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Experimental Investigations on Welding Characteristics of Aluminum Alloy (6082) Weldments, Using Pulsed and Non-Pulsed Current GTAW

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Abstract. Aluminum and its alloy 6082 usage in various aerospace applications is generating significant interest. Both Pulsed and Non pulsed Gas Tungsten Arc welding are being used for fastening of Aluminum. The impact of variation in pulsed frequency as well as different thicknesses of aluminum Al 6082 material on the quality of welded sample was examined. In this present investigation, Al 6082 samples of 3mm & 6mm thickness were welded using pulsed and non-pulsed current welding. Pulsed frequencies 5Hz and 10Hz were used during investigation. Liquid penetrate, radiography and mechanical tests as per ASTM were carried on the welded samples did not find defects in welded joint during liquid penetrate test. Maximum ultimate strength observed in non-pulsed current weldments at lower thickness and pulsed current weldments of higher thickness weldments.

INTRODUCTION

Superior weld quality is required for applications such as aero space engineering enables enhanced usage of Aluminum and alloy weld structures. TIG (Tungsten Inert Gas) and MIG (Metal Inert Gas) welding are the techniques widely used for welding of Aluminum. GTAW (Gas Tungsten Arc welding) is found to be the most appropriate method for welding of stainless steel as well as aluminum alloys producing finest quality weldments. Aluminum alloys are welded by GTAW using AC and DC electrical power supply.

PCW (Pulsed current welding) invented in 1960s as an alternative to CCW (Constant current welding) started yielding good results. Superior sized grains, stable arc quality, less sensitized hot cracking, improved fusion zone control, heat affected zone thinning, porosity decrease, minimum weld pool disturbance by gas, enhanced D/W (Depth/Width) ratio of weld and reduced input of heat are the several advantages of PCW over CCW [1-8].

In PCW, pulsed current is generated by fluctuating between pre set welding currents of low and high level [9]. Manufacturing of components of rocket motors, missiles, aerospace applications, gas storage tanks and air bottles withstanding high pressure is extensively done by using Pulsed current welding.

Much research is not done on welding of aluminum alloy using PCW[8]. In PCW of 5083 aluminumsheets, parameters such as shape of bead, speed of welding, composition of gas used for shielding,frequency of welding imperfections and strength of welding joint are considered for research purpose. Composition of grain structure [10], geometry of weld bead [11] and deformation phenomenonare considered for study purpose in the case of stainless-steel grade SS310[9]

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welding. Pulsed current follows rectangular pattern. Fig.1 shows the Current and timings of Base (I_b, t_b) & Peak(I_p, t_p), the important factors of PCW which influence the weld quality and other attributes of welding.

EXPERIMENTAL PROCEDURE

For conducting the experiment with pulsed and non pulsed gas tungsten arc welding, aluminum alloy test specimens in sizes of 150 x 300 mm with different thickness of 3 and 6mm of 6082 Grade were prepared. Usage of filler material ER4043, lowered the cracks in welding. Ductility and Strength of Weld were observed to be superior with ER4043 compared to other fillers [12]. Tables 1-3 show the mechanical properties and composition of Aluminum Al 6082 and filler material ER4043 used in experiment. Lower melt temperature of ER4043 than Al6082 was observed to be the reason for less cracks in welding. While cooling of weld pool, ER4043 was more plastic than Al6082, which in turn eased the stresses during contraction thus lowering cracks.

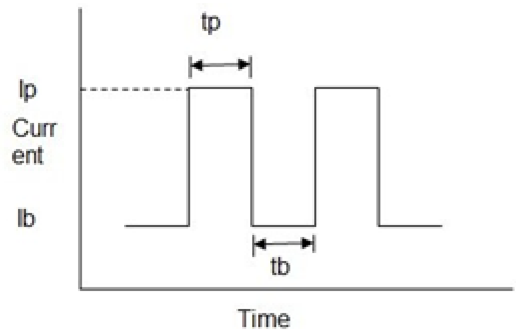

FIGURE 1. Pulsed current GTAW peak current Ip, base current I_b, peak time tp and base time tb.

The experimental set up consisted 3500-watt AC/DC Gas Tungsten Arc welding machine and is shown in Figures 3 & 4. Preparation of Al 6082 specimens included the sequential steps of chemical cleaning for 10 minutes with hot NaOH (Sodium Hydroxide) solution, HNO3 (Nitric Acid) plunging for duration of 15 Minutes and water washing.

During AC Pulsed current welding, 2%Zirconated Tungsten of Diameter-3mm electrodes with hemispherical shape which are most suitable for AC application were utilized. DC Pulsed current welding was done with taper shaped Thoriated Tungsten electrodes [13]. Selection of electrodes and their suitability was done based on the usage of AC or DC current during welding. Fig.2 Shows preparation of Al 6082 specimen edges for welding. Tables 4 & 5 indicate the different attributes used in AC and DC pulsed current welding of 3 & 6 mm thickness Al 6082 Samples.

After Completion of welding, various non-destructive tests i.e. Mechanical tests, Radiography test as per Div2 – Sec VII and liquid penetration test as per ASTM E–1417 were carried on the specimens [14]. Tables 6 – 7 demonstrate the attributes of the tests mentioned.

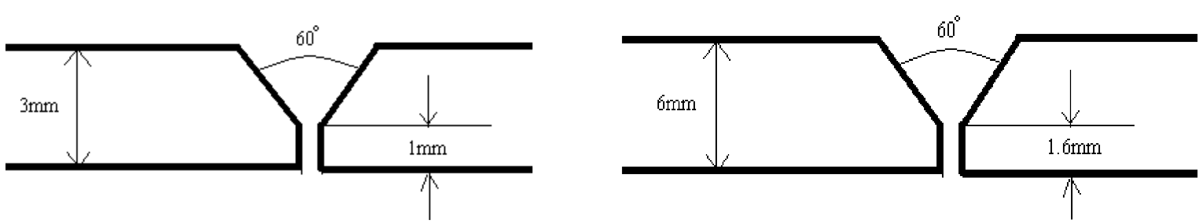

FIGURE 2. Al 6082 weld samples - preparation of Edge

FIGURE 3. GTAW Machine – Panel

FIGURE 4. 3500-watt AC/DC Gas Tungsten Arc welding machine

TABLE 1. Al 6082 Material - Chemical Constituents

	Chemical Constituents(% wt)								
Material	Silicon	Ferrous	Copper	Manganese	Magnesium	Zinc	Titanium	Chromium	Aluminum
Al 6082	0.7 - 1.3	0.5	0.1	0.4 – 1.0	0.6 – 1.2	0.2	0.1	0.25	Remaining

TABLE 2. ER4043 Filler Material - Chemical Constituents

	Chemical Constituents (% wt)							
Filler Material	Copper	Silicon	Manganese	Magnesium	Ferrous	Chromium	Titanium	Aluminum
ER4043	0.17	4.5 – 6.0	0.24	0.05		0.05	0.05	Remaining

TABLE 3. Al 6082 Material - Mechanical properties @ heat treated condition

Material	Ultimate Tensile Strength - MPa	0.2% Yield Strength - MPa	Elongation - %
6082 Aluminum	260	170	11

TABLE 4. Al 6082 Material – Non-Pulsed Current welding attributes

Thickness	Weld Layer	Filler Material Diameter - mm	Type of Current	I (amp)	V (volts)	ARC Travel Speed(cm/min)
3 mm	Root	2.4	AC	203	15.2	5.16
6 mm	Root	2.4	AC	180	15.5	6.12

TABLE 5. Al 6082 Material – Pulsed Current welding attributes

Thickness	Weld Layer	Filler Material Diameter - mm)	Pulse Frequency (Hz)	Type of Current	Ip (amp)	Ib (amp)	V (volts)	ARC Travel Speed(cm/min)
3 mm	Root	2.4	5	AC	119	68	14	6.9
	Root	2.4	10	AC	119	68	14	6.9
6 mm	Root	2.4	5	AC	215	68	19	9.3
	Root	2.4	10	AC	215	68	19	9.3

TABLE 6. Al 6082 Material – Radiography Test Attributes

6082 Aluminum Alloy		
Attributes - Exposure	Voltage KV	65/95
	Current (mA)	3
	Time (min)	2
	Film Used	MX-125
	SFD (min)	1
	Penetrometer	10-16-DINAI
Attributes - Processing	Developer Time (min)	5
	Stop Bath Time (min)	1
	Fixer Time (min)	10
	Sensitivity	2%

FIGURE 5. Al 6082 Weld Samples

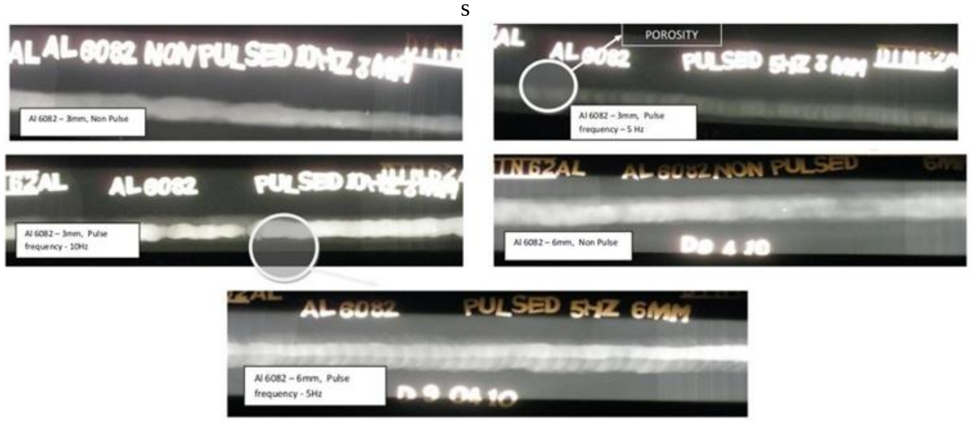

FIGURE 6. Al 6082 welded samples – Pictures of Radiographic Test

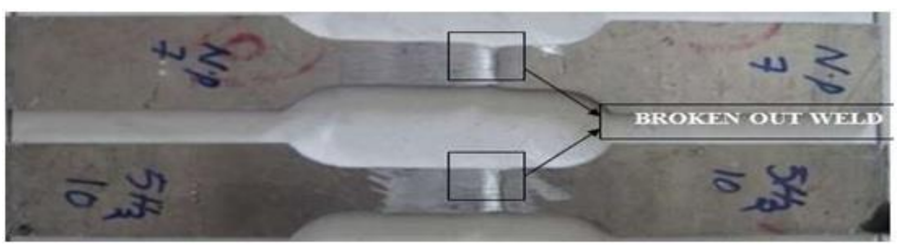

FIGURE 7. Fractured Al 6082 welded sample - Tensile Test

RESULTS AND DISCUSSION

Attributes such as specimen thickness and frequency of pulse were changed. Attributes that are providing the heat input to the welding like travel speed, voltage and average current of arc are not changed.

Thickness Impact

Table.8 shows the thickness variation effect and various attributes of pulse & non-pulse welding on quality of welding. In non-pulsed current welding, with speed of 5 cm/min porosity not seen in weld specimen of 3mm. 0.6mm sized pores were observed in 3mm thickness weldment [15] with pulsed frequency of 5 Hz and speed of 6 cm/min. In pulsed current welding with frequencies of 5 & 10Hz, porosity in clustered fashion was visible in 6mm thick weldments. With Non pulsed current welding, haphazard pore pattern of 0.1-0.3 mm size observed in 6mm thickness specimens [16].

Result indicate with pulsed current welding in 6mm thickness plates more porosity was visible compared to non-pulsed current welding [17]. Less porosity in non-pulsed current weldments is due to non-entrapment of gases in weld pool as the metal remained in liquid state for more time during the phase of solidification [24]. By providing appropriate and adequate amounts of shielding and purging gases, porosity can be further minimized [25].

Frequency Impact

Radiography tests were done on weld specimens to observe porosity. Table.8 shows the pulse frequency variation in pulsed current welding and varying thickness of weld specimen on quality of welding [20]. Pulsed frequencies 5Hz and 10Hz were used for studying the effect. 0.6mm sized pores with 5Hz and 7mm sized Cluster porosity with 10Hz were seen in 3mm thickness weldment [18]. 0.6mm sized pores – 2nos with 5Hz and 9mm sized Cluster porosity with 10Hz were seen in 6 mm thickness weldment [21]. More porosity is seen with 10Hz frequency than 5Hz.In adequate supply of gases, in appropriate cleaning and increased pulsation of welding torch can be attributed to the increased porosity in weldments [19]. Permissible levels of porosity observed in Al 6082 welded specimen with non-pulsed current welding.

TABLE 7. Test results of radiography test – al 6082 alloy

S. No	Al 6082 Thickness	Type of Welding	Pulse Frequency	Remarks
1	3 mm	Non PCW	-	Defect free
2	3 mm	PCW	5 Hz	0.6mm Sized Pores
3	3 mm	PCW	10 Hz	7mm sized Clusterporosity of
4	6 mm	Non PCW	-	0.1-0.3mm Sized poresin haphazard manner
5	6 mm	PCW	5 Hz	0.6mm Sized Pores – 2Nos
6	6 mm	PCW	10 Hz	9mm Sized Clusterporosity

TABLE 8. Test Results of Liquid penetrate test – Al 6082 alloy

S. No	Al 6082 Thickness	Type ofWelding	Pulse Frequency	Remarks
1	3 mm	NonPCW	-	Welded areais defect free
2	3 mm	PCW	5 Hz	-do-
3	3 mm	PCW	10 Hz	-do-
4	6 mm	NonPCW	-	-do-
5	6 mm	PCW	5 Hz	-do-
6	6 mm	PCW	10 Hz	-do-

Ultimate Tensile Strength

UTM (Universal Testing Machine) of 10T was used to conduct mechanical tests on weld specimens. Results indicate non pulsed current welding produced higher average UTS (Ultimate Tensile Strength) [22] than pulsed current welding. The UTS values are 173N/mm2 (Non-Pulsed), 172N/mm2 (10Hz Pulsed), 166.15N/mm2 (5Hz Pulsed) for 3 mm thickness specimen and 148N/mm2 (Non-Pulsed), 155N/mm2 (10Hz Pulsed), 154 N/mm2 (5Hz Pulsed) for 6 mm thickness specimen [23]. Test samples broke down in heat affected zone and welding portion as expected.

CONCLUSIONS

Al alloy 6082 samples of 3mm & 6mm thickness were welded using non pulsed and pulsed current tungsten arc welding. Liquid penetration, radiography and mechanical tests as per ASTM standards were carried on finished weld samples and results are discussed. Radiography tests indicated that enhancement of sample thickness and pulse frequency caused enhanced porosity in weld samples.

- Liquid penetrate tests showed Aluminum weld samples to be free of defects with pulsed and non-current welding irrespective at thickness at the plate.

- Mechanical tests on UTM Machine demonstrated that Maximum Ultimate Tensile Strength 173 N/mm^2 with non pulsed welding in 3mm thickness samples.
- In 6mm weldments, Maximum Ultimate Tensile Strength 155 N/mm^2 was seen with pulsed current welding.

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