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Evaluation of Mechanical Properties of AA6082-T6 Aluminium Alloy Using Pulse & Non-Pulse Current GTAW Process

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ABSTRACT: The 6xxx aluminium alloys have found application in automotive structures, as they offer an attractive combination of strength, formability and corrosion resistance, surface properties and good weldability. To make effective use of the automated systems it is essential that a high degree of confidence be achieved in predicting the weld parameters to attain the desired mechanical strength in welded joints. In this research, AA 6082 welds are made with gas tungsten arc welding (GTAW) using AA 4043 filler 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 evaluation of 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. From this investigation the pulsed current TIG welding produces the better mechanical properties compared to the other welding processes.

KEYWORDS: AA6082 aluminium alloy, Gas Tungsten Arc Welding, Non-destructive Testing, Tensile Properties, Pulsed current

I. INTRODUCTION

Welding is one of the most used methods for joining aluminium 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 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 aluminium sheets. Therefore, to produce high quality weldments, TIG welding process is preferred over gas metal arc welding.

Reduction of mass is a prime concern for many industries involved in transportation especially the automobile industry, which has become significant because of fuel saving, reduction of saving, reduction of emission and recyclability. Hence the focus on light weight materials like aluminium and magnesium has become predominant.

The AA6XXX aluminium alloys are magnesium and silicon containing alloys that are widely used in transportation and building applications for their light weight and attractive mechanical properties achieved by thermal treatments. It is well known that in aluminium alloys improvement of the mechanical properties is classically obtained by the precipitation produced by decomposition of the supersaturated solid solution during ageing. . Heat treatable 6xxx aluminium alloys are of special interest for they offer hardening possibilities that lead to specific properties. In the utilization of these alloys, one difficulty to be overcome is the general reduction, as compared to the parent material, of mechanical properties of welded joints. These are wrought alloys that are typically processed through forging, extruding or rolling. Specific applications of AA6XXX aluminium alloys are in automotive sheet and tread plates, architectural components, pipelines, ladders, etc. Since there is ever-increasing demand for high strength, low-cost materials, investigation of processing- microstructure relationships is strongly required

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Hence present study was carried out to understand the effect of pulsed current and non- pulsed current welding technique on tensile properties of Gas Tungsten Arc Weldments of 6082 –T6 aluminium alloy.

II. MATERIALS AND METHODS

The sheets of 2mm and 4mm thickness aluminium alloy 6082-T6 have been cut into requires size (150x300mm) by shearing machine. Chemical compositions and mechanical properties are shown in Table 1 and 2.

Table 1: Chemical Compositions of work material 6082 Aluminium alloy

	Chemical Composition % wt								
Material	**Si**	**Fe**	**Cu**	**Mn**	**Mg**	**Zn**	**Ti**	**Cr**	**Al**
6082 Aluminium Alloy	0.7-1.3	0.5	0.1	0.4-1.0	0.6-1.2	0.2	0.1	0.25	Balance

Table 2: Mechanical properties of 6082 Aluminium alloy at heat treated condition

Material	UTS(MPa)	0.2% Y.S(MPa)	% Elongation
6082 Aluminium	362	322	16

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 aluminium 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 sheets using filler wire AA4043 and its chemical compositions are show in Table 3.

Table 3: Chemical Compositions of filler wire ER4043

	Chemical Composition % Wt							
Material	**Cu**	**Si**	**Mn**	**Mg**	**Fe**	**Cr**	**Ti**	**Al**
4043filler wire	0.17	4.5-6.0	0.24	0.05	0.05	0.05	0.05	Balance

The equipment used for this study is Lincoln Electrical Precision TIG 375 GTAW machine is shown in Figure 1. The equipment consists of mainly of power supply source, a welding torch, connecting torch, cables and hoses for gas and water supplies. 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

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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. The weld parameters are show in Table 4 and 5.

Table 4: Welding parameters for non-pulsed current welding of 6082 Aluminium alloy

Material Thickness(mm)	Weld Layer	Filler wire dia (mm)	Current	I(amp)	V(volts)	Arc Travel Speed(cm/min)
2	root	2.4	AC	106	13.2	7
4	root	2.4	AC	170	13.6	7
	1st pass	2.4	AC	145	13.2	7

Table 5: Welding parameters for pulsed current welding of 6082 Aluminium alloy

Material Thickness(mm)	Weld Layer	Filler wire dia (mm)	Pulse/Sec (Hz)	Current	I_P (amp)	I_b (amp)	V(volts)	Arc Travel Speed (cm/min)
2mm	root	2.4	2	AC	110	78.8	13.93	6
	root	2.4	4	AC	110	72.08	14.64	6
	root	2.4	6	AC	110	77.13	14.13	6
4mm	root	2.4	2	AC	195	146	13.1	6
	1st pass	2.4		AC	195	146	13.7	6
	root	2.4	4	AC	190	139	12.8	6
	1st pass	2.4		AC	190	137	14.5	6
	root	2.4	6	AC	190	138	13.0	6
	1st pass	2.4		AC	190	138	13.7	6

After the welding process, the NDT was carried out on the weldments, the weldments are shown in the figure2.

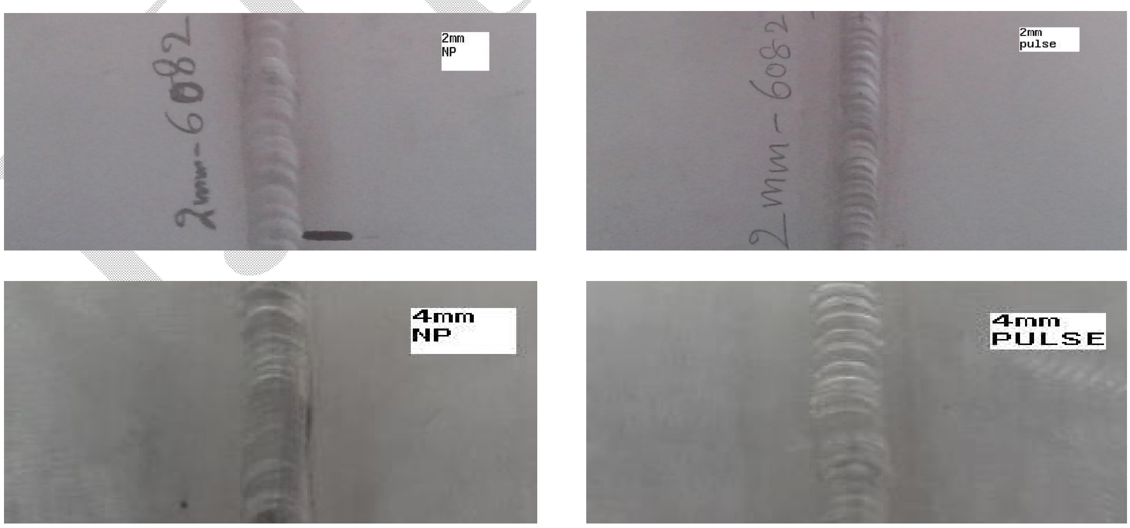

Figure 2: Weldments of AA6082-T6 Aluminium Alloy sheets

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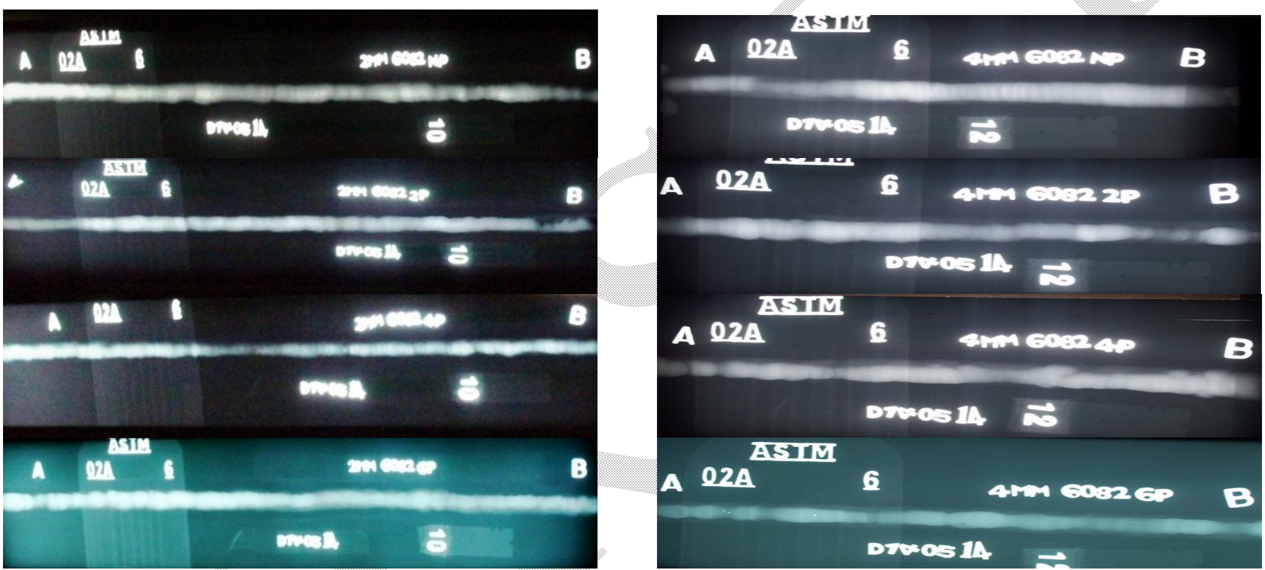
The radiography test is performed as per the ASTM standards, section VIII, division 2 and liquid penetrant tests as per ASTM E-1417 were conducted on AA6082-T6 weldments to find porosity and cracks. The parameters used for NDT are given in table 6.

Table 6: liquid penetrant test parameters

	6082 aluminium alloy
Penetrant used	The oriental chemical works
Cleaner used	The oriental chemical works
Developer used	The oriental chemical works
Dwell time	10 mins
Method	Solvent removable white light method

The X-ray images are taken during the radiography test to find the porosity of the weldments. The images are shown in figure 3.



2mm weldments 4mm weldments

Figure 3: X-ray images of AA6082-T6 Weldments

To investigate the mechanical properties of the weldments, as per ASTM B557 standard the tensile specimens (figure 4) were prepared on CNC wire cut EDM. The finished specimens were tested to find the ultimate tensile strength (UTS) and % elongation using 60 ton Universal Testing Machine (figure 5).

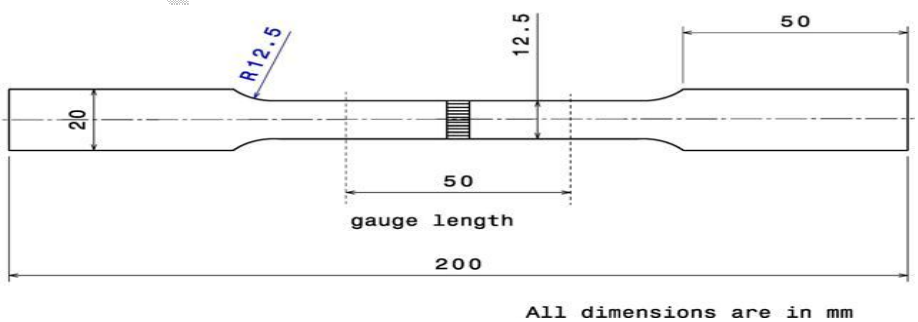


Figure 4: Tensile test specimen

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Figure 5: UTM machine

III. RESULTS AND DISCUSSION

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

3.1 Effect of Current on Porosity and Cracks: The effect of pulsed current on the porosity observed during radiography is presented in table 7. Porosity has been measured in present study. No porosity was observed at 2Hz, 4Hz and 6 Hz frequencies. 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 of this alloy in both thicknesses with non-pulsed current and pulsed current welding. The results are shown in table 8.

Table 7: Radiography test – To investigate the porosity of the weldments

S.No.	Thickness of the Plate	Method of welding		Observation
1.	2mm	Non-pulsed welding		No Defect Observed On Welded Area
2.		Pulsed welding (pulses/sec)	2	
3.			4	
4.			6	
5.	4mm	Non-pulsed welding		
6.		Pulsed welding (pulses/sec)	2	
7.			4	
8.			6	

Table 8: Liquid penetration test – To investigate the surface cracks of the weldments

S.No.	Thickness of the Plate	Method of welding		Observation
1.	2mm	Non-pulsed welding		No Defect Observed On Welded Area
2.		Pulsed welding (pulses/sec)	2	
3.			4	
4.			6	
5.	4mm	Non-pulsed welding		
6.		Pulsed welding (pulses/sec)	2	
7.			4	
8.			6	

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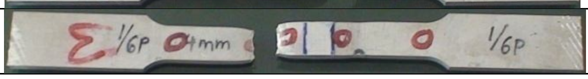
3.2 Tensile Test: The effect of frequency on the tensile strength (2Hz, 4HZ, 6Hz&NP) was shown in table 9. The finished test specimens were tested using the universal testing machine of 60 ton capacity. In this testing we found that all the weld specimens were failed at base metal area except 2mm thick, 6 pulses/sec weldment that is in HAZ. The failure locations of the weldments are shown Table 10.

Table 9: tensile test table

S.No.	Thickness of the plate	Method of welding		Ultimate Tensile Strength(MPa)	0.2% of Proof Stress(MPa)	% of Elongation
1	2mm	Non-pulsed welding		227.14	169.84	6.24
2		Pulsed welding	2p	238.75	173.57	6.12
3			4p	227.96	163.71	5.34
4			6p	231.16	164.83	5.42
5	4mm	Non-pulsed welding		204.72	133.06	6.82
6		Pulsed welding	2p	201.81	116.76	8.08
7			4p	197.40	110.50	8.24
8			6p	196.23	112.95	6.62

Table 10: Failure Locations of Tensile Test Specimens during Tensile Test.

S.NO.	Thickness of the sheet	Method of welding		Tensile specimen	Failure location
1	2mm	Non- pulsed welding			Outside of the weld
2		Pulsed welding (pulses/sec)	2		
3			4		
4			6		HAZ
5	4mm	Non- pulsed welding			Outside of the weld
6		Pulsed welding (pulses/sec)	2		
7			4		
8			6		

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These tests showed a remarkable reduction of both tensile strength and elongation as compared with nominal values of the parent metal. It was observed that in both the thicknesses the pulsed current weldments produced more strength than the non-pulsed current weldments. The welding made at 2 pulses/sec, 2mm thick AA6082-T6 weldments produced the higher value of UTS compared to 4mm thick AA 6082-T6 weldments

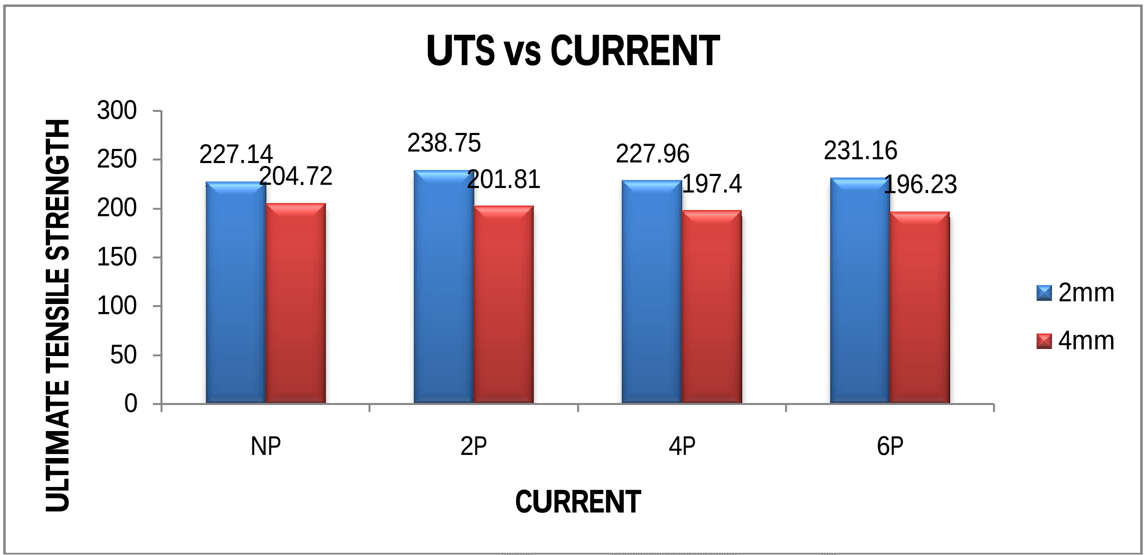

Figure 6: comparison between UTS and current

The effect of current on % of elongation values of both the thickness of AA 6082-T6 weldments are compared, it is observed that the maximum value is produced at 4 pulse current, 4mm thick AA6082 weldment. The effect of current on strength and % of elongation is shown in figures 6 and 7.

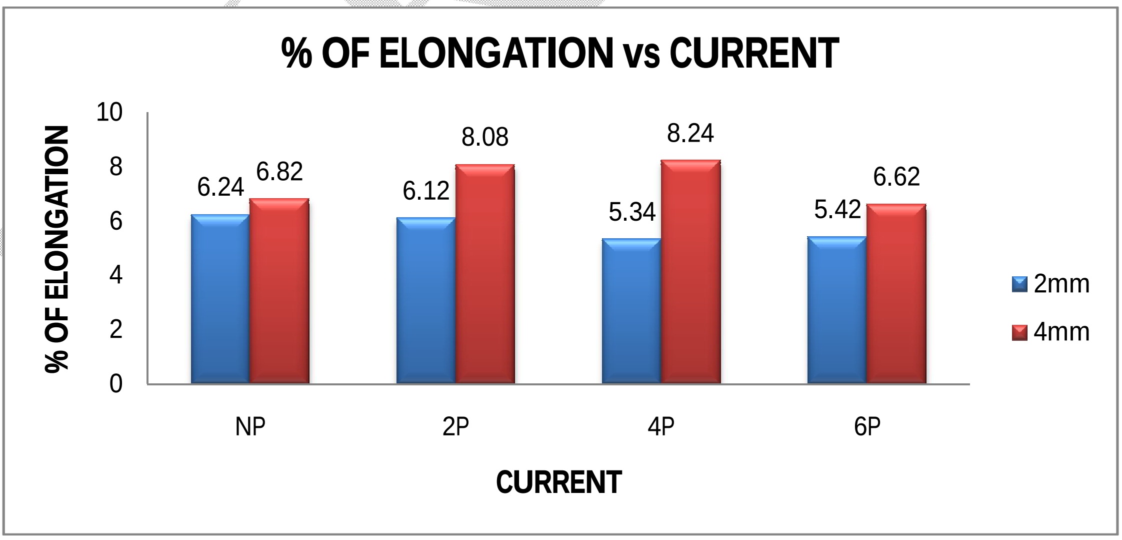

Figure 7: comparison between % of elongation and current

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3.3 Weld Joint Efficiency: The weld joint efficiency of material is shown in figure 8. 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 2mm thick at 2 pulses/sec. it is observed that the weldment produced at 2 pulses/sec has produced more weld joint efficiency i.e., 65.93%.

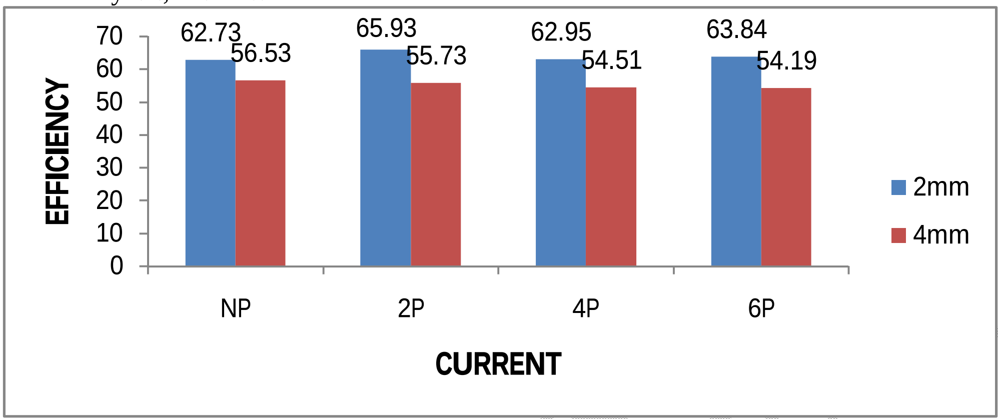

Figure 8: weld joint efficiency of 6082AA Weldments

IV. CONCLUSIONS

From the experimental results the following conclusions are drawn

- The results shows that there was no pores and cracks in the weldments AA 6082-T6 in 2mm and 4mm thick weldments.
- The 2mm thick AA6082-T6 at 2pulses/sec produced the maximum ultimate tensile strength i.e., 238.75 when compared with 4mm thick weldments.
- The pulsed current has produces more tensile strength than non-pulsed current.
- The 4mm thick AA6082 at 4 pulses/sec produced maximum % of elongation i.e., 8.24 when compared with 2mm thick weldments.

V. ACKNOWLEDGEMENT

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