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Micro-Hardness and Mechanical Properties of EN24 Alloy Steel Weldments Using Pulsed and Non-Pulsed Current Gas Tungsten Arc Welding

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ABSTRACT: In this experimental study, the weld micro hardness and mechanical properties of weldments have been carried out on EN24 alloy steel using GTAW with pulsed and non-pulsed current at different frequencies 2Hz, 4Hz and 6 Hz. Hardness is the ability of a metal to resist penetration . In order to improve the mechanical integrity of the weldments it would be desirable to study the micro hardness of weldments. The present study was performed in order to show difference of micro-hardness and mechanical properties of the weldments made with pulsed and non-pulsed current at different frequencies of GTAW. The hardness measurement can provide information about the metallurgical changes caused by the welding.

KEYWORDS: EN24Alloy steel, Gas Tungsten Arc Welding, Micro Hardness, Ultimate Tensile Strength (UTS),Yield Strength(YS) and % Elongation.

I. INTRODUCTION

The demand is increasing for alloy steel welded products where high quality is required such as marine applications. Alloy steel 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 and alloy steel since it gives best quality welds. GTAW process (DC) is used to weld EN24 alloy steel.

Another development has been pulsed current TIG Welding. Pulsed current welding(PCW) was introduced in the late 1960s as a variant of constant current welding(CCW),PCW process has many specific advances over CCW, including enhanced arc stability, increased weld depth/width ratio, narrower heat affected zone (HAZ)range, reduced hot cracking sensitivity, refined grain size, produced porosity, low heat input, low distortion, controlled weld bead volume, less absorption of gas by weld pool and better control of the fusion zone[1-8]. Pulsed current welding technology has been welding used in fabrication of high pressure gas storage tanks, rocket motors, structures in aerospace applications such as air crafts, rockets and missiles. Switching between predetermined high and low levels of welding current can be used to produce pulsed current gas tungsten arc welds[9].

Current pulsing has been used by a few investigators [10,11] to obtain grain refinement in weld fusion zones and improvement in weld mechanical properties. Significant refinement of the solidification structure has been reported in aluminium alloys and titanium alloys. Most of the reported literature is focused on pulsed current welding of medium strength aluminium alloys and the published information on pulsed current welding of high strength aluminium alloys could be counted with figures. Hence, the present investigation has carried out to understand the effect of the pulsed current welding technique on tensile properties of high strength EN24 alloy.

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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[12].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.

II. EXPERIMENTAL PROCEDURE

The work pieces were made of EN24 alloy steel of various thickness i.e. 2.0mm and 3.0mm. The test specimens were machined to the size of 150 mm X 300 mm and welded with pulsed and non-pulsed current GTAW process.

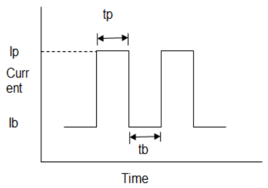

Fig.1 Parameters used for pulsed GTAW: peak current Ip, base current I_b , peak time t_p and base time t_b.

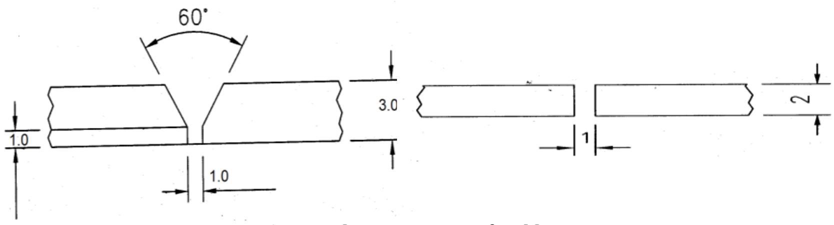

Fig.2 Edge preparation of weld specimens

Filler wire material of ER80SB2 was used during the welding , which reduced the weld cracks and produced the good strength and ductility than other filler metals [13]. 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 EN24 alloy steel 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 DC was used for welding of EN 24 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 DC wherein they keep hemispherical shape and thoriated tungsten electrodes (EWTh-2) should be ground to taper are suitable for DCEP welding are used for this purpose [14]. This welding process was conducted with 3.0 mm diameter 2% Zirconated tungsten electrode for EN24 alloy steel. 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 EN24alloy steel specimens are shown in figure 2. After welding process is over, Tensile and Micro-Hardness tests were conducted on the weldments (fig3,4,5,6,7&8),according to the ASTM standards.

Fig.3 Lincoln Electrical square wave TIG 355 Machine

Fig.4. Tensile test specimens after test

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Table 1. Chemical Compositions of work material

	Chemical Composition % wt								
Material	**C**	**Mn**	**Si**	**S**	**P**	**Ni**	**Ti**	**Cr**	**Mo**
EN24 Alloy	0.38	0.85	0.22	0.016	0.018	1.30	0.1	1.08	0.27

Table 2. Chemical Compositions of filler wire

	Chemical Composition % wt								
Material	**C**	**Si**	**Mn**	**Mo**	**Cr**	**P**	**S**	**Ni**	**Cu**
ER80S-B2	0.12	0.5	0.5	0.5	1.3	0.025	0.025	0.2	0.3

Table 3: Mechanical properties of 2.0 mm thick weldments

S.NO	Sample Description		Trial no	UTS(Mpa)	0.2%S(Mpa)	% of Elongation
1	Base Material		1	967.66	850.00	11.50
			2	957.08	848.68	11.00
			3	924.79	841.34	8.82
2	Non-Pulsed Current GTAW		1	964.84	831.34	6.00
			2	880.35	820.93	4.00
			3	954.34	819.19	4.00
3	Pulsed current GTAW	Pulse=2Hz	1	968.00	839.00	5.50
			2	948.80	837.30	4.50
			3	955.80	838.50	4.50
		Pulse=4Hz	1	957.79	840.90	4.30
			2	872.99	818.20	4.00
			3	951.60	820.40	4.20
		Pulse=6Hz	1	952.54	833.59	4.40
			2	948.96	810.61	4.20
			3	950.07	814.70	4.20

Table 5: Mechanical properties of 3.0 mm thick weldments

S.NO	Sample Description		Trial no	UTS(Mpa)	0.2%Y S(Mpa)	% of Elongation
1	Base Material		1	936.56	820.32	9.0
			2	942.45	821.12	8.9
			3	940.32	822.12	9.2
2	Non-Pulsed Current GTAW		1	933.19	852.37	5.0
			2	944.89	853.92	5.0
			3	945.20	854.33	5.0
3	Pulsed current GTAW	Pulse=2Hz	1	979.95	866.79	6.2
			2	933.67	856.37	6.2
			3	945.72	849.52	6.16
		Pulse=4Hz	1	938.74	817.64	7.2
			2	942.91	815,57	8.1
			3	945.94	819.80	8.2
		Pulse=6Hz	1	941.95	827.88	6.0
			2	942.22	831.86	6.0
			3	940.72	828.0	6.0

III. RESULTS AND DISCUSSIONS

3.1 *MECHANICAL PROPERTIES*

The tensile test specimens were tested using the universal testing machine of 10 ton capacity. The tables 4 and 5 show the tensile test results of the each trial specimen of two different thicknesses(2.0mm &3.0mm). The tensile specimens typically failed through the weld metal and HAZ in low thickness weldments (2.0 mm) and failed through the parent metal in high thickness weldments (3.0mm).

The low thickness (2.0mm) weldments produced maximum ultimate tensile strength and 0.2% yield strength ie., 968.00 Mpa and 831.34Mpa with low frequency(2Hz) than the high frequency(ie., 4Hz and 6Hz) and non-pulsed current welding, but these weldments produced high % elongation with increase of frequencies. The experimental

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results show that the low thickness weldments produced more ductility with pulsed current welding than the non-pulsed current welding. The performance curves of the weldments are shown in fig.5.

The high thickness (ie., 3.0 mm) weldments produced maximum UTS,0.2 % YS and % elongation at 2Hz are 979.95 Mpa, 866.79 Mpa and 6.2 than the high frequency pulsing and non-pulsed current welding. The performance curves of the high thickness weldments are shown in fig.6.

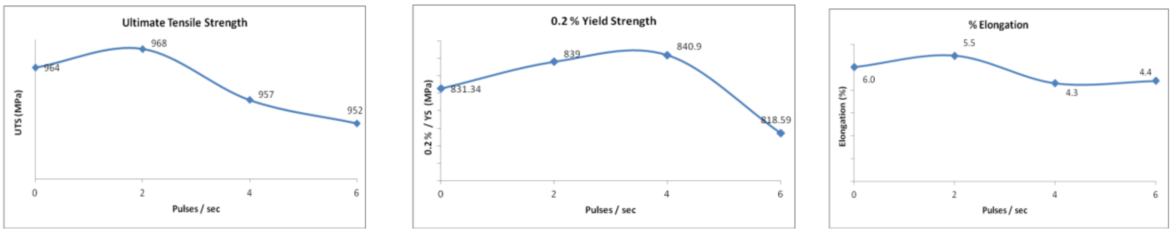

Fig.5 Mechanical Properties Performance Curves of 2.0 mm thick Weldments

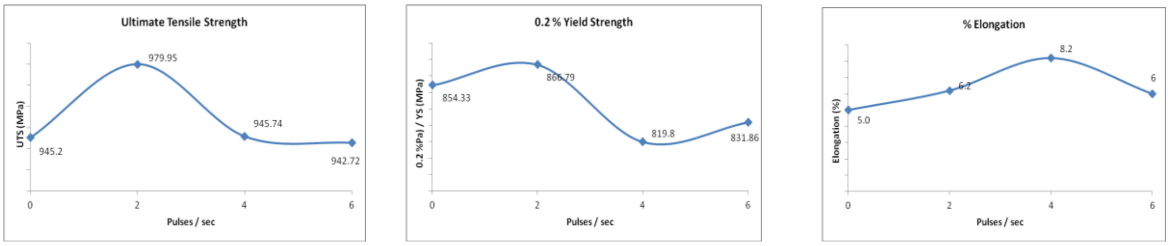

Fig.6 Mechanical Properties Performance Curves of 3.0 mm thick Weldments

3.2 *MICRO-HARDNESS*

The specimens were tested using Vickers micro hardness machine(HV1000ZDT). In non-pulsed current weldments ,the hardness traverse on the welded zone and HAZ shows little difference, its value gradually reduced and goes towards base metal. These 2mm thick weldments produced the maximum hardness value 650HV in weld zone than the HAZ. In pulsed current weldments, the maximum hardness produced was 720HV in the low frequency (2Hz)weldments than the other pulses. 3mm thick weldments produced the maximum hardness value 770HV in weld zone than the HAZ and in pulsed current weldments, the maximum hardness produced was 830HV in the low frequency (2Hz)weldments than the other pulses.

The use of pulsed current welding improves the strength of the weld over that observed for the case of continuous due to continuous welding. The refinement of microstructure due to the pulsed current welding results in a uniform distribution of the fine precipitates more effectively and enhances the amount of precipitates in the matrix. In general, hardness in the fusion zone is the lowest due to the 'as cast'nature of the microstructure, which is characterized by coarse dendritic grains, interdendritic segregate phases, and the lack of strengthening phases. Hardness is slightly higher in pulsed current weld as compared to continuous current welds and this could be due to the refined microstructure and low segregations of strengthening phases. The moderately higher hardness of pulsed current welds close to the fusion boundary is possibly due to a large fraction of alloying elements in solid solution at the end of the thermal cycle, thereby giving conditions for extensive age hardening.

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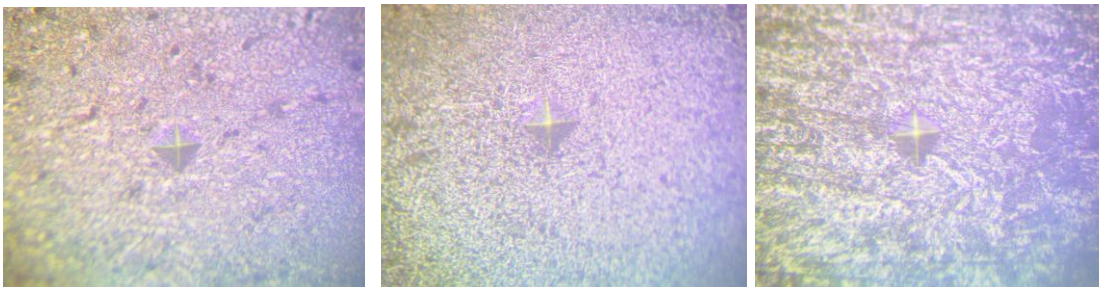

(a) (b) (c)

Fig.7 Micro indentations at (a) Weld Metal, (b) Base Metal and (c) Heat Affected Zone.

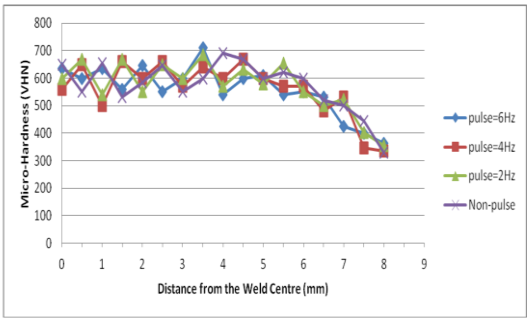

Fig.8. Micro-hardness profiles of 2.0mm Weldments

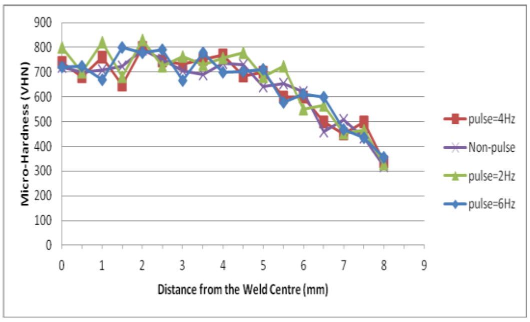

Fig.8. Micro-hardness profiles of 3.0mmWeldments

IV. CONCLUSION

From the results it is evident that the pulsed current has grater influence on mechanical and metallurgical properties. The weldments produced maximum UTS,0.2% YS and % elongation with pulse current welding than non-pulsed current weldments. The weldments have the better hardness in pulsed current welding than non-pulsed current welding.

The enhancement in mechanical properties such as tensile properties and weld metal hardness are mainly due to the refinement in fusion zone grain size. Hence the basic reason for the improvement in mechanical properties is the refinement produced in fusion zone grain size by pulsed current welding.

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] Mohandas T, Madhusudhan Reddy G(1996) Effect of frequency of pulsing in gas tungsten arc welding on the microstructure and mechanical properties of titanium alloy welds, J Mater Sci Lett 15:625-628.
[11] Shelwatker DA, Madhusudhan Reddy G, Gokhale AA(2002) Gas tungeten arc welding studies on similar and dissimilar combinations of Al-Zn-Mg alloy RDE 40 and Al-Li alloy 1441. Sci Technol weld Join 352-361.

ISSN: 2319-8753

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 10, October 2014

[12] Vahid Nazarpoor,Abdoreza,Soltanipoor,Khosrow Farmanesh"Effect of current on Mechanical,Metallurgical and Corrosion Properties of AA 5083 Aluminium Alloy Pulse TIG Welding Joints"Journal of Materials Science, vol.2,2010,54-67.
[13] Ramulu, M and Rubbert,M.P, "Gas Tungsten Arc welding of al-li-cu alloy 2090", Welding Reaserach Supplement, 109s-114s.
[14] Parmar, R.S., "Welding Engineering and Technology" p623.

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 India. He has 5 years of Industrial experience along with 12years of Teaching experience. His research interests include Pulsed Current TIG Welding. He is a life member of Indian Welding Society(IWS).

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