15	900	80	91
27	1100	100	91

IJISET - International Journal of Innovative Science, Engineering & Technology, Vol. 3 Issue 1, January 2016.
www.ijiset.com
ISSN 2348 – 7968

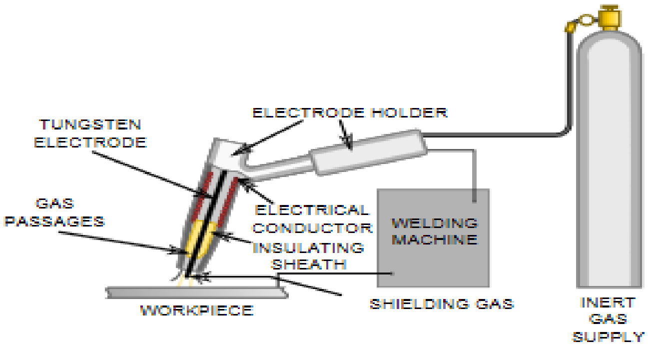


Figure 1:Schematic diagram of gas welding

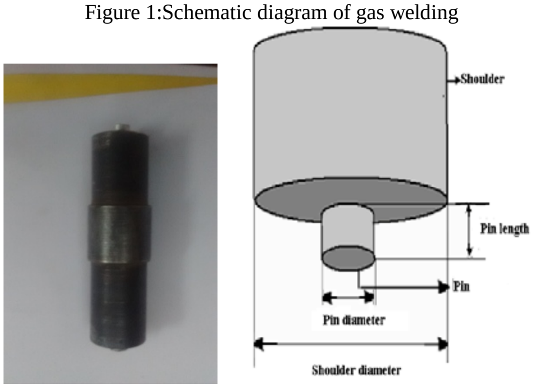


Figure 2: Friction stir welding Tool H13 and Tool geometry

Figure 3:Before welding clapping & Alignment

Figure 4: Experimental setup

Fig 5: Samples with Weld bead and fsw

Figure 6: Impact and tensile Test Welded samples cut by EDM

Fig. 7: Tensile and Impact Samples after test

2.1 TENSILE TEST RESULTS

Table 9:Base Metal

Sl.No.	Tensile strength (N/mm^2)	Yield strength ((N/mm^2)	% Elongation
1	296	170	21

Table 10:Tensile test result of sample id

Specimen Id	Average values of mechanical properties					
	Tensile strength (N/mm^2)		Yield strength (N/mm^2)		% Elongation	
	TIG	FSW	TIG	FSW	TIG	FSW
3	152	265	122	159	3	7
15	107	257	86	153	2	5
27	296	255	196	185	21	12

ISSN 2348 – 7968

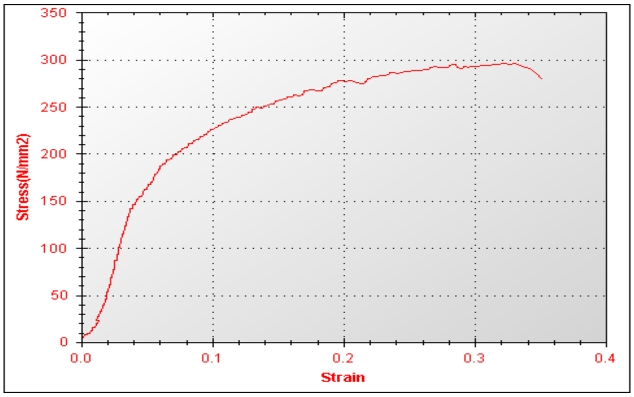
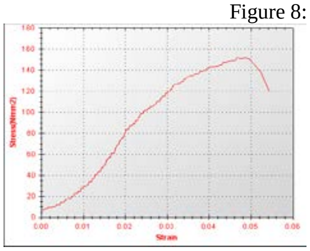
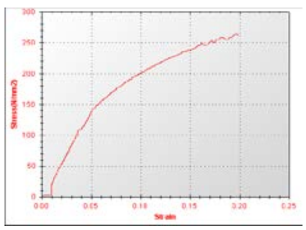


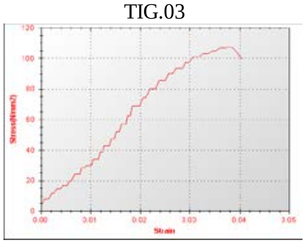
Figure 8: Base metal



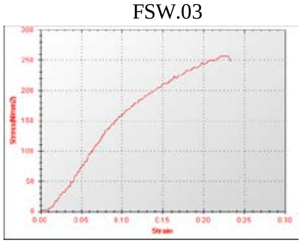
TIG.03



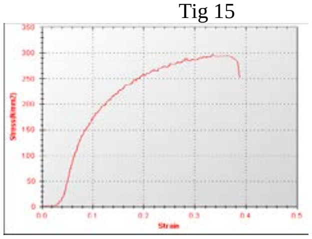
FSW.03



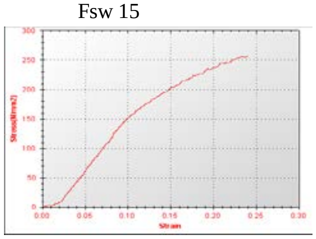
Tig 15



Fsw 15



Tig 27



Fsw 27

Figure 9: Stress strain curves of FSW and P TIG welding for different samples

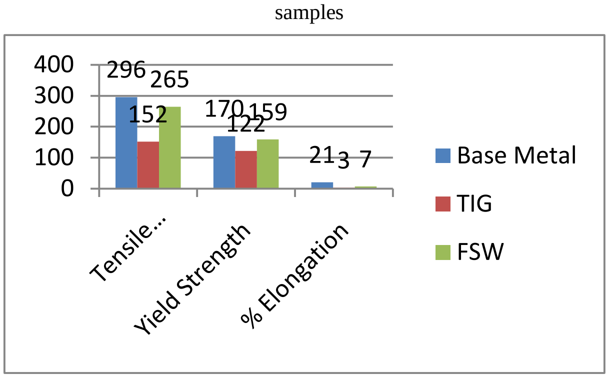


Figure 10: Relationship between base metal, Pulsed TIG welding for sample -3

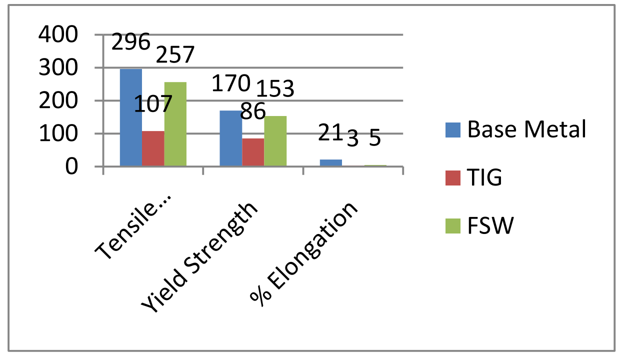


Figure 11: Relationship between base metal, Pulsed TIG welding for sample - 15

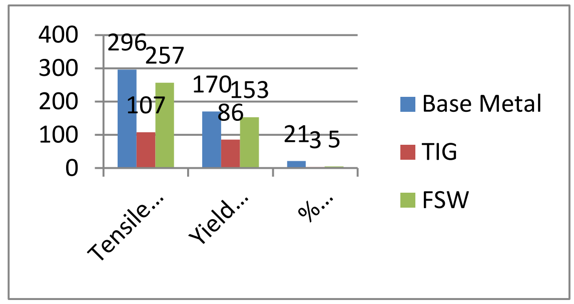


Figure 12: Relationship between base metal, Pulsed TIG welding for sample - 27

2.2 Impact energy test results

Table 11:base metal

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

Table 12: impact energy of test id

Sample Id	Pulse TIG	FS WELDING
	Impact Energy - Joules	Impact Energy - Joules
I - 003	6 - J	12 - J
I - 015	12 - J	12 - J
I - 027	14 – J	10 - J

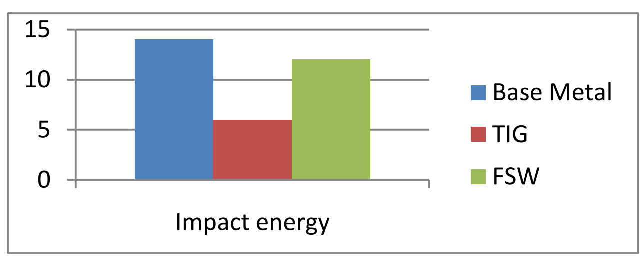


Figure 13: Bar diagram for Pulsed TIG & FSW of Sample 3

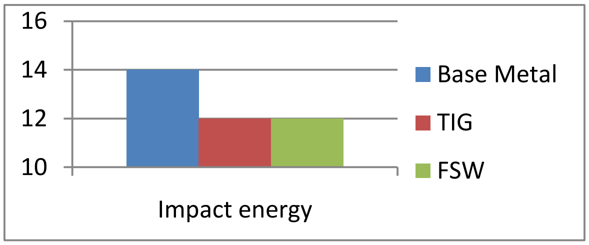


Figure 14: Bar diagram for Pulsed TIG & FSW of Sample 15

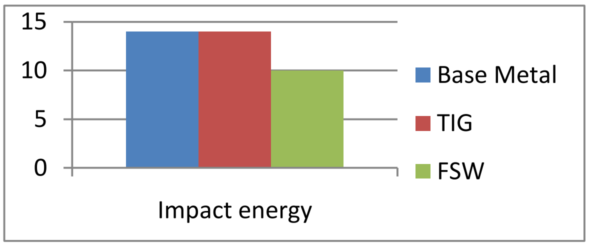


Figure 15: Bar diagram for Pulsed TIG & FSW of Sample 27

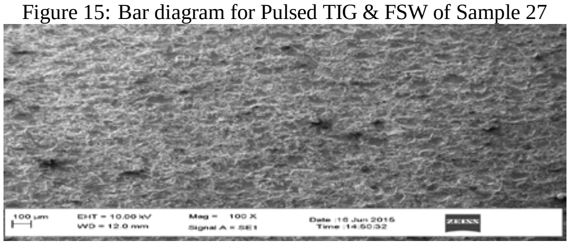
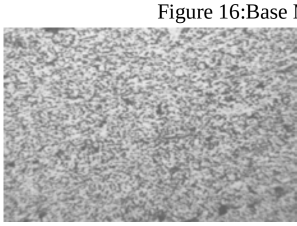
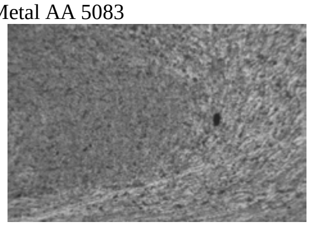


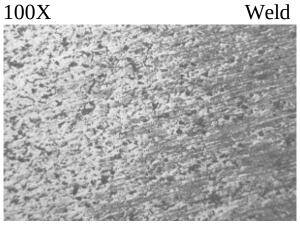
Figure 16:Base Metal AA 5083



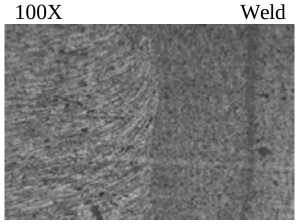
100X Weld



100X Weld



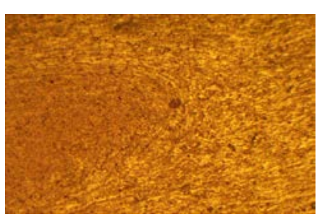
100X HAZ



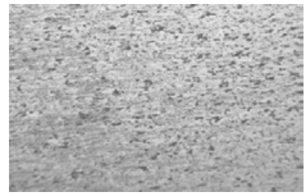
100X HAZ

Figure 17:Microstructures for sample Id: 3

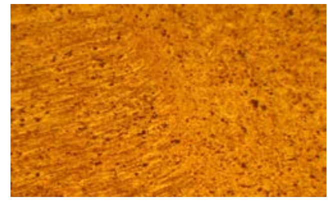
100X Weld



100X Weld

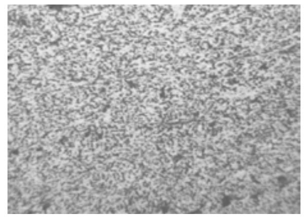


100X HAZ

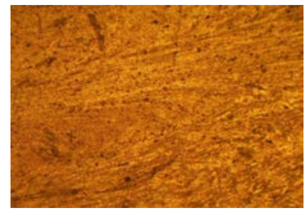


100X HAZ

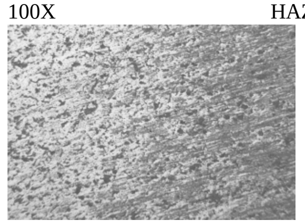
Figure 18:Microstructures for sample Id: 15



100X HAZ



100X HAZ



100X Weld

100X Weld

Figure 19:Microstructures for sample Id:27

3.CONCLUSIONS

1. The tensile test showed that the FSW joint exhibits superior tensile properties performance as compared with TIG welding. The sound welds have been obtained using FSW for 4 mm thickness of aluminium alloy AA 5083. TS of the welded joints and base metal produced adequate tensile strength values.
2. The FSW welded joints having a non- dendrite microstructure, whereas the microstructure of TIG welded joints contains dendrites. Because of dynamic recritallization in the FS welding. The nugget contains fine and fragmented grain compared to the TIG welded joint. The fusion zone of TIG welded joints contain dendritic structure and this may be due to fast heating of base metal and fast cooling of molten metal.
3. While a comparison between the base metal and stir zone indicating by FSW we can see a fine, equated grains due to temperature difference between tool shoulder side and base mental size and the tool centerline.
4. Test sample method HAZ of impact testing does posses certain advantage; these include ease of preparation, simplicity of test method. The result of impact tests of TIG weld aluminium alloy 5083 joints are lower than FSW joints, because of

larger grain size of the welded joints and precipitate distribution.

5. The stirring effect of FSW improved the microstructure of the weld. From the observation of Scanning Electron Microscope (SEM) an appreciable difference exists in the size and shape of the dimples with respect to welding processes.

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