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EFFECT OF PULSED CURRENT ON WELDING CHARACTERISTICS OF EN19 ALLOY STEEL USING GAS TUNGSTEN ARC WELDING

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Abstract : This paper covers the study of destructive and non-destructive properties of weldments EN19 alloy steel using GTAW with non-pulsed current and pulsed current at different frequencies of 2Hz,4HZ & 6Hz.The radiography, liquid Penetrant test of weldments were evaluated and compared with pulsed and non-pulsed current welding at different frequencies of two different thicknesses of EN19 material (2mm and 3mm).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: EN19 alloy steel, Gas Tungsten Arc Welding, Constant Current Welding, Pulsed current welding and Heat Affected Zone, Porosity and surface cracks

I. INTRODUCTION

The demand is increasing for alloy steel weld structures and products where high quality is required such as marine applications. Aluminium alloy, stainless steel 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, since GTAW gives best quality welds. Direct Current Straight Polarity GTAW process is preferred for welding alloy steels. 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 was there 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 5083 type [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 is shown in figure 1. The main characteristics of Pulsed Current Welding are determined by peak current I_p base current I_b , peak time tp and base time t_b.

II. EXPERIMENTAL PROCEDURE

The work pieces were made EN19 of various thickness i.e. 2mm and 3mm. The test specimens were machined in the size of 150 mm X 300 mm welded with pulsed and non-pulsed current GTAW process.

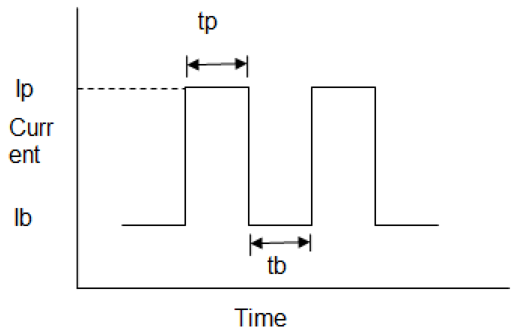

Fig.1 Parameters used for pulsed GTAW: peak current Ip, base current Ib , peak time tp and base time tb.

ER80S-B2 filler wire 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 alloy 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 **Lincoln Electrical square wave TIG 355** GTAW machine with AC & DC was used for welding of EN19specimens .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 2.5 mm diameter 2% Thoriated tungsten electrode for EN19 sheets.

The welding parameters used for this elding 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 and EN19 specimens are shown in figure 2.

After welding process is over, the radiography and liquid penetrant tests were conducted on the weldments(figure3),according to the ASTM standards , Section VIII, Division 2 for radiography and ASTM E-1417 for liquid penetrant test. The parameters used in the non-destructive testing are given in the Table 4.

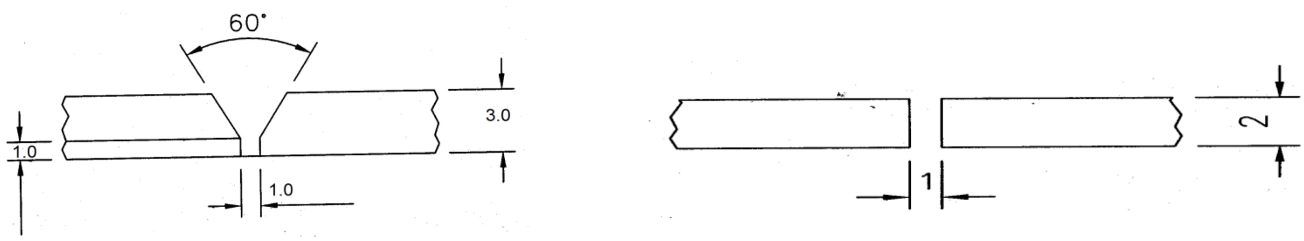

Fig.2 Edge preparation

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Vol. 2, Issue 5, May 2013

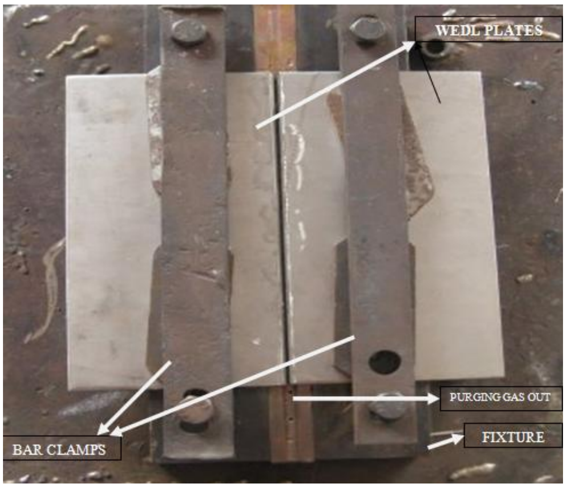

Fig.3 Fixture

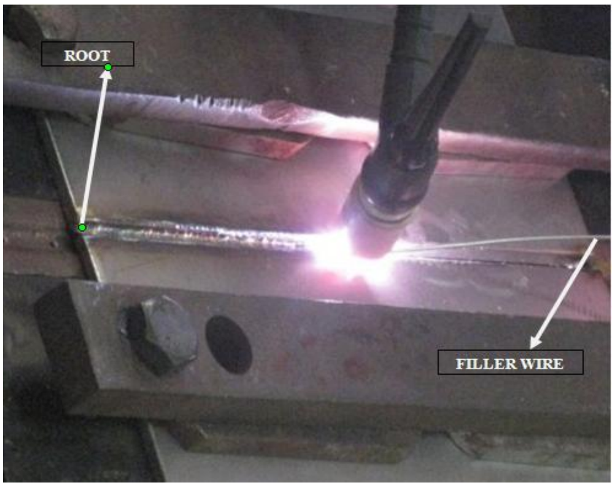

Fig.4 Root of the Welding

Fig.6 Lincoln Electrical square wave TIG 355

Fig.5 AC/DC Pulse Panel

Table 1. Chemical Compositions of work material EN19 alloy

	Chemical Composition % wt								
Material	**C**	**Mn**	**Si**	**S**	**P**	**Ni**	**Ti**	**Cr**	**Mo**
EN19 Alloy	0.38	0.85	0.22	0.016	0.018	0.10	0.1	1.08	0.27

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International Journal of Innovative Research in Science, Engineering and Technology
Vol. 2, Issue 5, May 2013

Table 2. Chemical Compositions of filler wire

	Chemical Composition % wt							
Material	**C**	**Si**	**Mn**	**Mo**	**Cr**			
ER80S-B2	0.08	0.5	0.5	0.5	1.3			

Table 3. Mechanical properties EN19 at heat treated condition

Material	UTS(MPa)	0.2% Y.S(MPa)	% Elongation
EN19 Alloy	>515	>480	>22

Table 4. Welding parameters for non-pulsed current welding of EN 19alloy

Material Thickness(mm)	Weld Layer	Filler Wire dia(mm)	Current	I (amp)	V (volts)	ARC Travel Speed(cm/min)
2	Root	1.6	DCSP	75	12	3.2
3	Root	1.6	DCSP	100	12	3.2
	Ist pass	2.4	DCSP	100	12	3.5

Table 5. Welding parameters for pulsed current welding of EN19 Alloy steel

Material Thickness(mm)	Weld Layer	Filler Wire dia(mm)	Pulse/Sec (Hz)	Polarity	Ip (amp)	Ib (amp)	V (volts)	ARC Travel Speed(cm /min)
2	Root	1.6	2	DCSP	81	38	13	5.0
2	Root	1.6	4	DCSP	100	47	13	3.0
2	Root	1.6	6	DCSP	110	53	13	4.2
3	Root	1.6	2	DCSP	81	38	13	5.0
	Ist pass	2.4	2	DCSP	124	58	13	4.1
3	Root	1.6	4	DCSP	100	47	13	3.0
	Ist pass	2.4	4	DCSP	119	57	13	4.3
3	Root	1.6	6	DCSP	110	53	13	4.2
	Ist pass	2.4	6	DCSP	120	58	13	5.5

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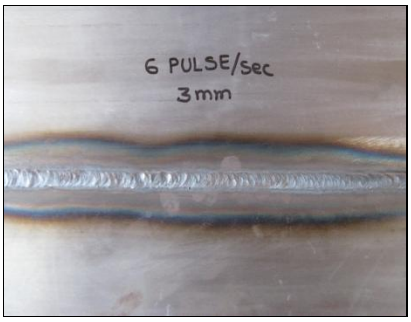
International Journal of Innovative Research in Science, Engineering and Technology
Vol. 2, Issue 5, May 2013

Table 6. Radiography test parameters of EN 19 Alloy steel

		EN19 Alloy steel
Exposure Parameters	Voltage KV	65/100
	Current (mA)	3.0
	Time (min)	0.8
	Film Used	T-200
	SFD (min)	0.7
	Penetrameter	AI-10-16
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 EN19 Alloy steel

	EN19 Alloy steel
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



ISSN: 2319-8753

International Journal of Innovative Research in Science, Engineering and Technology

Vol. 2, Issue 5, May 2013

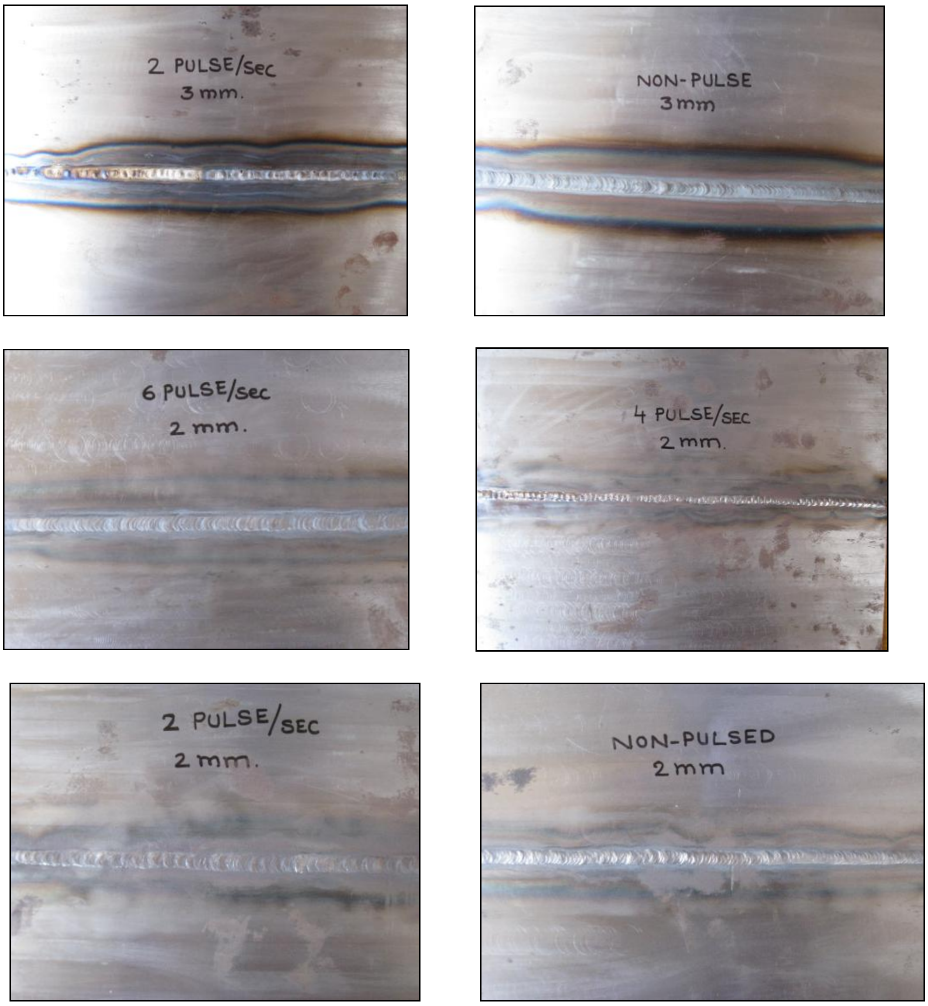


Fig.7 Welded joints of EN19 Alloy steel

ISSN: 2319-8753

International Journal of Innovative Research in Science, Engineering and Technology

Vol. 2, Issue 5, May 2013

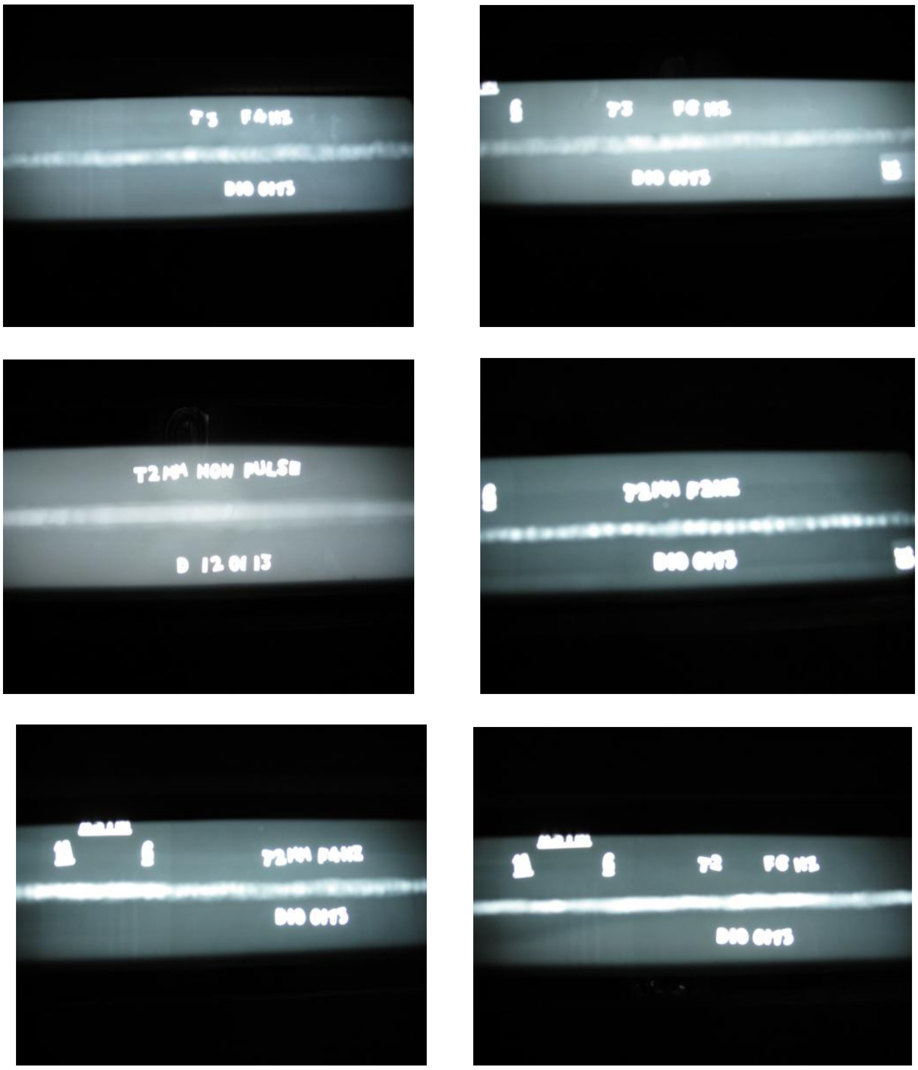


Fig.8 Radiographic images of EN19 Alloy steel weldments

III. RESULTS AND DISCUSSIONS

Table 8. The radiography test results of EN19 Alloy steel

S.No	Material thickness	Pulse/non-pulse welding	Frequency(Hz)	Observations
1	2.0	Non-pulse	-	No significance defect
2	2.0	Pulse	2	No significance defect
3	2.0	Pulse	4	One pores size 0.1mm
4	2.0	pulse	6	One pores size 0.4mm
5	3.0	Non-pulse	--	One pores size 0.4mm
6	3.0	pulse	2	No significance defect
7	3.0	Pulse	4	Three pores size 0.1mm,0.1mm and0.4mm
8	3.0	pulse	6	Three pores size 0.2mm,0.2mm and0.3mm

Table 9. The liquid penetrant test results of EN 19 alloy steel

S. No.	Material thickness	Pulse/non-pulse welding	Frequency(Hz)	observations
1	2.0	Non-pulse	-	No defect observed on welded area
2	2.0	Pulse	2	No defect observed on welded area
3	2.0	Pulse	4	No defect observed on welded area
4	2.0	pulse	6	No defect observed on welded area
5	3.0	Non-pulse	--	No defect observed on welded area
6	3.0	pulse	2	No defect observed on welded area
7	3.0	Pulse	4	No defect observed on welded area
8	3.0	pulse	6	No defect observed on welded area

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.

A. EFFECT OF THICKNESS

The effect of thickness and welding parameters are given in the table 8&9 . During the radiography test no porosity was observed in 2.0 mm thick weldments welded at welding speed of 3.2cm/min in 2HZ,4HZ frequency. One porous of size 0.1mm and one porous of size 0.4mm were observed in the weldments welded with 4HZ and 6HZ frequencies respectively. In the 3mm weldments (non-pulsed) found one porous of size 0.4 mm .In 3mm thick weldments no porous was observed in the weldments welded with 2HZ. Three porous of size 0.1mm,0.1mm,0.4mm observed in the weldments of 4HZ, three porous of size 0.2mm,0.2mm and 0.3mm observed in the weldments of 6HZ.
The results shows that more porous found in higher thickness weldments with pulsed welding than the non pulsed current weldments, because the molten metal remains in solidification phase for the longer duration in non-pulsed then the gases are escaped and minimized the porous in the weldments, even though the porous sizes are within the acceptable limits, the observed porous can be minimized by proper supply of purging and shielding gases.

B. EFFECT OF FREQUENCY

Effect of pulsed frequency on the porosity during radiography are presented in the table 8, the porosity is measured in this present study in three frequencies i.e. 2HZ, 4HZ, 6 HZ. No porosity observed in weldments made at non frequency and 2HZ, whereas one pore size of 0.1 mm found in 4HZ weldment of 2mm thickness and one pore size of 0.4 mm found in weldments made at 6HZ, in 2mm thick weldments.
One pore of size 0.4mm found in 3mm thick weldments done at non-pulsed current. No significant defect found at 2HZ weldments.Three pores of size 0.1mm,0.1mm and and 0.4mm found in the weldments of 4HZ. Three pores of size 0.2mm, 0.2mm and 0.3mm found in the weldments made with 6HZ.
These results shows that porous size increased with the increase of frequency. This may be due to more vibration in weld torch and improper cleaning and supply of gases. The alloy steel EN19 contains porosity within the acceptable limits. No cracks were observed in liquid Penetrant test.

IV .CONCLUSION

In this experimental work, selection of process parameters for non-pulsed & pulsed current GTAW welding of material EN19 having two different thickness, radiography, liquid Penetrant test were presented .In this alloy steel weldments(welded with pulsed current and non-pulsed curren)it is observed that porosity increased with increase in thickness and pulse frequency. No defect was observed in the weldments welded with non-pulsed and pulsed current weldments 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.

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International Journal of Innovative Research in Science, Engineering and Technology
Vol. 2, Issue 5, May 2013

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BIOGRAPHY

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