Effect of Pulsed Current on Welding Characteristics of Aluminium Alloy (5052) using Gas Tungsten Arc Welding

A. Raveendra[1], B. V. R. Ravi Kumar[2]

[1]Associate Professor, Mech. Engg. Dept, Mallareddy Engineering College, JNTU Hyderabad, India

[2]Professor, Mech. Engg. Dept., VNR.Vignana Jyothi Institute of Engineering & Technology, Bachupally, Nizampet (SO) Hyderabad, India,

Abstract: ***In this experimental work, aluminium alloy(5052) weldments were made using Gas Tungsten Arc Welding with pulsed current and non- pulsed current at different frequencies 2Hz,4Hz,6Hz. Non-destructive tests like radiography, liquid penetrant test were conducted, evaluated and compared with pulsed and non-pulsed current welding at different frequencies of two different thick materials (1.5mm and 2.5 mm of 5052 aluminium alloy).The aim of this experimental work is to see the effect of pulsed current on the quality of weldments. The experimental results pertaining to different welding parameters for the above material using pulsed and non-pulsed current GTAW are discussed and compared.***

Keywords: 5052 aluminium alloy, Gas Tungsten Arc Welding, Constant Current Welding, Pulsed current welding and Heat Affected Zone.

1. Introduction

The demand is increasing for aluminium alloy welded products where high quality is required such as aerospace applications. Aluminium alloy can be welded easily by conventional arc welding methods like Metal Inert Gas Welding (MIGW) and Tungsten Inert Gas Welding (TIGW).Among these two methods, The Gas Tungsten Arc Welding (GTAW) process has proved for many years to be suitable for welding aluminium alloy since it gives best quality welds. GTAW process (AC) is used in this study for welding of aluminium alloy (5052).

Further development has been pulsed current TIG welding. Pulsed current welding (pcw) was introduced in the late 1960's as a variant of constant current welding (ccw). pcw process has many advantages over ccw, 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 [1-8]. Pulsed current welding technology has been widely used in fabrication of high pressure air bottles, high pressure gas storage tanks, rocket motors, structures in aerospace applications such as aircrafts, rockets and missiles. Switching between predetermined high and low level of welding current can be used to produce pulsed current gas tungsten arc welds [9].

Some progress is done on pulsed current GTAW of aluminium alloy [8]. So far the pulsed current welding is used to study the effect of pulse current, shielding gas composition, weld speed and bead shape, the incidence of welding defects, joint strength, using alloy sheets of 5083type [8] angular distortion in SS310 type [9], to study the microstructure [10] and weld bead geometry [11] .Usually the pulsed waves are in rectangular shape and the parameters used for pulsed GTA welding are in shown in figure 1. The main characteristics of PCW are determined by peak current $I_{p,}$ base current I_b, peak time t_p and base time t_b.

2. Experimental Procedure

The work pieces were made of 5052 aluminium alloy of various thicknesses i.e. 1.5mm and 2.5mm. The test specimens were machined to the size of 150 mm X 300 mm and welded with pulsed and non-pulsed current GTAW process.

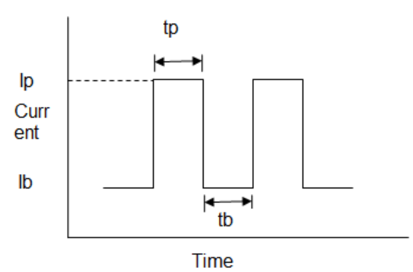

Figure 1: Parameters used for pulsed GTAW: peak current Ip, base current I_b, peak time t_p and base time t_b.

Filler wire material of ER4043 was used during the welding, which reduced the weld cracks and produced the good strength and ductility than other filler metals [12]. These filler metals melt at a temperature lower than that of the base metal, for this reason it yields during cooling, since it remains more plastic than the base metal and relieves the contraction stresses that might cause cracking. The chemical composition and mechanical properties of work material and filler wire as shown in Tables 1-3.

The aluminium alloy work pieces were 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**. Lincoln Electrical square wave TIG 355** GTAW machine with AC was used for welding of 5052 aluminium alloy test specimens .The choice of tungsten electrode depends upon the type of welding current selected for the application. Zirconated tungsten (EWZr) electrodes are best suited for AC wherein they keep hemispherical shape and thoriated tungsten electrodes (EWTh-2) should be ground to taper are suitable for DCSP welding are used for this purpose [13]. This welding process was conducted with 3.0 mm diameter 2% Zirconated tungsten electrode for 5052 aluminium The welding parameters used for this welding process both in pulsed current and non-pulsed current for two different thicknesses of the above material are given in Tables 4&5. The edge preparation of the tested 5052 aluminium alloy specimens are shown in figure 2.

After welding process is over, the radiography , liquid penetrant test were carried out on the weldments (fig3,4,5 &6),according to the ASTM standards , Section VIII, Division 2 for radiography and ASTM E-1417 for liquid penetrant test [14]. The parameters used in the non-destructive testing are given in the Tables 6 and 7.

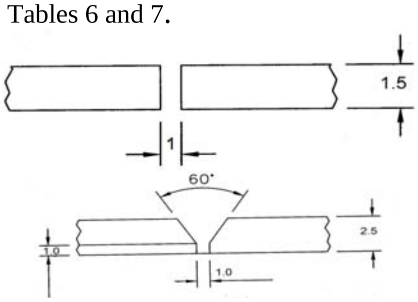

Figure 2: Edge preparation of weld specimens

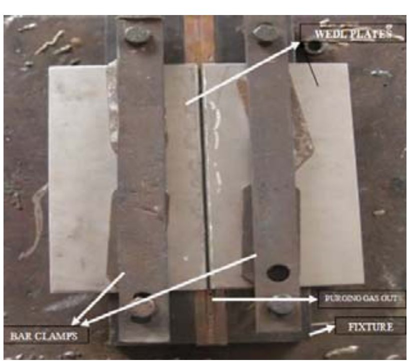

Figure 3: Fixture

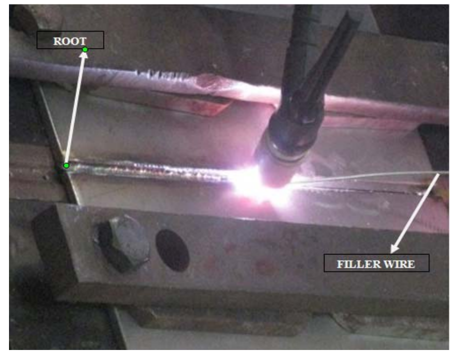

Figure 4 Root of the Welding

Figure 5. AC/DC Pulse Panel

Figure 6: Lincoln Electrical square wave TIG 355 GTAW

Table 1. Chemical Compositions of work material 5052 Aluminum alloy

	Chemical Composition % wt								
Material	*Si*	*Fe*	*Cu*	*Mn*	*Mg*	*Zn*	*Ti*	*Cr*	*Al*
5052 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. Chemical Compositions of filler wire

	Chemical Composition % wt							
Material	*Cu*	*Si*	*Mn*	*Mg*	*Fe*	*Cr*	*Ti*	*Al*
ER4043	0.17	4.5 – 6.0	0.24	0.05	0.05	0.05	0.05	Balance

Table 3. Mechanical properties of 5052 Aluminium alloy

Material	*UTS(MPa)*	*0.2% Y.S(MPa)*	*% Elongation*
5052 Aluminium Alloy	260	170	11

Table 4. Welding parameters for non-pulsed current welding of 5052 Aluminium alloy

Material Thickness(mm)	*Weld Layer*	*Filler Wire dia(mm)*	*Current*	*I (amp)*	*V (volts)*	*ARC Travel Speed (cm/min)*
1.5	Root	1.6	AC	89	16	6.0
2.5	Root	2.4	AC	123	20	5.0

Table 5. Welding parameters for pulsed current welding of 5052 Aluminium alloy

Material Thickness, mm	*Weld Layer*	*Filler Wire dia(mm)*	*Pulse /Sec (Hz)*	*Current*	*Ip (amp)*	*Ib (amp)*	*V (volts)*	*ARC Travel Speed(cm/min)*
1.5	Root	1.6	2	AC	93	49	18	6.0
1.5	Root	1.6	4	AC	117	59	16	6.0
1.5	Root	1.6	6	AC	90	54	16	6.0
2.5	Root	2.4	2	AC	129	71	20	5.0
2.5	Root	2.4	4	AC	128	70	20	5.0
2.5	Root	2.4	6	AC	131	72	20	6.0

Table 6. Radiography test parameters of 5052Aluminium alloy

Exposure Parameters	Voltage KV	65/95
	Current (mA)	3.0
	Time (min)	2.0
	Film Used	MX-125
	SFD (min)	1.0
	Penetrameter	10-16-DINAI
Processing Parameters	Developer Time (min)	5.0
	Stop Bath Time (min)	1.0
	Fixer Time (min)	10
	Sensitivity	2%

Table 7. Liquid Penetrant Test parameters of 5052 Aluminium alloy

DP DIT	*MAGNA FLUX*
Penetrant Used	SKL-SP
Cleaner Used	SKC-1
Developer Used	SKD-S2
Dwell Time (at room temp)	10 min
Viewing Media	Normal Light
Sensitivity	30 microns

Figure 7. Welded Plates of Aluminium Alloy 5052

Figure 8. Radiographic images of aluminium alloy (5052) weldments

Table 8. The radiography test results of 5052 aluminium alloy

Slno	*Material thickness*	*Pulse/non-pulse welding*	*Frequency (Hz)*	*observations*
1	1.5	Non-pulse	-	No significance defect
2	1.5	Pulse	2	No significance defect
3	1.5	Pulse	4	No significance defect
4	1.5	pulse	6	No significance defect
5	2.5	Non-pulse	-	One pore size 0.5 mm, ramdom pores size 0.1-0.3mm
6	2.5	pulse	2	Two pores size 0.6mm
7	2.5	Pulse	4	Cluster porosity:12mm
8	2.5	pulse	6	Cluster porosity:8mm

Table 9. The liquid penetrant test results of 5052 aluminium alloy

Slno	*Material thickness*	*Pulse/non-pulse welding*	*Frequency(Hz)*	*observations*
1	1.5	Non-pulse	-	No defect observed on welded area
2	1.5	Pulse	2	No defect observed on welded area
3	1.5	Pulse	4	No defect observed on welded area
4	1.5	Non-pulse	6	No defect observed on welded area
5	2.5	Non-pulse	-	No defect observed on welded area
6	2.5	pulse	2	No defect observed on welded area
7	2.5	Pulse	4	No defect observed on welded area
8	2.5	pulse	6	No defect observed on welded area

3. Results and Discussions

The parameters used in the NDT are presented in the tables 6 and 7. The average current, arc voltage and travel speed were kept constant i.e. the heat input per unit length in a weld is fixed, while pulse frequency and thickness of the sheet during the pulsed GTAW were varied.

3.1. 5052 Aluminium alloy weldments

3.1.1. Effect of Thickness

The effect of thickness and welding parameters are given in table 8 & 9. During radiography test, no posity was observed in 1.5mm thick weldments welded at welding speed of 6 cm/min at all frequencies of 2, 4, and 6. Specimen 2.5mm thickness weldments produced one pore of maximum size 0.5mm and random pores of size 0.1 - 0.3mm was observed at non-pulsed GTAW, maximum pore size of 0.6mm observed in the weldments welded at a frequency of 2 HZ. Cluster porosity was observed at two pulses 4 HZ & 6 HZ i.e. 12mm and 8mm respectively.

The results shows that more pores were observed in higher thickness weldments with pulsed current welding than the non-pulsed current because of molten metal remaining in solidification phase for the longer duration in non-pulse and the gases escaped minimized the pores in the weldments. Even though the pore sizes are within the acceptable limits, the observed pores can be minimized by proper supply of purging and shielding gases.

3.1.2. Effect of Frequency

Effect of frequency on the porosity during radiography is observed in the table 8. The porosity is measured in the present study at three frequencies 2HZ, 4HZ and 6HZ. No porosity was observed in 1.5mm thick weldments welded at non-pulsed current and at all frequencies. One pore size with 0.5mm, random pore size of 0.1 – 0.3mm were observed in non-pulsed at 2.5mm thick weldments.

Two pores of size 0.6mm observed at 2HZ in 2.5mm thick welded plates. Cluster porosity of 12mm at 4HZ and cluster porosity of 8mm at 6HZ frequency were found in 2.5mm thick weldments. The results show that porous size increases with the increase of frequency. This may be due to more vibrations in weld torch and improper cleaning and supply of gases. The present aluminium alloy 5052 contains porosity within the acceptable limits. No cracks were observed (Table No 8)

4. Conclusions

In this experimental work, selection of process parameters for non-pulsed current and pulsed current GTAW welding of Aluminium alloy of 5052 having two different thicknesses, radiography, liquid penetrant test were presented.

In this Aluminium alloy 5052 weldments, it is observed that porosity increased in the weldments with increase in thickness and pulsed frequency. No defect was observed on the weldments with non-pulsed current and pulsed current weldments (2HZ, 4HZ &6HZ) during the liquid Penetrant test. Effect of pulsed current on these weldments (non-pulsed current weldments, pulsed current weldments) can be studied further, by conducting hardness test, tensile strength test and microstructure tests.

References

[1] Troyer,W.,Tomsic,M.,and Barhotst, R , “Welding characteristics of Aluminium alloy ” welding journal,56(1),1977,26-32.

[2] Becker,D,W. and Adams, C.M, ”The role of pulsed GTA welding variables in solidification and grain refinement” welding journal,58(5)1979,134s-152s

[3] Becker, D, W. and Adams, C.M, “"Investigation of Pulsed GTA Welding parameters" welding journal, 57(5)1978, 134s-138s.

[4] Omar, A.A, and Lundin, C.D,”welding journal”, 58(4), 1970, 97s-104s.

[5] Tseng, C.F. and Savage, w, f, “The effect of oscillation” welding journal, 50(11)1971, 777-786.

[6] Sharir, Y., Peiieg, J. and grill, “Metallurgical Technology”, 5, 1978, 190-196.

[7] Tsai, C.L., and Hou, C, A, "Theoretical Analysis of Weld Pool Behavior in the Pulsed Current GTAW Process", Heat Transfer, 110, 1988, 160-165.

[8] Kate, S and Tanabe, S, "High speed welding of 0.5mm thickness alloy sheets using pulsed TIG welding", welding International 7, 1988, 602-608.

[9] Tsen, K.H. and Chou, C.P, “Effect of pulsed gas tungsten arc welding on angular distortion in austenitic stainless steel weldments”, science and Technology of welding and joining 6, (3), 2001, 149-153.

[10] Reddy,G.M.,Gokhale,A,A. and Prasad Rao K, "Effect of filler metal composition on weldability of Al-Li alloy 1441",Material Science&Technology,14,1998,61-66.

[11] Giridharam, P.M. and Muragan, N, “Sensitivity Analysis of pulsed current GTA welding process parameters on weldbead geometry”, National conference in advances in joining Technology 2004.

[12] Ramulu, M and Rubbert, M.P, “Gas Tungsten Arc welding of al-li-cu alloy 2090”, Welding Research Supplement, 109s-114s.

[13] Panwar, R.S., “Welding Engineering and Technology” p623

[14] ASTM , section VIII, Division VIII, Division II standards

Authors Biography

Mr. Raveendra Akunuru is born in India, Andhra Pradesh. He received B.Tech (Mechanical) degree from R.E.C (Now National Institute of Technology), Warangal, Andhra Pradesh, India and M.Tech (Production Engineering) degree from Visveswaraya Technological University Belgaum, Karnataka, India. He is pursuing his doctoral study in Joining Processes at JNTU, Hyderabad, India. He is working as Associate Professor in Malla Reddy Engineering College, Secunderabad. He has 5 years of Industrial experience along with 10 years of Teaching experience. His research interests include Pulsed Current TIG Welding. He is a life member of Indian Welding Society (IWS).

Dr. B. V. R. Ravi Kumar received M.Tech (Design & Production Engineering) from R.E.C (Now National Institute of Technology), Warangal, Andhra Pradesh, India and PhD (Joining Process) from JNTU Hyderabad, Andhra Pradesh, India. He is working as a Professor in the Department of Mechanical Engineering, V.N.R.V.J.I.E.T, Hyderabad, India. And he has published more than 25 research papers in various National/International Journals and Conference proceedings. He is a life member of various professional bodies like The Institution of Engineers (India), Indian Welding Society (IWS) and Society for Aerospace Quality and Reliability (SAQR) and ISTE