

Experimental Study of Mechanical Properties of 5083 Aluminium Alloy Using Gas Tungsten Arc Welding

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ABSTRACT: The aluminium and its alloys are widely used in marine applications such as ship hulls and its components due to its light weight and corrosion resistance. The aluminium alloy require special tool and skill to weld due to high thermal conductivity Aluminum Alloy 5083 [AA 5083] considered as a one of the best weldable aluminum alloys and exhibits a slight reduction of the strength of the Heat Affected Zone [HAZ], comparatively to the most of other aluminum alloys. This alloy is commonly used in the manufacturing of pressure vessels, marine vessels, armored vehicles, aircraft cryogenics, drilling rigs, structures and even in missile components etc. Aluminium alloy 5083 contains Mg-Mn-Cr, in the tempered condition, it is strong and retaining good formability due to excellent ductility. 5083 has high resistance to corrosion and used in marine applications. This report also investigates the weld quality through NDT and also study mechanical properties like UTS, 0.2% YS and % of elongation and micro hardness using Gas Tungsten Arc welding (GTAW) with non-pulsed current and pulsed current at different process like 2Hz, 4Hz and 6Hz were studied and also to find the weld joint efficiency.

KEYWORDS: Gas Tungsten Arc Welding (GTAW), Pulsed current, Non-destructive Test (NDT), Heat Affected Zone (HAZ), Ultimate Tensile Strength (UTS), Vickers Hardness Test.

I. INTRODUCTION

Welding is one of the most used methods for joining aluminum and its alloys. Tungsten Inert Gas (TIG) process and Gas Metal Arc Welding (GMAW) are the welding processes which are used the most, but there are some problems associated with this welding process like porosity, lack of fusion, incomplete penetration [1] and cracks. Gas metal arc welding offers the advantage of high deposition rate and high welding speed besides deeper penetration because of high heat input. However, excessive heat input imposes the problems such as melt and distortion specially in welding of thin aluminum sheets [2]. Therefore, to produce high quality weldments, TIG [7] welding process is preferred over gas metal arc welding.

Al-Mg alloys are extensively used in defense and aerospace applications. Tungsten inert gas (TIG) welding is an arc welding process that produces coalescence of metals by heating them with an arc between a consumable electrode and the base metal. TIG welding process [3] is generally used for welding of Al-Mg alloys. The initial strength of the non-heat treatable aluminum alloys depends primarily upon the hardening effect of alloying elements such as silicon, iron, manganese and magnesium [4]. These elements increase the strength either as dispersed phase or by solid solution strengthening. The welding of non-heat treatable aluminum alloys typically has distinct effects when the heat input is increased, the width of the heat affected zone (HAZ) is increased and the minimum reduction in the mechanical properties is observed. Alloys 5XXX series with more than 3.0% magnesium are not recommended for elevated temperatures above 150°F because of their potential for sensitization and subject susceptibility to stress corrosion cracking [5]. The minimum HAZ strength approximates to that of the annealed parent metal regardless of the starting temperature. During welding, vaporization of alloying elements like magnesium can occur and this vaporization loss of any alloying elements can influence the mechanical properties of the welded joints by affecting the chemistry of the

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weld pool. The gas tungsten arc welding (GTAW) and gas metal arc welding (GMAW) welding processes are very often used for welding of these alloys. However, gas tungsten arc welding (GTAW) process is generally preferred because it produces a very high quality welds. Distortion is the major problem in welding of thin sections. However, the distortion is controlled in pulsed and magnetic arc oscillation GTAW process. Metallurgical advantages of pulsed and magnetic arc oscillation weld that are frequently reported in the literature includes grain refinement in the fusion zone, reduced width of HAZ, less distortion, control of segregation, reduced hot cracking sensitivity and reduced residual stresses [6].

II. MATERIAL

Aluminium alloy AA-5083 (Composition and mechanical properties are shown in Table 1 and 2) sheet of the dimension 150×300×2 mm were taken for TIG welding technique. These sheets are cleaned from dirt, grease and other foreign materials by using cleaning agents, dirt removers and other re-agents. Edge preparation is carried out where double V edge is prepared for an angle of 60°. The Aluminium sheets are placed on welding table where the welding process is carried out.

Table 1. Chemical Composition of the 5083 aluminum alloy (in Wt %).

Element	Mg	Mn	Fe	Si	Zn	Cr	Ti	Cu	Al
%wt	4.5	0.7	0.4	0.4	0.25	0.15	0.15	0.1	93.0

Table 2. Mechanical properties of 5083 aluminum alloy

Material	UTS (MPa)	0.2% Y.S (MPa)	Elongation (%)
5083	300	145	15

Table 3. Chemical composition of 5356 filler wire

Element	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Be	others
%wt	0.25	0.40	0.10	0.05-0.20	4.5-5.5	0.05-0.20	0.10	0.06-0.20	0.0003	0.15

III. EXPERIMENTAL WORK

Before welding, the test materials were properly cleaned by removing dirt and any other foreign material to produce sound welds. The 5083 aluminum alloy work pieces were pickle. This process consists of the work pieces are dipped in the mixture of hot water and sodium hydroxide (NaOH) about 15 minutes. Then the work pieces are placed into cold water for cleaning the chemicals on the top surface of aluminum plates. Then the aluminum plates are dipped in to the diluted nitric acid solution for about 10 minutes.

The equipment used for this study is Lincoln Electrical Square Wave TIG 375 GTAW machine is shown in Fig.1. The equipment consists of mainly of power supply source, a welding torch and the connecting torch and cables and hoses for gas and water supplies. GTAW was conducted with 2.4 mm diameter 2% Zirconated tungsten electrode.



Fig.1. TIG welding machine



Fig. 2. UTM machine

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In this process, all the various welding parameters such as the flow rate, inert gas used and the number of passes is kept constant for all the trails and the welding current is used as varying parameter (The welding parameters for both non-pulsed current and pulsed current are given in Table 4 and 5) to study the effect of welding current on the structural and mechanical properties of weldments. The inert gas used in this investigation is 99.9% pure argon keeping the flow rate constant. The filler metal selected for the process is AA-5356 (composition shown in Table 3) which is the standard filler rod to be used for AA-5083 alloy (According to AWS Standards).

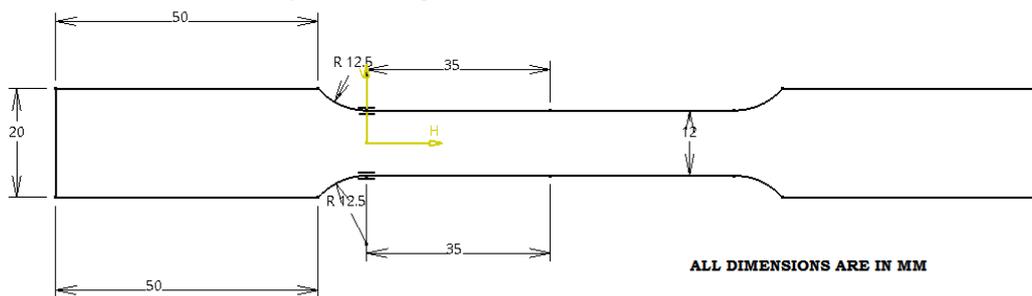


Fig.3. Tensile test specimen

In this study, TIG welding technique was adopted with three different welding currents for the Aluminum plates i.e., Non-pulsed welding at 90A and Pulsed welding at 2Hz, 4Hz, and 6Hz respectively and these welded joints were further subjected to the following mechanical tests. The Tensile test specimens were prepared on HMT CNC wire-cut EDM ASTM E-08 standards given in the Fig.4. The finished specimens were tested using Universal Testing Machine (shown in Fig 2) of 40ton capacity

Table 4. Welding parameters for non-pulsed current welding

Material thickness (mm)	Filler wire dia.(mm)	Current	I (amp)	V (volts)	Arc travel speed (cm/min)
2.0	2.4	AC	75	12.5	3.15

Table 5. Welding parameters for pulsed current welding

Material thickness (mm)	Filler wire dia. (mm)	Current	Pulses/sec (Hz)	I (amp)		V (volts)	Arc travel speed (cm/min)
				Ip	Ib		
2.0	2.4	AC	2	26	100	13.36	3.0
2.0	2.4	AC	4	31	105	12.33	1.36
2.0	2.4	AC	6	36	110	12.75	1.30

After welding process is over, the radiography and liquid penetrant test was carried out on the weldments (shown in Fig.4), According to the ASTM Standards, Section VIII, Division 2 for radiography (images shown in Fig.5) and ASTM E-1417 for liquid penetrant tests. The parameters used for the liquid penetrant test are given in Table 6

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Table 6. Liquid penetrant test parameters.

	5083 aluminum alloy
Penetrant used	The oriental chemical works
Cleaner used	The oriental chemical works
Developer used	The oriental chemical works
Dwell time	10 min
Method	Solvent removable white light method



Fig.4. Weldments of 5083 aluminium alloy

IV. RESULTS AND DISCUSSION

4.1 Effect of current on porosity

The effect of pulse current on the porosity observed during radiography is presented in table7. Porosity has been measured in present study at frequencies i.e., 4 and 6Hz. No porosity was observed at 2Hz frequency. Two pores with 0.6 mm size were observed with 6Hz frequency. The results show that pores size increases with the increase of frequency. This may be due to more vibration in weld torch and improper cleaning and supply of gases. The 6 pulse contains porosity 0.6mm is negligible and within the acceptable limits.

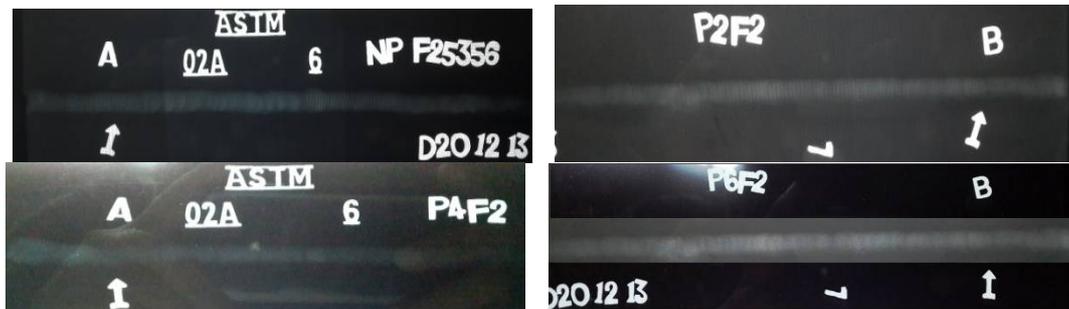


Fig.5. Radiography images

4.2 Cracks in the weldments

Cracking is a major concern in welding aluminum alloy. Utilization of pulsed current GTA welding produced a higher sensitivity to solidification cracks than non-pulsed current welding. According to the ASTM E-1417, the dye-penetrant (DP) test was conducted on these weldments. The test results are shown in table7. The experimental results show that no cracks were observed in the weldments of this alloy with non-pulsed current and pulsed current welding.

Table 7. NDT Results

Radiography test – To investigate the porosity of the weldments		
Sl.No.	Method of welding	observation
1	Non – pulsed welding	No defect observed on welded area
2	Pulsed welding	2 Pulses/sec No defect observed on welded area
3		4 Pulses/sec Two pores of 0.6 mm observed on welded area
4		6 Pulses/sec Two pores of 0.6 mm observed on welded area
LP Test – To investigate the surface cracks of the weldments		

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5	Non –pulsed welding	No defect observed on welded area
6	Pulsed welding	2 Pulses/sec
7		4 Pulses/sec
8		6 Pulses/sec

4.3 Tensile Test

4.3.1 Effect of frequency on the tensile strength of Al 5083 weldments

The effect of frequency on the tensile strength at four frequencies (2Hz, 4Hz, and 6Hz&NP) was shown in table 8. The finished test specimens were tested using the universal testing machine of 20ton capacity(shown in fig 3). The weldment Specimens failed through the parent metal in all the cases. It was observed that UTS and yield strength values of pulsed current were more than the base metal and non-pulsed current weldments.

Table 8. Tensile Test Table

Method of welding		Ultimate Tensile Strength (MPa)	0.2% proof stress (MPa)	% of elongation
Non –pulsed welding				
	Sample 1	296.326	151.447	15.140
	Sample 2	277.821	145.443	10.480
Pulsed welding	2 Pulses/sec	Sample 1	295.121	159.892
		Sample 2	303.198	152.948
	4 Pulses/sec	Sample 1	286.385	164.588
		Sample 2	277.142	161.178
	6 Pulses/sec	Sample 1	296.936	162.365
		Sample 2	253.54	151.392

The experimental results shown that the weldments produced more strength in pulsed current welding (2Hz,4Hz,6Hz). From the values of UTS obtained for 2 pulse, it is observed that weldment depicted maximum ultimate tensile strength when compared to weldments NP, 4 pulse and 6 pulse. The effect of current on % of elongation values of Al 5083 alloy compared with the help of graph. It is observed that the maximum value is at 2pulse current. The comparison graph is shown below (Fig 6).

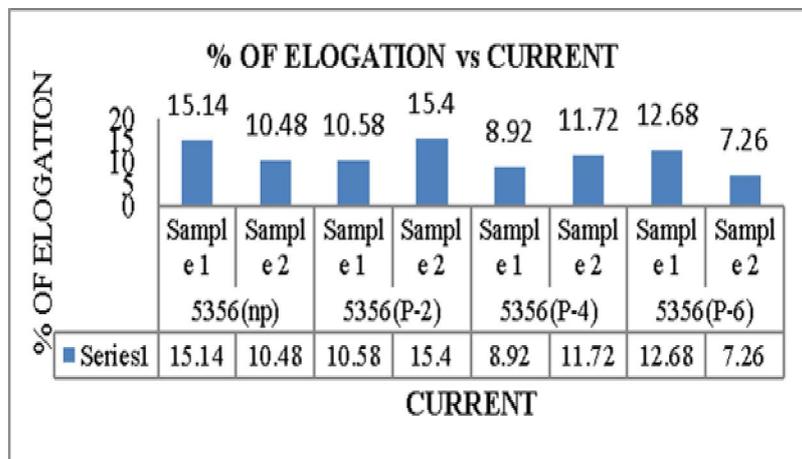


Fig.6. Comparison between % of Elongation and Current

The effect of current on ultimate tensile strength (UTS) values of Al 5083 alloy compared with the help of graph. It is observed that the maximum value is at 2pulse current. The comparison graph is shown below (Fig 7).

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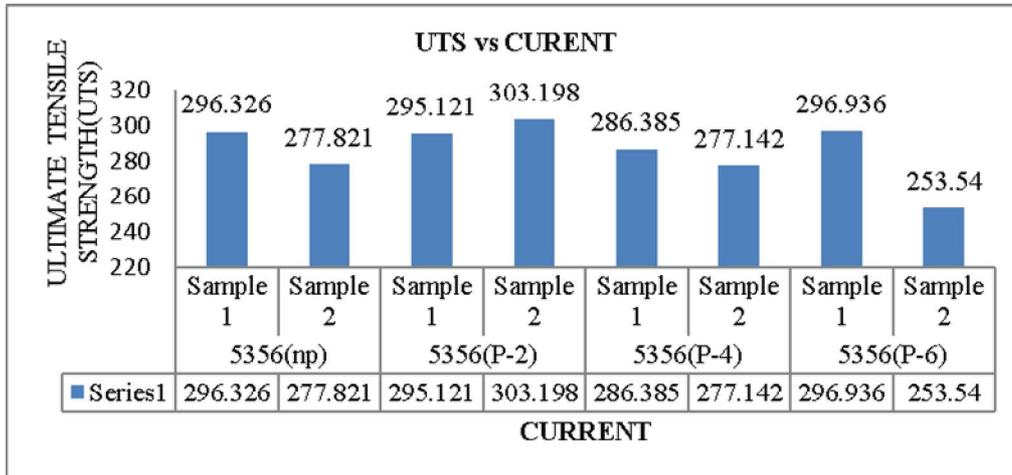


Fig.7. Comparison between UTS and Current

The effect of current on 0.2% Proof Stress values of Al 5083 alloy compared with the help of graph. It is observed that the maximum value is at 4pulse current. The comparison graph is shown below (Fig 8).

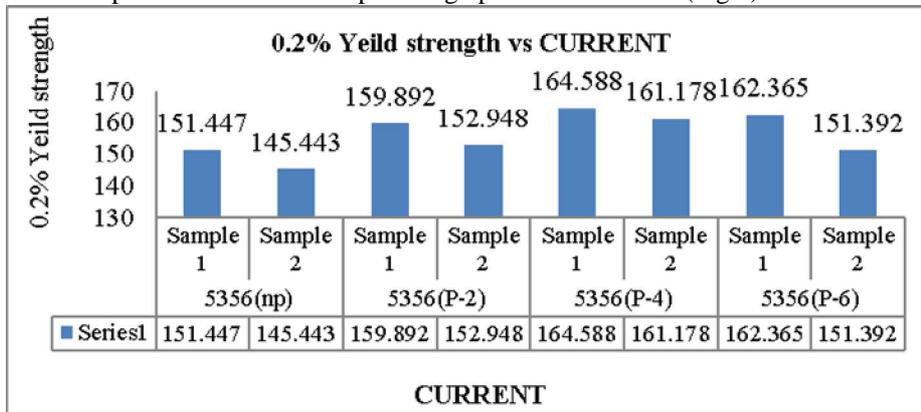


Fig.8. Comparison between 0.2% Proof Stress and Current

The weld joint efficiency of material is shown in Fig.9. The efficiency is calculated from ultimate tensile strength (UTS) of weldments in comparison to the base metal UTS. The results presented were best values obtained from two trails.From the figure it is observed that the sample2 has produced more joint efficiency i.e., 94.68% at 2 pulse current.

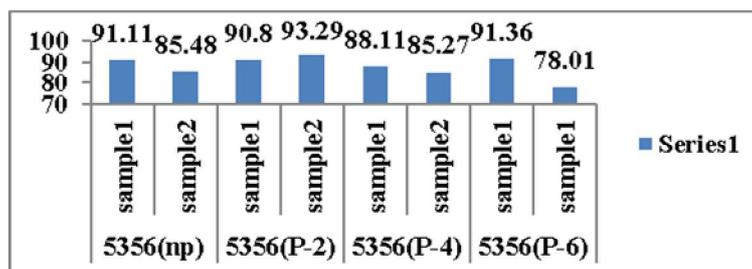


Fig.9. Weld joint efficiency of 5083AA weldments

4.4 Micro – Hardness study

The micro-hardness indentations of the weldments are shown in Figure 10. And micro-hardness profile for the different welds made with non pulsed and different frequencies i.e., 2 Hz, 4 Hz and 6 Hz are shown in Figure 11.

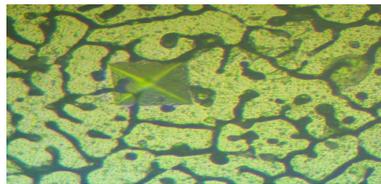


Fig.10. Micro hardness indentation of 5083AA weldments

4.4.1 Effect of Current on Micro-hardness

From the micro hardness values it is observed that there is slight vary in the hard values at different currents and filler materials. The maximum hardness value is observed at 2 pulse. The hardness values are shown in Fig 11. From the hardness values it is observed that the pulsed current has produced high hardness than non-pulsed current. The filler wire 5356 has produced high hardness due to fine grain structure and the composition of filler wire 5356. In the filler wire 5356 there is a more percentage of magnesium available. The presence magnesium will increase the strength and hardness of parent material.

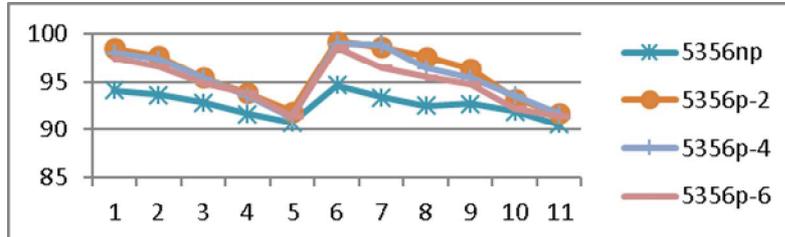


Fig.11. Micro hardness values of 5083AA weldments

4.5 Microstructure study

4.5.1 Effect of Current on Microstructure

It is observed that more fine grain structure is observed in pulsed current images than non-pulsed. At the HAZ the images showed in Fig. 13 more elongated particles. This seems the particles become finer this may be the reason that has produced high tensile strength, % of elongation and hardness.

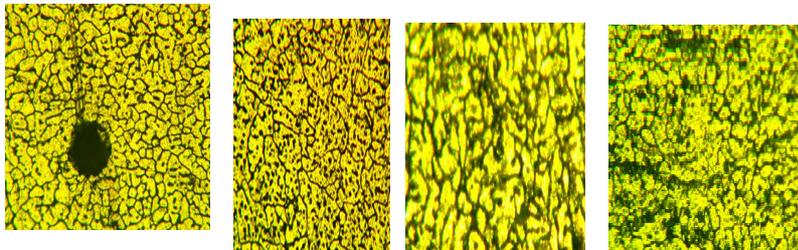


Fig.12. Microstructure of cross section at welded zone

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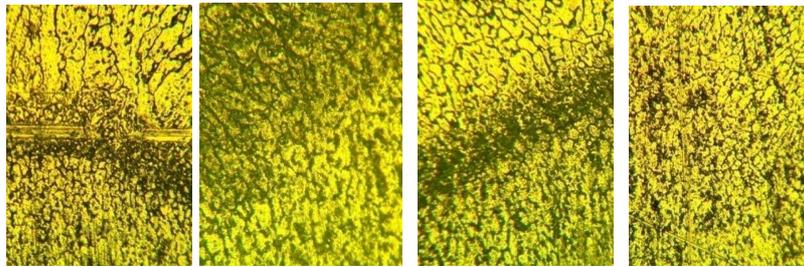


Fig.13. Microstructure of cross section at Heat Affected Zone

V. CONCLUSIONS

From the experimental results the following conclusions are drawn

- The increasing of arc welding current in 5083 aluminum alloy will increase the welding heat input by using 5356 filler wire. Accordingly, the chance of defect formation such burns, pores, cracks in welded metal also increases. These will effect on the mechanical properties and quality of welded metal badly.
- The results shown that at 2 pulse and 4 pulse current there are pores available in the welding area but these pores are within the acceptable limit of ASTM Standards.
- There are no surface cracks observed in the weld zone.
- The pulse 2sample 2 produced maximum ultimate tensile strength i.e., 303.198. This may due to fine grain structure due to low heat input.
- The pulsed current has produced more tensile strength than non-pulsed current
- The pulse 2 sample 2 has maximum % of elongation i.e., 15.40, this is equal to parent material % of elongation.

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