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Effect of Pulsed Current on TIG Weldments of Aluminium Alloy (5052) and Alloy Steel (EN24)

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ABSTRACT*:* In this experimental work destructive and non-destructive tests have been carried out on an aluminium alloy(5052) and alloy steel of EN24 using GTAW with pulsed and non-pulsed current at different frequencies 3Hz 5Hz,&7Hz.The Liquid Penetrant, radiography and tensile strength of weldments were evaluated and compared with pulsed and non-pulsed current welding at different frequencies of two materials (5052 aluminium alloy of 2.5mm thick and alloy steel EN24 of 4.5 mm thick).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 pulsed current welding for the above materials using pulsed and non-pulsed current GTAW are discussed and compared

KEYWORDS*:* Gas Tungsten Arc Welding, Constant Current Welding, Pulsed current welding and Heat Affected Zone.

I. INTRODUCTION

The demand is increasing for aluminium alloy and alloy steel weld structures and products where high quality is required such as aerospace applications. Aluminium alloy and alloy steels can be welded easily by conventional arc welding methods like Metal Inert Gas (MIG) and Tungsten Inert Gas(TIG).Among the two methods ,the gas tungsten arc welding(GTAW)process has proved for many years to be suitable for welding aluminium alloy and alloy steels and stainless steels. The AC and DCSP GTAW process is used in this experimental work for 5052 aluminium alloy and EN24 alloy steel respectively.

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].

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 , angular distortion , to study the microstructure[10] and weld bead geometry[11] . The main characteristics of PCW are determined by peak current Ip base current Ib , peak time tp and base time tb.

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II. EXPERIMENTAL PROCEDURE

The work pieces were made of 5052 aluminium alloy and EN24 of various thickness i.e. 2.5mm and 4.5mm. The test specimens were machined to the size of 150 mm X 150 mm welded with pulsed and non-pulsed current GTAW process.

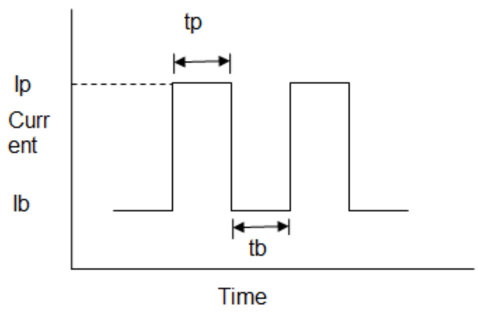

Fig.1 Parameters used for pulsed GTAW: peak current Ip, base current Ib , peak time tp and base time tb.

Aluminium alloy 5356 and ER90SB2 filler wire were used during the welding , which reduced the weld cracks and produced the good strength and ductility than other filler metals . 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 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. The steel work pieces were roughly polished with 400 grit abrasive paper and pneumatic rotary brush to remove surface impurities and then clean with Acetone.

A Mastertig AC/DC 3500W GTAW machine with AC & DCSP was used for welding of 5052 aluminium alloy and EN24 .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 . This welding process was conducted with 2.5 mm diameter 2% Zirconated tungsten electrode for 5052 aluminium alloy and 2.5 mm diameter 2% Thoriated tungsten electrode for EN24.

After welding process is over, the radiography , liquid penetrant test and mechanical tests are carried out on the weldments ,according to the ASTM standards , Section VIII, Division 2 for radiography and ASTM E-1417 for liquid penetrant tests were done on the weldments. Pulsed welds showed fine grain structure due to thermal disturbances and decrease in heat input. In general, hardness is lower in HAZ region compared to the weld metal and base metal regions, irrespective of welding technique which is characterized by the coarse dendrite grains and lack of the strengthener phase. Hardness was higher compared to the continuous welds and this could be due to refinement of grain structure [14].

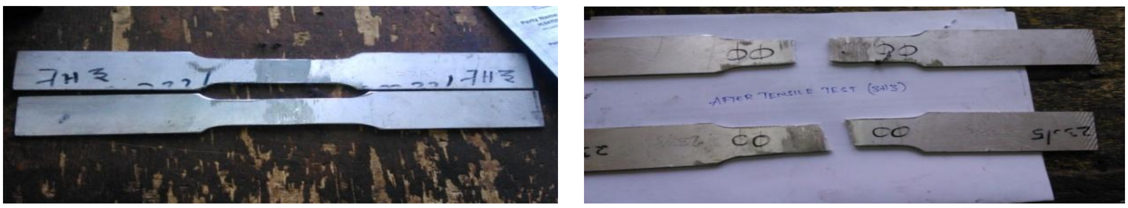

Fig 2 Tensile strength test specimens before and after test

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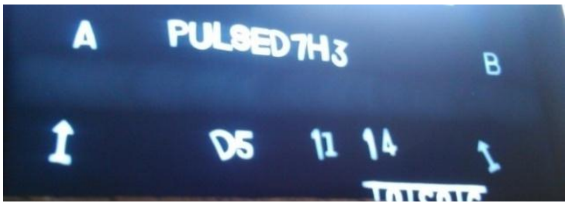

Fig 3. Radiography image of weldment

Table 1. Weld Parameters for pulsed current welding of Aluminium alloy 5052

Material Thickness(mm)	Filler wire diameter (Root) in mm	Filler wire dia(mm) first layer	Pulse/sec (Hz)	Polarity	Voltage(V)	Arc travel speed(cm/min)
2.5	Root 1.6	2.5	3	AC	12.5-13.1	1.05
2.5	Root 1.6	2.5	5	AC	13.0-13.3	1.03
2.5	Root 1.6	2.5	7	AC	12.7-12.5	1.14

Table 2.Weld parameters for non-pulsed current welding of Aluminium alloy (5052)

Material Thickness(mm)	Weld layer(Root)	Filler wire dia(mm)	Current(Amp)	Polarity	Volts	Arc Traval Speed(cm/min)
2.5	1.6	2.5	95	AC	13.5-14.5	1.2
2.5	1.6	2.5	95	AC	12.8	1.5

Table 3.Weld Parameters for pulsed current welding of Alloy steel EN24

Material Thickness(mm)	Weld layer	Filler wire dia(mm)	Pulses/sec (Hz)	Polarity	Current (amp)	Voltage(v)	Arc travel speed(m/min)
4.5	Root	1.6	3	DCSP	150-157	12.2-11.6	1.12
	Ist Layer	2.5	3	DCSP	170-168	13.1-12.6	1.27
4.5	Root	1.6	5	DCSP	150-139	12.3-11.9	1.03
	Ist Layer	2.5	5	DCSP	170-140	13.1-12.6	1.12
4.5	Root	1.6	7	DCSP	150-143	11.1-11.6	1.26
	Ist Layer	2.5	7	DCSP	170-164	13.1-12.7	1.08

Table 4.Weld Parameters for non-pulsed current welding of Alloy steel EN24

Material Thickness(mm)	Filler wire diameter (Root) in mm	Filler wire diameter(first layer) in mm	Current(Amp)	Polarity	Voltage(Volts)	Arc travel speed(cm/min)
4.5	1.6	2.5	150	DCSP	11.8-11.1	2.06
4.5	1.6	2.5	170	DCSP	12.5-10.2	1.47
4.5	1.6	2.5	180	DCSP	13.2-10.8	2.44

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Table 5. Liquid Penetrant Test parameters of 5052 Aluminium alloy and Alloy steel EN24

	Aluminium Alloy 5052	Alloy steelEN24
DP DIT	MAGNA FLUX	MAGNA FLUX
Penetrant Used	SKL-SP	SKL-SP
Cleaner Used	SKC-1	SKC-1
Developer Used	SKD-S2	SKD-S2
Dwell Time (at room temp)	10 min	10 min
Viewing Media	Normal Light	Normal light
Sensitivity	30 microns	30 microns

Table 6. Radiography test parameters of 5052 Aluminum alloy and alloy steel EN24

		Aluminium Alloy 5052	Alloy steel EN24
Exposure Parameters	Voltage KV	65/95	65/100
	Current (mA)	3.0	3.0
	Time (min)	2.0	0.8
	Film Used	MX-125	T-200
	SFD (min)	1.0	0.7
		10-16-DINAI	AI-10-16
Processing Parameters	Developer Time (min)	5.0	5.0
	Stop Bath Time (min)	1.0	1.0
	Fixer Time (min)	10	10
	Sensitivity	2%	2%

III. RESULTS

Table 7. liquid Penetrant test results of 5052 Aluminium alloy and Alloy steel EN24

S.No.	Material Thickness,mm	Pulse/non-pulse welding	Frequency(Hz)	Observations
1	2.5	Non-pulse	-	No defect was observed on welded area
2	2.5	pulse	3	No defect was observed on welded area
3	2.5	pulse	5	No defect was observed on welded area
4	2.5	pulse	7	No defect was observed on welded area
5	4.5	Non-pulse	-	No defect was observed on welded area
6	4.5	pulse	3	No defect was observed on welded area
7	4.5	pulse	5	No defect was observed on welded area
8	4.5	pulse	7	No defect was observed on welded area

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Table 8. The Radiography test results of aluminium Alloy 5052 and Alloy steel EN24

S.No.	Material	Thickness, mm	Pulse/non-pulse welding	Frequency(Hz)	Observations
1	Al 5052	2.5	Non-pulse	-	One pore size 0.3mm,random pores 0.1-0.4mm
2	Al 5052	2.5	pulse	3	Two pores of size 0.5mm
3	Al 5052	2.5	pulse	5	Cluster porosity:13mm
4	Al 5052	2.5	pulse	7	Cluster porosity:10mm.
1	EN24	4.5	Non-pulse	-	One pore size 0.4mm
2	EN24	4.5	pulse	3	Found two pores sizes0.3mm
3	EN24	4.5	pulse	5	Found three pores sizes 0.1mm,0.2mm&0.4mm
4	EN24	4.5	pulse	7	Found three pores sizes 0.2mm.0.3mm&0.4mm.

Table 9. Tensile strength test results of pulsed current TIG welding of 5052 Aluminium alloy

S.No.	Material	Frequency	Thickness (mm)	Ultimate tensile strength, Mpa
1	Al 5052	Base metal	2.5	295.68
2	Al 5052	Base metal	2.5	286.54
3	Al 5052	Base metal	2.5	302.64
1	Al 5052	3Hz	2.5	318.54
2	Al 5052	3Hz	2.5	303.84
3	Al 5052	3Hz	2.5	271.12
1	Al 5052	5Hz	2.5	248.56
2	Al 5052	5Hz	2.5	220.45
3	Al 5052	5Hz	2.5	242.56
1	Al 5052	7Hz	2.5	265.35
2	Al 5052	7Hz	2.5	256.50
3	Al 5052	7Hz	2.5	352.32

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Table 10. Tensile strength test results of non- pulsed current TIG welding of 5052Aluminium alloy

S.No.	Material	Thickness (mm)	Ultimate tensile strength, Mpa
1	Al Alloy 5052	2.5	289.68
2	Al Alloy 5052	2.5	284.52
3	Al Alloy 5052	2.5	301.25

Table 11. Tensile strength test results of pulsed current TIG welding of EN24

S.No.	Material	Frequency	Thickness (mm)	Ultimate tensile strength, Mpa
1	EN24	Base metal	4.5	942.56
2	EN24	Base metal	4.5	940.84
3	EN24	Base metal	4.5	952.24
1	EN24	3Hz	4.5	968.34
2	EN24	3Hz	4.5	956.86
3	EN24	3Hz	4.5	961.72
1	EN24	5Hz	4.5	951.62
2	EN24	5Hz	4.5	953.45
3	EN24	5Hz	4.5	960.54
1	EN24	7Hz	4.5	946.72
2	EN24	7Hz	4.5	948.86
3	EN24	7Hz	4.5	950.68

Table 12. Tensile strength test results OF non- pulsed current TIG welding of EN24

S.No.	Material	Thickness (mm)	Ultimate tensile strength, Mpa
1	EN24	4.5	948.56
2	EN24	4.5	942.87
3	EN24	4.5	946.42

IV **CONCLUSIONS**

In this experimental work Aluminium alloy 5052(2.5mm thick) and Alloy steel EN24(4.5mm thick) plates are welded with pulsed current(3Hz,5Hz&7Hz) and non-pulsed current TIG welding .Non-destructive and destructive tests were conducted upon these weldments to know the effect of pulsed current on the welding characteristics of these two metal alloys. No defect was observed during liquid penetrant test of these two metals , porous found in all the weldments but all porous sizes are within the acceptable limits. Tensile strength values at 3Hz frequency of these two metals are high compared to other frequencies and non-pulsed current TIG welding. During welding welding torch starts vibrating at higher frequencies, may be this could be the reason of lesser tensile strength values in the both metals at higher frequency welding.,ie at 5Hz &7Hz.

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