Study of Mechanical Properties of Aluminium Alloy (AA5083) Welds with CC & PC GMAW Parameters

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I. ABSTRACT

The objective of the present work is to investigate the effects of the various welding parameters on the welding quality of both CC (continuous current) GMAW and PC (pulsed current) GMAW and to obtain the best welding parameters to achieve the good mechanical properties and that the welding quality of welding can be enhanced.

In this, firstly investigation on CC GMAW and PC GMAW of AA5083 welds with ER & R-5183 filler wire is made use for both the welding techniques and alloys. Identification of PC GMAW process parameters such as pulsed current (PC), base current (BC) and compared with all welding parameters and concludes the best welding parameters.

***Keywords*— AA5083, PC-GMAW, CC-GMAW, Mechanical Properties.**

II. INTRODUCTION

AA5083 is an Aluminium-magnesium alloy is widely accepted for application in shipbuilding for accommodation cabins, pressure vessels, rail road cars and bodies of aircraft industries, because of its excellent properties like ductile, light and corrosion resistance.

Gas Metal Arc Welding (GMAW) process techniques are continuous current (CC) and pulsed current (PC). CC GMAW processes are very often used for welding of AA5083 in ship building industries. However, distortion, porosity and cracking are the major problems in CC GMAW of AA5083 welds. It offers high heat energy required to melt the base material and this excessive heat input imposes the problems such as melt through, distortion etc [1].

Therefore, to produce high quality weldments, PC GMAW is preferred over CC GTAW. Presently, PC GMAW process is one of the most well established processes which cannot only weld all metals of industrial use but also produces the best quality welds amongst the CC GMAW processes. In PC GMAW process, the current is supplied in pulses rather than at a constant magnitude. A typical variation of welding current with time is shown in figure. 1

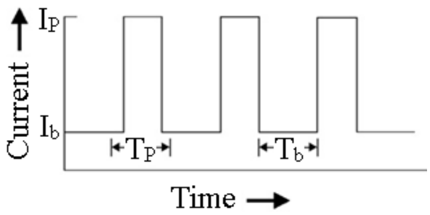

Fig. 1. Pulsed current wave form

Where I_p is peak current, I_b is base or background current, T_p is peak time, T_b: base or background time, frequency = $1/(T_p + T_b)$, Average Current (I_{avg}) = $(I_pT_p+I_bT_b) / (T_p+T_b)$

The aim of pulsing is mainly to achieve maximum penetration without excessive heat build-up, by using the high current pulses to penetrate deeply and then allowing the weld pool to dissipate some of the heat during relatively longer arc period at a low current.

The purpose of the present investigation is to optimize the pulsed current GMA welding (PC GMAW) process parameters for increasing the mechanical properties. This investigation permits evaluation of the effects welding parameters on the identified quality characteristics, i.e. ultimate tensile strength, yield strength, hardness, etc [2], [6].

Mechanical properties of the alloy welds are largely governed by its microstructural characteristics apart from the mechanical constraints. The microstructure includes types of phases, their relative amounts and distribution besides grain structure. The grain structure of the weld metal shows the size, shape and the distribution of phases in the alloy.

III. EXPERIMENTATION

The hot rolled plates of AA5083 with dimensions 150 mm X 150 mm X 4 mm thickness as shown in the figure. 2 were selected as test material.

Fig. 2. AA5083 plate

The reason is all the shipbuilding, aircraft industries uses of AA5083 plates of size that ranges from 3 to 6 mm thickness. Mostly 4 mm thickness is preferred. Hence 4 mm thickness plates of AA5083 were taken and welded using CC GMAW and PCGMAW for improvement in Mechanical properties (hardness & tensile strength). Table. I shows the chemical composition of AA5083 Alloy.

TABLE I
CHEMICAL COMPOSITION OF AA5083 ALLOY

Element	Si	Mg	Mn	Fe	Pb
Wt.%	0.11	4.17	0.85	0.47	0.41
Element	Cu	Ti	Cr	Zn	Al
Wt.%	0.81	0.08	0.15	0.06	93.17

A. *Evaluation of mechanical properties for base material hardness test of base material*

Hardness testing is one way of describing a material's strength. Hardness testing was done on the base metal and across the welds by using a LECO's LV700 Vickers hardness testing machine with a 2N load applied. Average of three readings were taken as the hardness of the base metal/welds.

B. *Tensile Test of Base Metal*

Specimens of standard ASTM-E8 were taken from BM and weld coupons were cut using Water Jet cutting machine. Tensile tests were conducted on these cut specimens. The dimensions of the ASTM-E8 standard test specimen is shown in figure. 3 tensile tests were carried out in a computerized universal testing machine (UTM) of capacity 100 KN for finding weld strength. Tensile elongations were measured manually after arranging the fractured pieces together.

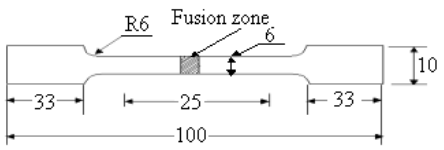

Fig. 3. Tensile specimen used as per ASTM- E8

C. *Experimental details of CC GMAW & PC GMAW OF 80/20, 70/30,60/40,50/50 OF AA5083*

In this analysis, the experimental work done is, finding out the Mechanical properties, Chemical composition and Microstructures of the weld joints done by both continuous current GMAW and pulsed current GMAW and compare with base material.GMAW welding is conducted for base material at continuous current and 4 different samples at pulsed current say 80/20, 70/30, 60/40, 50/50 using GMAW technique.

Firstly material cut by plasma cutting machine as required dimensions of 150 mm x 150 mm x 4 mm are prepared and weld was made by joining two pieces. The configuration of the joint groove was V- shaped. Root gap is 2mm, Root height is 2 and angle is 60°. During the CC GMAW the currents and frequencies for both peak current and base current set same, i.e. 111 amps and average voltage is taken as 18 volts, where as in PC GMAW the peak current set for all samples is 150 amps base currents are set as 120 amps, 105 amps, 90 amps, 75 amps respectively for 80/20, 70/30, 60/40 and 50/50. And the frequencies are set as 4 Hz and 1 Hz for peak current and base current for 80/20 PC GMAW, 3.5 Hz and 1.5 Hz for 70/30 PC GMAW, 3Hz and 2Hz for 60/40 PC GMAW and 2.5Hz and 2.5Hz for 50/50 PC GMAW. The average voltage is taken as 17 Volts. The process of welding in pulsed MIG Welding completed by one pass by using ER & R-5183 filler metal of 1.6 mm diameter [4].

All the five specimens are tested for hardness, tensile strength and microstructure. Microstructure is observed for each specimen along the grains and across the grains at the weld zone. Weld specimens are tested for tensile on UTM and hardness of each specimen is measured by Vickers hardness testing machine at an interval of 2 mm away from the centre of the weld zone. The results of various tests are obtained and it is discussed in results section.

D. *Evaluation of (hardness testing of welds)mechanical properties of weldments*

Hardness testing is one way of describing a material's strength. Hardness test was carried out using LECO's LV700 Vickers hardness testing machine. A load of 2 N was applied across the weld cross-section for 20 sec dwell time. Minimum three readings for each sample on weld centre were taken and average of three readings was taken as the required hardness value. Study of hardness along the transverse direction of the weld was conducted with hardness measurements at regular intervals of 2 mm from the centerline of the weld to either side.

E. *Evaluation of (tensile testing of welds) mechanical properties of weldments*

Tensile testing is conducted to determine the ultimate tensile strength and percentage elongation. The tensile sample is prepared as per ASTM standard and it is shown in figure. 4. The tensile test is conducted for all combination of the welding parameter ranges. The results of the tensile test are shown in the Table. From the table it is found that the test result obtained is close to the standard value.Tensile tests were performed according to ASTM standard E8-04, on un-welded, as-welded and dressed welded specimens. The machined specimens (Figure. 4) were wet-ground flush in the longitudinal direction (LD) to remove all machining marks for un-welded and weld reinforcing for dressed weld specimens. Undressed welded specimens were wet-ground without changing the weld the geometry

Fig. 4. Specimens for tensile test

F. *Microstructure Characterization*

Micro-structural characterization studies were conducted on metallographically polished and chemically etched samples to investigate morphological characteristics of grains and secondary phases. To examine the microstructures around the weldments, we pre-pared samples by cutting off a weldment in the transverse direction. Samples were first polished by using silicon carbide waterproof electro coated abrasive papers from CW400 to CW2000, and were then polished, followed by etching ,the etchant used is 10ml Methanol+10ml Hcl+10ml Nitric Acid+1ml Hf (Hydro Floric Acid). Specimens were examined both along the grains and across the grains .The structures of the specimens are shown at a magnification scale of 200 X.

IV. RESULTS AND DISCUSSION

A. *Microhardness of Base Metal and CC GMAW of AA5083 Welds*

The hardness was measured using Vickers hardness test and it is measured along the mid thickness line of cross section of the joint. In the weld condition, the micro hardness profile, shown in figure.5, shows that the as weld hardness showed to fluctuate in the weld zone and minimum hardness was found at partially melted zone (weld metal -heat affected zone (HAZ) interface) of the weldment. The minimum hardness is due to precipitate coarsening or dislocation of precipitates.

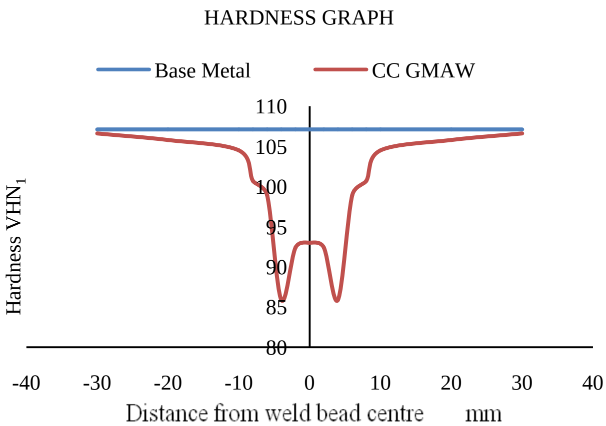

Fig. 5. Effect of CC GMAW on microhardness of AA5083 weld

B. *Mechanical Properties of base metal, PC GMAW of AA5083*

The traverse tensile properties such as hardness, yeild strength, tensile strength and percentage of elongation of un-welded base metal (BM), & PC GMAW of AA5083 welds were evaluated. In each condition, three specimens were tested and average of three results is presented in table. II

TABLE III
MECHANICAL PROPERTIES OF BM & PC GMAW OF AA5083 WELDS

Sample	Y.S (N/mm2)	T.S (N/mm2)	Hardness VHN1	Elongation %
Base material	307.5	392.8	113.0	14.0
PC GMAW (80/20)	210.0	218.0	92.8	5.0
PC GMAW (70/30)	275.0	283.0	99.0	8.8
PC GMAW (60/40)	173.0	198.0	96.5	7.2
PC GMAW (50/50)	175.0	189.0	91.5	4.0
CC GMAW	195.0	210.0	90.4	7.0

C. *Micro Hardness of base metal and PC GMAW of AA5083 welds*

The hardness was measured using Vickers hardness test and it is measured along the mid thickness line of cross section of the joint. In the as weld condition, the micro hardness profile, shown in figure. 6, shows that the as weld hardness showed to fluctuate in the weld zone and minimum hardness was found at weld bead centre for (80/20, 70/30 and 60/40) PC GMAW welds, whereas for 50/50 the minimum hardness found at partially melted zone (weld metal -heat affected zone (HAZ) interface) of the weldment. The minimum hardness is due to precipitate coarsening or dislocation of precipitates. Compared to hardness (113VHN$_1$) of parent metal (BM), PC GMAW joints exhibits lower hardness values (for 80/20 PC GMAW - 92.8 VHN$_1$, 70/30 PC GMAW - 99 VHn1, 60/40 PC GMAW - 96.5 VHn1, and 50/50 PC GMAW 91.5 VHN$_1$) compared to un-welded parent metal (BM). The failure of tensile specimens was invariable at the fusion zone (weld metal - heat affected zone interface), which was consistent with the lowest hardness distribution in the partially melted zone (weld metal- heat affected zone interface).

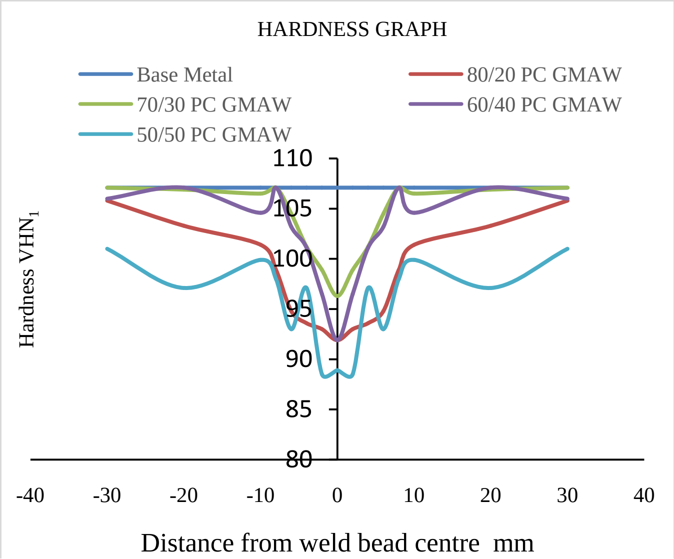

Fig. 6. Effect of PC GMAW on microhardness of AA5083 welds

D. Tensile Properties of BM And PC GMAW of AA5083 Welds

This study evaluated the transverse tensile properties namely yield strength, tensile strength, percentage of elongation of PC GMAW joints. Three specimens were tested and the average of three results is presented in the table. II. The stress (Vs) Strain graphs of base metal and CC GMAW are shown in the figure. 4. Base metal shows better strength then CC GMAW weld. The joint fabricated with a welding speed of 2.0 m/min. PC GMAW, exhibits yield strengths at (80/20 - 210 N/mm^2, 70/20 – 275 N/mm^2, 60/40 -173N/mm^2 , 50/5 – 175 N/mm^2) and tensile strengths (at 80/20-218N/mm^2,70/20 283N/mm^2,60/40-198N/mm^2, 50/50-189N/mm^2) compared to the yield strength (307.5 N/mm^2) and tensile strength (392.8 N/mm^2) of unwelded parent metal. The stress-strain graph is shown in figure .7

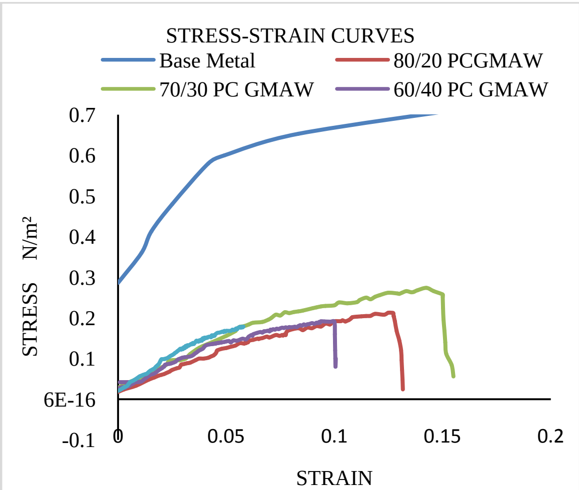

Fig. 7. Tensile properties of BM and PC-GMAW welds of AA5083

E. Mechanical Properties of BM, CC GMAW and best of PCGMAW of AA5083

The traverse tensile properties such as hardness, yield strength, tensile strength and percentage of elongation of un-welded base metal (BM), CC GMAW and best of PC GMAW of AA5083 welds were compared and tabulated in table. III. When the results all of CC GMAW and PC GMAW were compared it was observed that 70/30 PC GMAW scored over the rest of the welds. Fusion zone with 70/30 showed maximum Tensile and Yield strength values compared to its others.Better mechanical properties i.e., microhardness (99 VHN$_1$), Yield Strength (275 N/mm^2) and tensile strength (283 N/mm^2) are achieved over the other welds. The stress-strain graph is shown in figure .8.

TABLE IIIII
MECHANICAL PROPERTIES OF BM, CC & BEST OF PC GMAW OF AA5083 WELDS

Sample	Y.S (N/mm^2)	T.S (N/mm^2)	Elongation %	Hardness VHN$_1$
Base material	307.5	392.8	14.0	113.0
CC GMAW	195.0	210.0	7.0	90.4
PC GMAW (70/30)	275.0	283.0	8.8	99.0

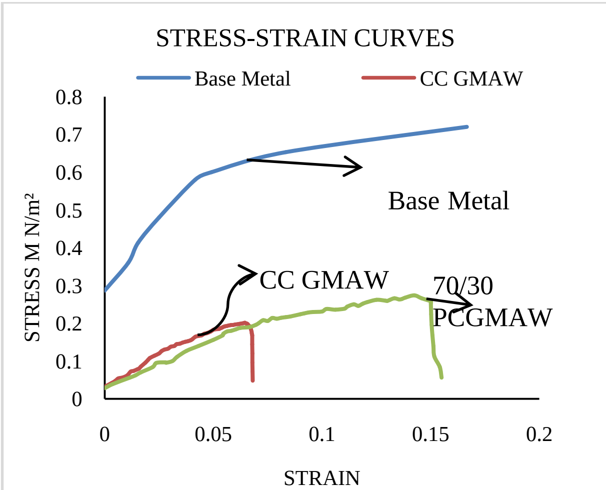

Fig. 8. Tensile properties of BM, CC and best of PC-GMAW welds of AA5083

F. Microstructure characterization of BM, CC GMAW and best of PCGMAW ofAA5083 [5]

The microstructural features of aluminum 5083 (AA5083) weldments processed by gas metal arc welding (GMAW) of BM, CC GMAW and PC GMAW are investigated by light optical microscopy (LOM) as shown in figures. 9, 10, 11. Weldments processed by PC GMAW are mechanically softer than the parent material AA5083, and could be potential sites for plastic localization. It is revealed that AA5083 weldments processed by PC GMAW are mechanical more reliable [3].

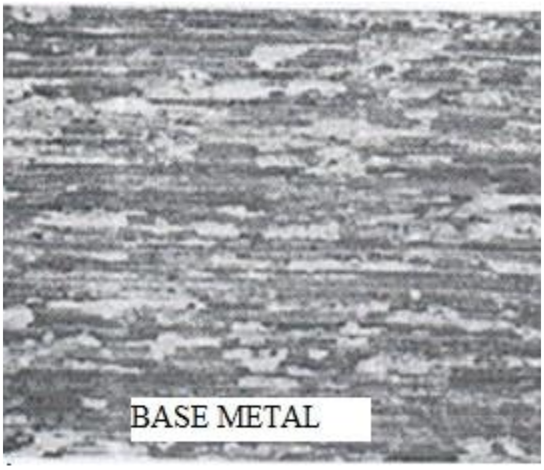

Fig. 9. Optical Micrographs of fusion zone of BM, PC GMAW (200X)

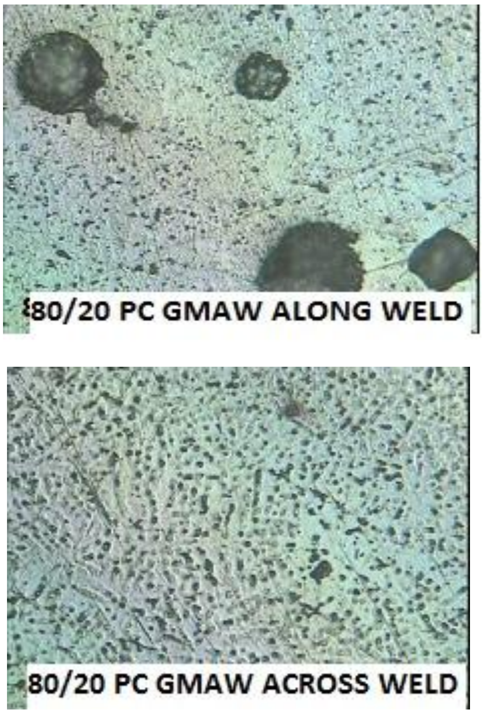

Fig. 10. Optical Micrographs of fusion zone along and across the weld at 80/20 PC GMAW

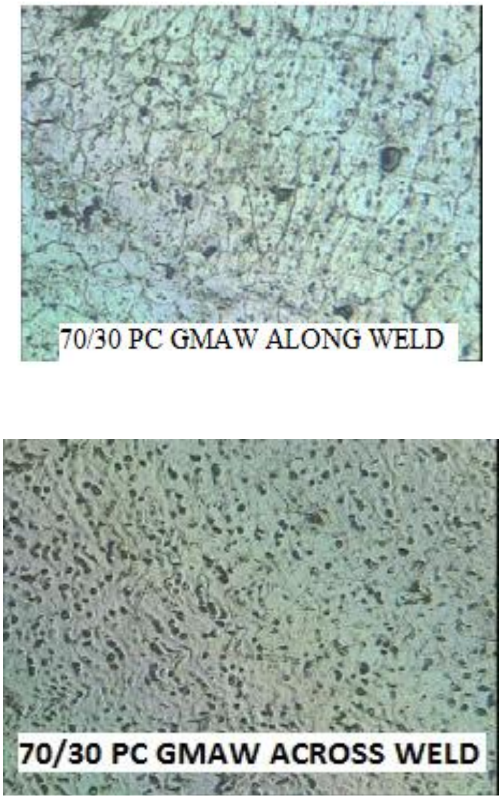

Fig. 11. Optical Micrographs of fusion zone along and across the weld at 70/30 PC GMAW

Perceivable porosity in weldments by GMAW is found, which could account for the distinct mechanical properties between weldments processed by GMAW [5]. It is suggested that caution should be exercised when using GMAW for AA5083 where such light weight metal is broadly used.

V. CONCLUSIONS

AA5083 were joined using CC GMAW and PC GMAW methods and main conclusions are as follows

i. Welding of AA5083 in CC GMAW and PC GMAW was carried successfully.
ii. The obtained joints showed no porosity or other defects in both top and root weld surface in as welding conditions.
iii. Pulsed current resulted in relatively higher hardness values compared to their continuous current (CC) counterparts.
iv. The benefit was more significant when AA 5083 was welded with pulsed current (PC) technique.
v. The mechanical properties such as hardness, Tensile strength, yeild strength, % elongation of the AA5083 CC GMAW and PC GMAW joints was observed.
vi. Out of all welds 70/30 PC GMAW shows better mechanical properties.
vii. 70/30 PC GMAW shows an increase of 9.5 % in hardness in when compared to CC GMAW.
viii. 70/30 PC GMAW shows an increase of 34.7 % in Tensile strength in PC GMAW when compared to CC GMAW.

ix. 70/30 PC GMAW shows an increase of 42.1 % in Yeild Strength in PC GMAW when compared to CC GMAW.
x. 70/30 PC GMAW shows an increase of 25.7% in% Elongation in PC GMAW when compared to CC GMAW.
xi. Significant grain refinement was exhibited with pulsed current (PC) GMA welding technique.
xii. The pulsing of the welding current influences the solidifying pool thermally and mechanically, causing periodic shaking of the liquid metal. However in continuous current GMAW, weld pool is not agitated sufficiently to break the dendrite tips and hence no grain refinement takes place.
xiii. Better mechanical properties and micro structures are observed in the welded joints at PCGMAW 70/30.

VI. FUTURE SCOPE OF THE WORK

The present work can be extended to carry out SEM testing, SEM EDAX, factrography and X-ray analysis to study the detailed micrograph analysis of the optimized parameters on CC and PC GMAW of AA5083.

The addition of alloying elements in AA5083 inorder to improve the mechanical properties.

VII. BIOGRAPHIES

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