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Comparison of Pulsed TIG Welding and FSW Processes of 5083 Aluminium Alloy

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Abstract

In This study AA 5083 plate of thickness 4mm have been welded by Pulsed Tungsten Inert gas (PTIG) Welding and Friction Stir Welding (FSW) Process. The Welding process was performed with different process parameters and the weldments have been investigated to find their mechanical properties. Vickers hardness tester was used to characterize the hardness of the weld area for both the welding process. Then Scanning Electron microscope is used to analyses the size and shapes of the grains at weld zone and heat affected zone. The aim of this experimental work is to see the effect of pulsed current on the characteristics of weldments and as well as characteristic of friction Stir Welding weldments. The experimental results pertaining to different welding parameters for the above material using pulsed and FSW are discussed and compared. The mechanical properties and micro structure results show that FSW weldments are better than PTIG welding. The result of impact strength of PTIG are lower than FSW weldments, because of large grain size of the welded joints and precipitate distribution at HAZ, due to The stirring effect of FSW improved the microstructure of the weld. The Vickers hardness tester was used to characterize the hardness of the weld area for both welding process. Microstructural examination reveals that smaller grain sizes are obtained in the weld center of FSW weldments and coarse grains are formed. The Scanning Electron Microscope (SEM) is used to analyze the grain structure at weld zone and heat affected zone. The Vickers hardness test results shown that FSW has more hardness when compared with PTIG weldments. The evaporation of magnesium is more in PTIG when we compared with FSW. From the observation of SEM an appreciable difference exists in the size and shape of the dimples with respect to welding processes. Then from the chemical analysis test found that the percentage of magnesium is decreased in PTIG weld joint and the slight decrement is seen in FSW joints. This is reason for in PTIG welding very high temperature increases and the cooling rate is very slow, so the magnesium is evaporated such that the strength of the PTIG welded joint is decreased.

***Key Words*:**AA5083, Friction Stir welding, Pulsed TIG welding, tensile strength, % elongation, yield strength..

1 Introduction

The demand is increasing for aluminium alloy weld structures and products where high quality is required such as aerospace applications. Further development has been pulsed current TIG welding. Pulsed current welding (PCW) was introduced in the late 1960s as a variant of constant current welding (CCW). Pulsed Current Welding (PCW) process has many advantages over constant current welding, including enhanced arc stability, increased weld depth/width ratio, narrower HAZ range, reduced hot cracking sensitivity, refined grain size, reduced porosity, low heat input, lower distortion of gas by weld pool and better control of the fusion zone.

The PTIG welding technology has advanced to provide excellent welding performance on thin gauge aluminium. PTIG welding could potentially help for increasing productivity, improved weld quality, reduced welding costs and boosts operator efficiency, narrow HAZ. In the pulsed-current mode, the welding current rapidly alternates between two levels. The higher current state is known as the pulsed current, while the lower current level is called the background current. During the period of the pulsed current, the weld area is heated and fusion occurs. Open drop-in to the pulsed current GTAW has a numerous advantages, including lower heat input and consequently a reduction, distortion and warps in this work pieces. In addition, it allows greater control of the weld pool and can increase weld penetration, welding speed and quality. Welded successfully with PTIG and FSW.

Design of experiments conducted based on full factorial parameters of PTIG and FSW. Three parameters in PTIG and Three parameters in FSW. This makes total levels of experiments 33. Keeping two parameters constant and changing one parameter so that we conducted total 27 experiments to find the above parameters.

In PTIG welding performed on AA5083 Aluminium alloy with ER 5356 as electrode material. The electrode diameter namely 1.6mm, 2.4mm and 3.2mm are used. The effect of process parameter i.e., Welding Current (WC), Gas Flow Rate (GFR) and different Filler Rod Diameters (FRD) are studied on mechanical Properties and microstructure analysis. This result in a Heat Affected Zone (HAZ) with a better grain refinement required for a good weld joining.

In FSW welding performed on AA 5083 Aluminium alloy with Flat tool of material H13 as electrode material. The effect of process parameters i.e., Tool Rotation Speed (TRS), Welding Speed (WS) and Tool Tilt Angle (TTA) are studied on mechanical Properties and microstructure analysis. The experimental results indicate that the welding process parameters have a significant effect on mechanical properties of the weldments.

2 Aluminium Alloy 5083

Aluminium Alloy 5083 is known for excellent performance in extreme environments. Alloy 5083 is higher anti-attack by both industrial chemical environments and sea water. Alloy 5083 also relates excellent strength after welding. It has the greatest strength of the non heat treatable alloys. Generic Physical & Mechanical Properties of Aluminium Alloy 5083 is shown in table 1.

Table 1.1: Properties of Aluminum

S.No.	Property	Value
1	Atomic Number	13
2	Atomic Weight	26.98 g/mol.
3	Density	2.6989 g/cm^3
4	Melting Point	669.7°C
5	Boiling Point	1800°C
6	Specific Heat	0.2259 Cal/g-K
7	Heat Of Fusion	93 Cal/g
8	Young's modulus of pure aluminium	10 x 10^6 psi
9	Poisson's ratio	0.33
10	Specific Weight	2.7 g/cm3

3 Experimental Work

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 fits into the hand piece. An electric arc is then created between the tungsten electrode and the work piece using a constant-current welding power supply that produces energy and conducted across the arc through a column of highly ionized gas and metal vapours. The tungsten electrode and the welding zone are protected from the surrounding air by inert gas. The electric arc can produce temperatures of up to 20,000oC and this heat can be focused to melt and join two different parts of the material. The weld pool can be used to join the base metal with or without filler material. Schematic diagram of TIG welding and mechanism of TIG welding is shown in Fig. 1 & Fig. 2 respectively.

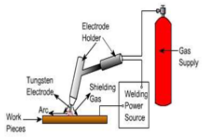


Fig. 1.1: Schematic Diagram of TIG Welding
(Courtesy:nptel.ac.in)

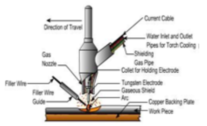


Fig. 1.2: Principle of TIG Welding System (Courtesy: nptel.ac.in)

Pulsed Tungsten Inert Gas (PTIG) welding, developed in 1950s, is a variant of TIG welding which involves cycling of the welding current from a high level to a low one of a selected regular frequency. The high level peak current is generally selected to give adequate penetration and bead contour, while the lower one of the background, current 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 overlapping nuggets and limits the wastage of heat by conducting into the adjacent parent material in a normal constant current welding. In contrast to constant current welding, the fact that the heat energy required to melt the base material is supplied only during peak current pulses for brief intervals of time allows the heat to dissipate into the base material leading to a narrower 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. Metallurgical advantages of pulsed current welding frequently reported in literature include refinement of fusion zone grain size and substructure, reduced width of the HAZ, control of segregation, etc. All these factors will help in improving mechanical properties. Current pulsing has been used by several investigators to obtain refined grains in weld fusion zones and improvement in weld mechanical properties.

Fig.1.3: PTIG Welding Machine- Samples- Model AC/DC

Fig. 1.4: A View on Preparation of Shearing Machine

Preparation of Specimens

The specimens of size 100 X 100 X 4mm3 are prepared on shear machine (Fig. 3.8). The chamfers of 450 are provided on all specimens using CNC Milling machine (Fig. 3.9). All specimens are cleaned and made free of dust, grease and oil. The root with 2mm width and 2mm height is provided with clamps during welding (Fig. 3.10 & 3.11). The prepared sample specimens are shown in the Fig.3.12.

Fig.1.5: Chamfer Prepared on CNC Milling Machine

4 RESULTS

Result and Analysis of PTIG Welding

The effect of welding input parameters on mechanical properties such as TS, YS and PE on the welded joint are discussed in this section. The tensile test of PTIG is the fundamental test in which, a specimen is subjected to uniaxial tension until failure takes place.

The material properties that are directly measured through a tensile test are ultimate tensile strength, yield strength, percentage of elongation.

Effect of WC on TS, YS& PE

The experiments are conducted on PTIG welding to study the effect of Tensile Strength on weldment for a given FRD, WC and GFR. In this regard, we have chosen three WC i.e. 180A, 210A and 240A at three levels of FRD i.e. 1.6mm, 2.4mm 3.2mm.All these variables may affect the characteristics of the tensile strength of weld joint significantly. The results of the above parameters are tabulated in Table 4.2 and corresponding graphs are depicted in Fig. 4.50 to 4.52.

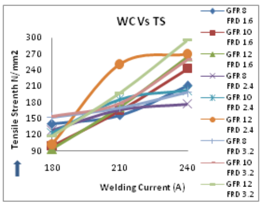


Fig 1.7: Welding Current Vs Tensile Strength

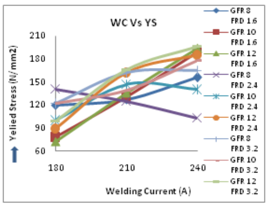
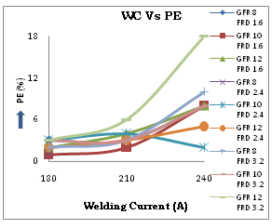


Fig 1.8: Welding Current Vs Yield Stress



1.9: Welding Current Vs Percentage of Elongation

From the graphs it is observed that as the Welding Current increases from 180A to 240A the average Tensile Strength increases considerably. And also Yield Stress and Percentage of Elongation changes in line with the property of Tensile Strength. This effect is occurred due to higher current in PTIG welding can lead to splatter and work piece become damage, and at lower current setting in PTIG welding leads to sticking of the filler wire. Sometimes larger heat affected area can be found for lower welding current, as high temperatures need to applied for longer periods of time to deposit the same amount of filling materials.

Effect of GFR on TS, YS, and PE

The effect of GFR on mechanical properties, i.e. TS, YS and PE are studied along the weld bead. For this weld samples were prepared by varying WC and GFR.

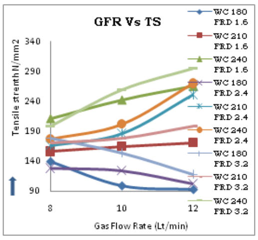


Fig 1.10 Gas Flow Rate Vs Tensile Strength

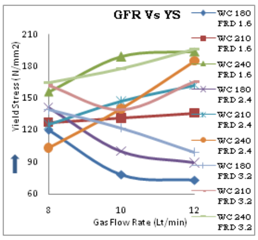
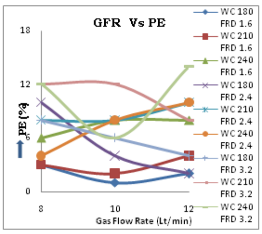


Fig 1.11: Gas Flow Rate Vs Yield Stress



1.12: Gas Flow Rate Vs Percentage of Elongation

From the above graphs it is concluded that as the GFR increases from 8Lt/min to 12Lt/min, the average TS is decreases considerably. Similarly YS and PE decreased. This phenomenon was observed due to low current, the thin oxide film will not break which offers more percentage of oxygen during welding. When GFR increases, it protects oxide layer and ultimately tensile strength decreases.

Result and Analysis of FSW

The proposed work of PTIG welding parameters are extended to FSW to make a comparative study between them. This section elaborates the procedure and results of FSW. The effect of welding input parameters on mechanical properties such as TS, YS and PE on the welded joint are discussed in this section. The Tensile Test of FSW is the fundamental test in which, a specimen is subjected to uniaxial tension until failure takes place. The material properties that are directly measured through a tensile test are Ultimate TS, YS, and PE.

Effect of TRS on TS, YS, PE

The experiments are conducted on FSW to study the effect of mechanical properties TS, YS, PE at weldment for a given TTA and WS. In this regard, we have chosen three WS i.e. 60mm/min, 80mm/min and 100 mm/min at 3 levels of TTA i.e. 900, 90.50 and 910. All these variables may affect the characteristics of the TS, YS and PE weld joint significantly. TRS of Friction Tool and can be directly related to the friction heat generation.

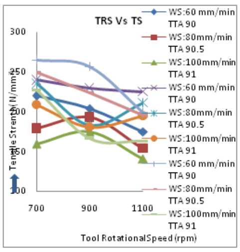


Fig 1.13: Tool rational Speed Vs Tensile Strength

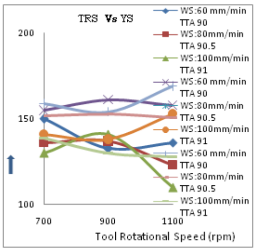


Fig 1.14: Tool rational Speed Vs Yield Stress

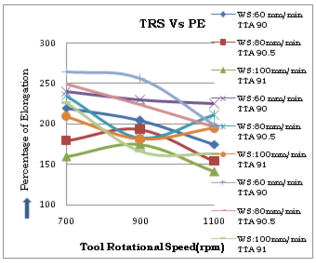


Fig 1.15: Tool rational Speed Vs Percentage of Elongation

From the graphs it is absorbed that as the Tool Rotational Speed increases from 70rpm to 1100rpm the average Tensile Strength decreases considerably, and also Yield Stress and Percentage of Elongation changes in line with the property of Tensile Strength. This effect occurred due to more downward force applied by tool shoulder that generates additional heat. And it is also evidenced from Microstructure and SEM Analysis the coarse grain structure is produced and grain growth changes along the weldbead due to. High heat generated by increasing TRS.

Effect of WS on TS, YS, PE

The effects of Welding Speed on TS, YS &PE are studied along the weld bead. For this weld samples were prepared by varying Tool Tilt Angle and Tool Rotational Speed.

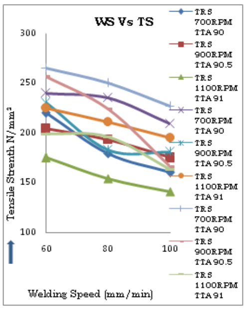


Fig 4.59: Welding Speed Vs Tensile Strength

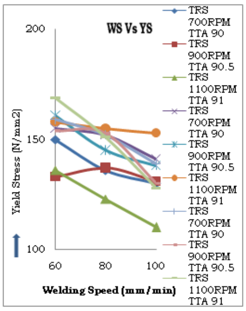


Fig 4.60: Welding Speed Vs Yield Stress

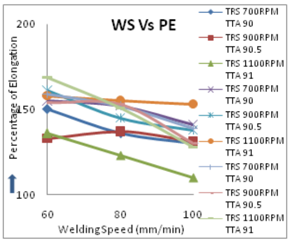


Fig 4.61: Welding Speed Vs Percentage of Elongation

From the graphs it is concluded that as the Welding Speed increases from 60mm/min to 100mm/min Tensile Strength decreases. And also Yield Stress and Percentage of Elongation changes significantly. The Phenomenon observed due to improper stirring effect for lack of time, because as the WS increases weld time decreases.

5 Conclusions

1. In PTIG welding with the increase in current, tensile strength and Impact strength of the weld joint increases. Hardness value of the weld zone change with the distance from weld center due to change of microstructure.

2. At lower welding speeds, strength of the weldment is more in FSW due to proper stirring of material during process. The tensile test showed that the FSW joint exhibits superior tensile properties' performance as compared with PTIG welding.

3. The average tensile strength obtained in PTIG welded joint was 176 N/mm2. This indicates a 40 % reduction in tensile strength of PTIG welded joint. FSW joints showed the highest average Tensile Strength of 207 N/mm2, this indicates a 30 % reduction in tensile strength.

4. The tensile strength of friction stir weld joints and Pulsed weld joints was lower than the base metal, but the tensile strength of friction stir weld joints was 10% higher than PTIG welded joints.

5. The friction stir welded joints were stronger than PTIG welded joints. The average yield strength of the base metal is 170 N/mm2. The average yield strength obtained in PTIG welded joint was 135 N/mm2. This indicates a 20 % reduction in tensile strength of PTIG welded joint.

6. FSW joints showed the highest average tensile strength of 147 N/mm2, this indicates a 13 % reduction in tensile strength.

7. Though the tensile strength of friction stir weld joints and Pulsed weld joints was lower than the base metal, but the tensile strength of friction stir weld joints was 7% higher than PTIG welded joints.

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