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Mechanical and Micro Structural Characterization of Al 5083 and Al 6082 Butt Joints Made By GTAW

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ABSTRACT: Gas Tungsten Arc Welding is most commonly called Tungsten Inert Gas welding .TIG welding has become indispensible as a tool for many industries because of the high quality welds produced at relatively low equipment cost. Aluminum Alloy 6082 [AA 6082] is typically used in highly stressed applications, trusses, bridges, cranes, trusses, milk churns, transport applications etc. Aluminum Alloy 5083 [AA 5083] is commonly used in the manufacturing of pressure vessels, marine vessels, storage tanks shipbuilding, armored vehicles, aircraft cryogenics, drilling rigs, structures and even in missile components etc. In this research, AA5083 and AA6082 welds are made with gas tungsten arc welding (GTAW) using AA 5356filler wire with non-pulsed current and pulsed current at different pulse frequencies like 2 pulses/sec, 4 pulses/sec, and 6 pulses/sec using precision TIG 375 welding machine. This report to investigates the weld quality through non destructive testing(NDT) to study the porosity and surface cracks and also the mechanical properties like ultimate tensile strength(UTS), 0.2% yield strength(YS) and % of elongation using GTAW with non-pulsed current and pulsed current at different pulse frequencies were studied and also to find the weld joint efficiency of the weldments.

KEYWORDS: Gas Tungsten Arc Welding, Non-Destructive Testing, Heat Affected Zone, Ultimate Tensile Strength.

I. INTRODUCTION

Aluminium alloys have been more and more extensively utilized in structural applications and transportation industry for their light weight and attractive mechanical properties. Al–Mg alloys are extensively used in defense, aerospace, Shipbuilding applications. The traditional and the most often used Al-alloys in shipbuilding are 5083 type Al- Mg alloy for plates, and 6082 type Al-Mg-Si alloy for extrusions. The corrosion resistance of the 5xxx series alloys is another major factor in the selection of aluminum for marine applications. The evolution of ship performances promoted the need for the development of new Al-alloys with improved mechanical properties, corrosion resistance, weldability, etc. The non-heat-treatable Al-Mg alloys were appointed as favorable ones in respect to the costs and all the required properties for successful vessel service. The weight saving normally ranges from 50% in hulls (although 59% is possible in this application) to 62% in commercial deckhouse structures.

Welding is one of the most used methods for joining aluminum and its alloys. Tungsten inert gas process and gas metal arc welding 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 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. Therefore, to produce high quality weldments, TIG welding process is preferred over gas metal arc welding.

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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 is generally used for welding of Al–Mg alloys. However, GTAW process is generally preferred because it produces a very high quality welds. Distortion is the major problem in welding of thin sections. 5*xxx* series alloys are based on magnesium. They are strain hardenable, but not heat treatable. . These elements increase the strength either as dispersed phase or by solid solution strengthening. The welding of non-heat treatable aluminum alloys typically have distinct effects when the heat input is increased, the width of the heat affected zone is increased and the minimum reduction in the mechanical properties. 6*xxx* series alloys have both magnesium and silicon as their main alloying elements, which combine as magnesium silicide following solid solution. Alloys in this series are heat treatable.

In this experimentation weldments of dissimilar aluminium alloy of 6082AA and 5083AA of thickness 2mm are made using filler wire AA5356 using Tungsten Inert Gas welding process.

II. MATERIALS & METHODS

The sheets of 2mm thickness aluminum alloys 6082 and 5083 have been cut into size 150x300mm by shearing machine. The chemical compositions of AA6082 and AA5083 are shown in table 1 .

Table 1: Chemical composition of the 6082AA and 5083AA (wt %)

	Si	Mg	Mn	Fe	Cr	Cu	Zn	Ti	Al
6082	1.2	0.78	0.50	0.33	0.14	0.08	0.05	0.10	balance
5083	0.4	4.0-4.9	0.4-1.0	0.4	0.25	0.1	0.25	0.15	balance

The mechanical properties of AA6082 and AA5083 are shown in table 2 .

Table 2: Mechanical properties of 6082AA and 5083AA

Material	UTS *(MPa)*	0.2% Y.S *(MPa)*	Elongation *(%)*
6082	360	322	16
5083	320	145	15

These sheets are chemically cleaned in hot Sodium Hydroxide for 10 minutes followed by dipping in Nitric Acid solution for about 15 minutes and then washed in water to remove dirt, grease and other foreign materials. . The aluminum sheets are placed on welding table and the initial joint configuration is obtained by securing plates in position using mechanical clamps where the welding process is carried out. . In this research study the welding process was performed on AA6082 and AA 5083 sheets using filler wire AA5356 and its chemical compositions are show in table 3.

Table 3: Chemical composition of 5356 filler wire (wt %)

%	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Be	others
5356	0.25	0.4	0.10	0.05-0.2	4.5-5.5	0.05 -0.2	0.1	0.06 -0.2	0.0003	0.15

The parameters used in this welding are peak current Ip ,base current Ib,voltage, arc travel speed. The weld parameters are show in table 4 and 5.

Table 4: Welding parameters for non-pulsed current welding of 6082 and 5083 Aluminum alloys

Filler wire	Material thickness *(mm)*	Filler wire dia. *(mm)*	Current Type	I *(A)*	V *(V)*	Arc travel speed *(cm/min)*
5356	2.0	2.4	AC	94	13	5

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Table 5: Welding parameters for pulsed current welding of 6082 and 5083 Aluminum alloys

Filler wire	Material thickness *(mm)*	Filler wire dia. *(mm)*	Current	Pulses/sec *(Hz)*	I (A)		V *(V)*	Arc travel speed *(cm/ mm)*
					Ip	Ib		
5356	2.0	2.4	AC	2	110	80	14	5
		2.4	AC	4	110	77	14	6
		2.4	AC	6	110	76	12	5

The equipment used for this study is Lincoln Electrical Precision TIG 375 GTAW machine is shown in figure 1. GTAW was conducted with 2.4mm diameter 2% zirconated tungsten electrode. Argon gas of having 99.99% purity was used for shielding and backing gas during the welding process.

Figure 1: precision TIG 375-TIG welding machine

In this study, TIG welding process was carried out with three different welding currents i.e., constant current, pulsed current at 2 pulses/sec, 4 pulses/sec and 6 pulses/sec respectively. After the welding process, the NDT carried out on the weldments that are shown in figure 2.

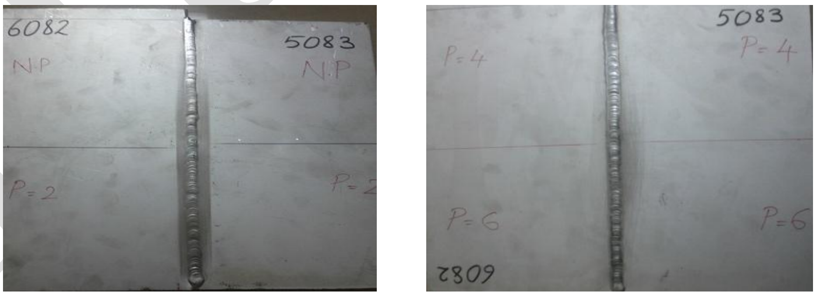

Figure 2: weldments of 6082 and 5083 aluminum alloy

The ASTM standards, section VIII, division 2 for radiography and ASTM E-1417 for liquid penetrant tests were conducted on AA6082 and AA5083 weldments to find porosity and cracks. The radiography images are shown in the figure 3.

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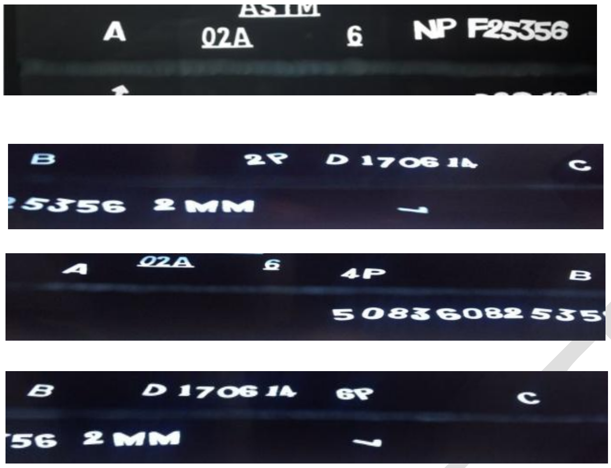

Figure 3: Radiography images of AA 6082 and AA5083Weldments using AA5356 filler wires

To investigate the mechanical properties of the weldments, as per ASTM E 8 standard the tensile specimens were prepared on milling machine. The finished specimens were tested to find the ultimate tensile strength (UTS) and % elongation using 40 ton Universal Testing machine. The test specimen was shown in the figure 4.

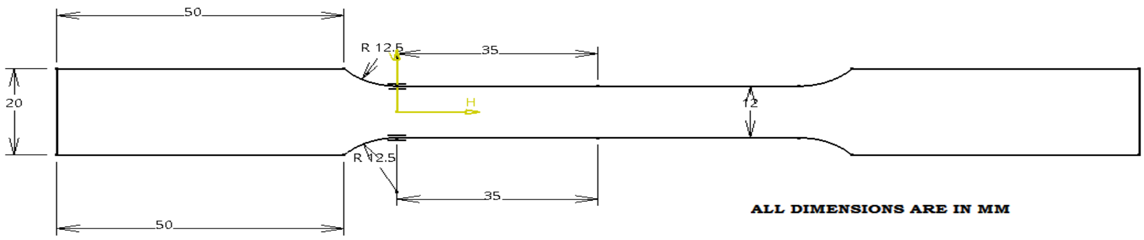

Figure 4: Tensile test specimen

III. EXPERIMENTAL RESULTS

In this research, we studied the following weld characteristics of the 6082and 5083 aluminum alloy sheets welded with constant current and pulsed current using gas tungsten arc welding (GTAW) process.

A. Effect of Current on Porosity and Cracks: The effect of pulsed current on the porosity observed during radiography is presented in table 6. Porosity has been measured in present study. Porosity was observed at 2Hz, 4Hz and 6 Hz frequencies but under the acceptable limit. These results shows that porous size increased with the increase of frequency.

Table 6: Radiography test results

Sl. No.	Filler wire	Pulsed/non pulsed welding	Frequency *(Hz)*	Physical observation
1	5356	Non –pulsed	-	Acceptable
2		Pulsed	2	Acceptable

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3		Pulsed	4	Acceptable
4		Pulsed	6	Acceptable

According to the ASTM E-1417, the liquid penetrant (LP) test was conducted on these weldments. The experimental result shows that no cracks were observed in the weldments with non-pulsed current and pulsed current welding. The results are shown in table 7.

Table 7: Liquid penetration test results

Sl. No.	Filler wire	Pulsed/non pulsed welding	Frequency *(Hz)*	Observations
1	5356	Non -pulsed	-	No defect observed on welded area
2		Pulsed	2	No defect observed on welded area
3		Pulsed	4	No defect observed on welded area
4		Pulsed	6	No defect observed on welded area

B. Tensile Test: The finished test specimens were tested using the universal testing machine of 40 ton capacity. In this testing we found that all the weld specimens were failed at outside the weld area. It was observed that pulsed current weldments produce more strength than the non-pulsed current weldments. The results of tensile test are shown in the table 8.

Table 8: Tensile test table

Filer wire	Method of welding		Ultimate Tensile Strength *(MPa)*	0.2% proof stress *(MPa)*	% of elongation *(%)*
5356	Non –pulsed welding		168.2	132.5	3.90
	Pulsed welding	2 Pulses/sec	173.6	138.6	4.12
		4 Pulses/sec	181.5	79.1	5.14
		6 Pulses/sec	186.4	99.3	5.96

The effect of current on UTS values of weldments are compared with the help of graph. It is observed that the welding made at 6 pulse/sec current AA6082and AA5083 weldments produces the higher value of UTS compared to other welding currents i.e., 186.4 Mpa. From this we know that as the frequency of current increases UTS goes on increases. The effect of current on UTS is shown in figure 6.

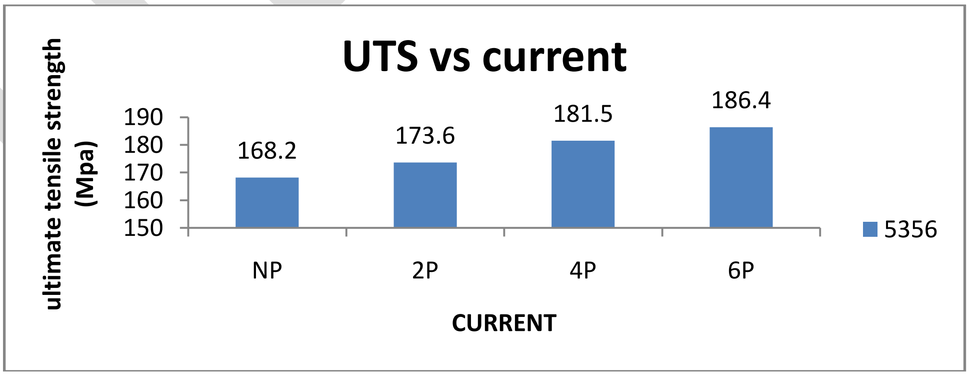

Figure 6: comparison between UTS and current

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The effect of current on % of elongation values of weldments are compared with the help of graph. It is observed that the maximum value is produced at 6 pulses/sec current AA6082 and AA5083weldment i.e., 5.96. The effect of current on % of elongation is shown in figures 7.

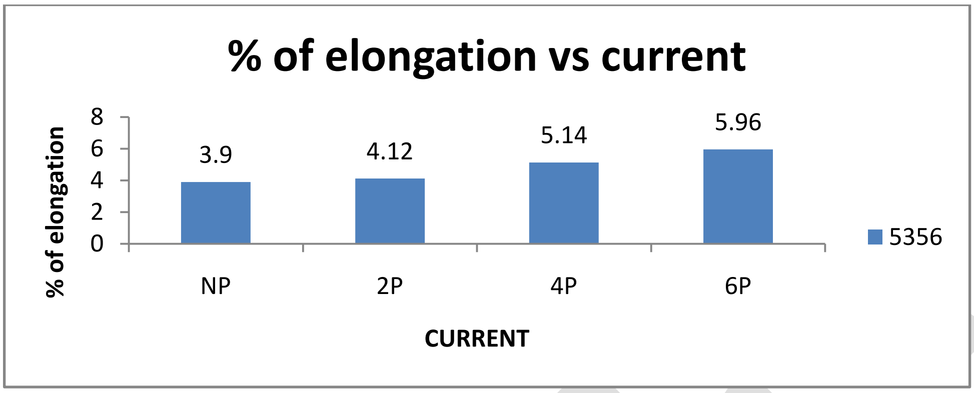

Figure 7: comparison between % of elongation and current

C. Microstructure Results: The microstructure at weld zone, fine grain structure was observed in the filler wire 5356 at 2P and 4P. It is observed that more fine grain structure is observed in pulsed current images than non pulsed images, due to fine grain structure the tensile strength of filler wire 5356 should be more but due to fluctuations and drop outs in the current the tensile strength was less. The various photographs showing microstructure of 2 pulse/sec and 4 pulse/sec at Fusion Zone.

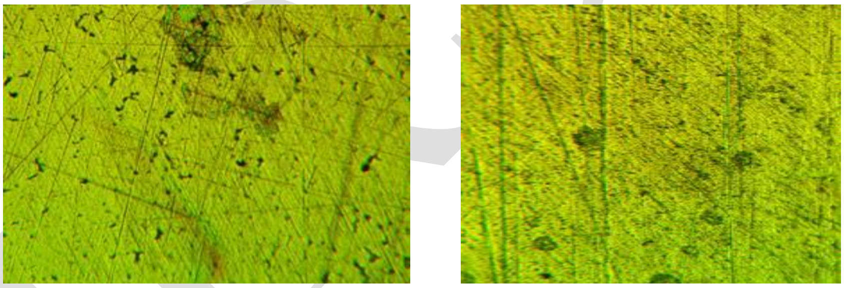

Figure 8: microstructure of weldments of 2P and 4P at FZ

D. Micro-hardness test results: The sample of micro hardness indention of the weldment is shown in the figure 9.

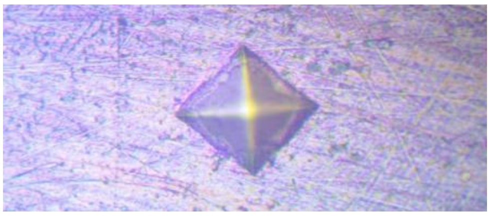

Fig. 9: Micro hardness indention of weldment.

From the micro hardness values it is observed that there is variation in the hardness values at different currents.. Hardness was checked at different locations and observed that hardness increased in the Weld Metal Zone. From the

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hardness values it is observed that the non- pulsed current has produced high hardness than pulsed current. The graph and the values related to micro hardness are shown in the figure 10.

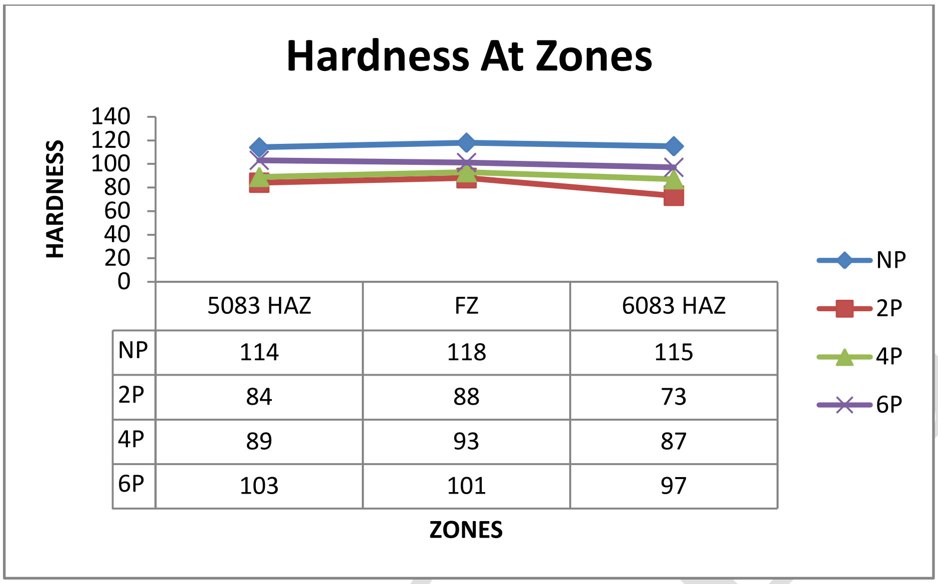

Figure 10: hardness values at different zones

IV. CONCLUSIONS

From the experimental results the following conclusions are drawn

- The results show that there are small pores present in the welding area but they are within the acceptable limit of ASTM Standards
- There are no surface cracks observed in the weld zones
- The current 6 pulse/sec produced maximum ultimate tensile strength i.e., 186.4 Mpa.
- The pulsed current has produces more tensile strength than non-pulsed current.
- The current 6 pulse/sec produced maximum % of elongation i.e., 5.96.
- The pulsed current has produces more % of elongation than non-pulsed current.
- The more fine grain structure was observed at 2P and 4P which increases the tensile strength
- The non-pulsed current has produced high hardness i.e., 118VHN due to the composition of filler wire. In the filler wire 5356 there is a more percentage of magnesium available. The presence of magnesium will increases the strength and hardness of the parent material.

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