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A Study on Weld Quality Characteristics of Pulsed Current Micro Plasma Arc Welding of SS304L Sheets

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ABSTRACT

Micro Plasma Arc Welding plays a vital role in attaining good weld quality in various engineering applications like bellows, diaphragms etc. The main objective of the present work is to use current pulsing technique while welding SS304L sheets. The paper focuses on studying the influence of various Micro Plasma Arc Welding process parameters like peak current, back current, pulse and pulse width on the weld quality characteristics like weld pool geometry, microstructure, grain size, hardness and tensile properties. The results reveals that the usage of pulsing current, grain refinement has taken place in weld fusion zone, because of which improvement in weld quality characteristics have been observed.

1. Introduction

Welding thin sheets is quite different from welding thick sections, because during welding of thin sheets many problems are experienced. These problems are usually linked with heat input. Fusion welding generally involves joining of metals by application of heat for melting of metals to be joined. Almost all the conventional arc welding processes offer high heat input, which in turn leads to various problems such as burn through or melt trough, distortion,

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porosity, buckling warping & twisting of welded sheets, grain coarsening , evaporation of useful elements present in coating of the sheets, joint gap variation during welding, fume generation form coated sheets etc. Use of proper welding process, procedure and technique is one tool to address this issue (M.Balasubramanian *et al.*, 2010). MPAW is a good process for joining thin sheet, but it suffers high equipment cost compared to GTAW. However it is more economical when compare with Laser Beam welding and Electron Beam Welding processes.

The plasma welding process was introduced to the welding industry in 1964 as a method of bringing better control to the arc welding process in lower current ranges (Modern Application News, 1999). Today, plasma retains the original advantages it brought to the industry by providing an advanced level of control and accuracy to produce high quality welds in both miniature and pre precision applications and to provide long electrode life for high production requirements at all levels of amperage. Plasma welding is equally suited to manual and automatic applications. It is used in a variety of joining operations ranging from welding of miniature components to seam welding to high volume production welding and many others.

Pulsed current MPAW involves cycling the welding current at selected regular frequency. The maximum current is selected to give adequate penetration and bead contour, while the minimum is set at a level sufficient to maintain a stable arc (K.Prasad Rao, 2001 & G.Madusudhan Reddy *et al.*, 1993). This permits arc energy to be used effectively to fuse a spot of controlled dimensions in a short time producing the weld as a series of overlapping nuggets. By contrast, in constant current welding, the heat required to melt the base material is supplied only during the peak current pulses allowing the heat to dissipate into the base material leading to narrower heat affected zone (HAZ) (M.Balasubramanian *et al.*, 2006). Advantages include improved bead contours, greater tolerance to heat sink variations, lower heat input requirements,, reduced residual stresses and distortion, refinement of fusion zone microstructure and reduced with of HAZ. There are four independent parameters that influence the process are peak current, back current, pulse and pulse width.

From earlier works, it has been observed that much work is not reported so far to investigate the effect of pulsed current MPAW process parameters particularly joining thin sheets. Hence an attempt has been made to study important pulsed MPAW process parameters. This work presents the influence of weld input parameters like Peak Current, Back Current, Pulse and Pulse Width on weld quality characteristics of MPAW welded SS 304L joint.

2. Experimental Procedure

Experiments are conducted using the Pulsed Micro Plasma Arc Welding (MPAW) process. Industrial pure and commercial grade argon gases are used for shielding and back purging, respectively. Automatic voltage control available in the welding equipment is used. Fixture variation effects are not considered as the same setup has been used throughout the experiment.

There are many influential process parameters which effect the weld quality characteristics of MPAW process like peak current, back current, pulse , pulse width, flow rate of shielding gas, plow rate of purging gas, flow rate of plasma gas, welding speed etc. From the works carried out by numerous researchers on usage of pulsing current on various welding processes (N.Karunakaran *et al.*, 2011, S.Babu *et al.*, 2008, M.Balasubramanian *et al.*,2008) it was understood that peak current, back current, pulse and pulse width are the dominating parameters which effect the weld quality. However in the present work the optimal established values are obtained by conducting trail experiments on various combinations of selected process parameters as per Response Surface Method (RSM) by considering four factors, five levels, rotatable central composite design matrix. The values of process parameters used in this study are the optimal values obtained from RSM.

Peak Current = 7 Amperes
Back Current = 4 Amperes
Pulse = 40 pulse/sec
Pulse Width = 50%

Table 1: Fixed pulsed MPAW process parameters and their values.

Power source	Secheron Micro Plasma Arc Machine (Model: PLASMAFIX 50E)
Polarity	DCEN
Mode of operation	Pulse mode
Electrode	2% thoriated tungsten electrode
Electrode Diameter	1mm
Plasma gas	Argon & Hydrogen
Plasma gas flow rate	6 Lpm
Shielding gas	Argon
Shielding gas flow rate	0.4 Lpm
Purging gas	Argon
Purging gas flow rate	0.4 Lpm
Copper Nozzle diameter	1mm
Nozzle to plate distance	1mm
Welding speed	260mm/min
Torch Position	Vertical
Operation type	Automatic

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The fixed pulsed MPAW process parameters and their values are presented in Table 1.

Austenitic stainless steel sheets of type SS 304L 100×50×0.25 mm as shown in Figure 1 are welded autogenously with square butt joint without edge preparation (K.Siva Prasad et al., 2011). The chemical composition of SS 304L was given in Table 2.

Table 2: Chemical composition of SS304L (weight %).

C	Si	Mn	P	S	Cr	Ni	Mo	Ti	N
0.021	0.35	1.27	0.030	0.001	18.10	8.02	--	--	0.053

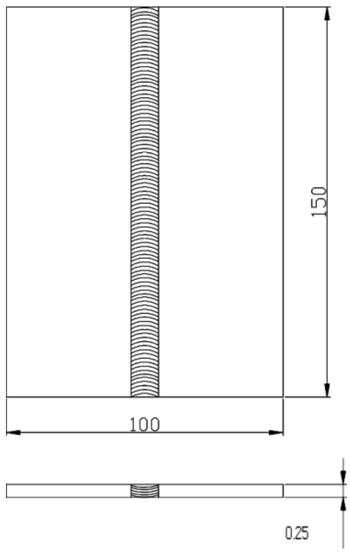

Figure 1: Typical weld joint.

After preparation of weld joint, visual inspection was carried out to detect surface defects and X-ray was taken to know internal defects like cracks, improper fusion etc. After clearing X-ray the welded samples were prepared to carry out various tests mentioned in the succeeding paragraphs.

3. Measurement of Output Responses

3.1 Weld Bead Geometry

Sample preparation and mounting was done as per ASTM E 3-1 standard. The samples were cut from the welded specimens and mounting using Bakelite powder. After standard matallurgial polishing process, Oxalic acid is used as the etchant to reveal weld bead geometry. The weld pool geometries were measured using Metallurgical Microscope, Make :Dewinter Technologie, Model No. DMI-CROWN-II. A typical weld bead geometry is shown in Figure 2.

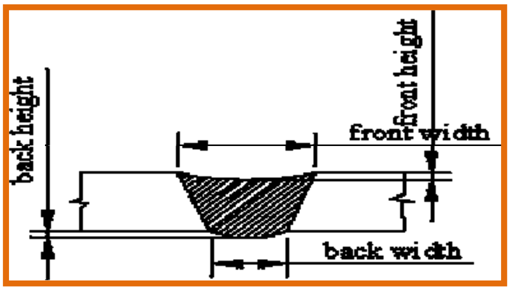

Figure 2: Typical weld bead geometry.

Photo macrograph of typical weld specimens showing the bead profile at 100X magnification is presented in Figure 3a & 3b. The values of weld bead geometry for SS304L are presented in Table 3.

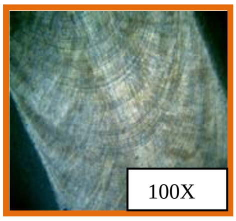

Figure 3a: Front Width

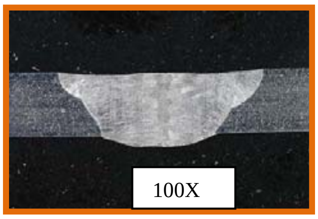

Figure 3b: Sectional View across the weld

Table 3: Weld bead parameters of SS304L.

Weld bead parameter	Dimension in Microns
Front Width (Microns)	1509.859
Back Width (Microns)	1394.383
Front Height (Microns)	51.903
Back Height (Microns)	34.312

3.2 Micro Hardness

Vickers Micro hardness was done as per ASTM E384. The samples were cut from the welded specimens and Vickers Micro Hardness values across the weld joint at an interval of 0.3mm using Digital Micro Hardness testing Machine, make METSUZAWA CO LTD, JAPAN, Model No: MMT-X7 and the values recorded are presented in Table 4.

Table 4: The variation of hardness values across the weld joint at 0.3mm interval.

Location	1	2	3	4	5	6	7	8	9
Vickers Micro Hardness (VHN)	189	202	197	194	199	189	193	186	188

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In the above table points 1,2,8,9 are on the base metal at Heat Affected Zone, points 4, 5, 6 across the Weld Zone and points 3,7 indicates at Fusion Zone and are represented in Figure 4 . The variation of hardness across the weld joint is represented in Figure 5.

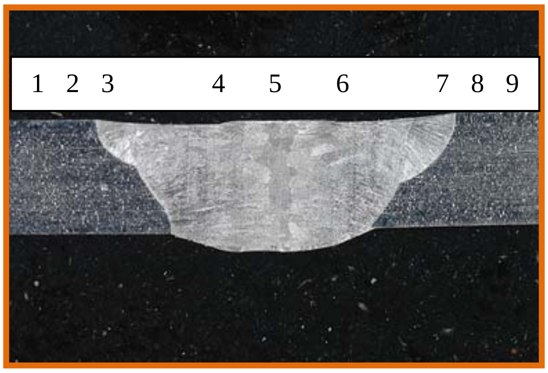

Figure 4: Location of hardness measuring points in weld joint.

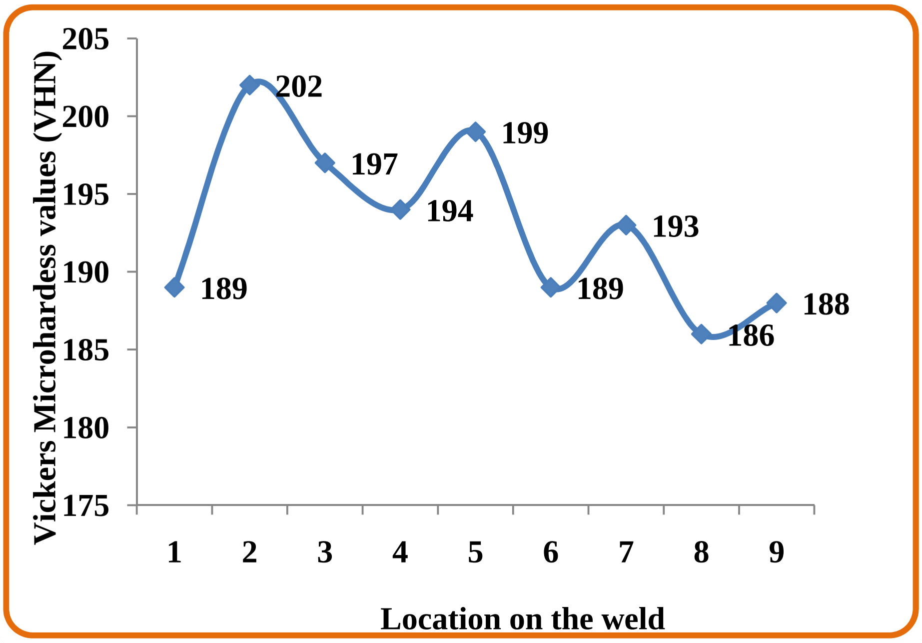

Figure 5: Variation of Hardness values at an interval of 0.3mm across the weld joint.

From Figure 4 it is understood that the weld zone is having higher hardness values compared to parent metal.

3.3 Microstructure

For Microstructure measurement ASTM E 407 was followed for Etching along with ASM Metal Hand Book, Volume 9. For revealing the Microstructure the weld samples are mounted using Bakelite and polishing was done according to standard Metallurgical procedure. Oxalic

Acid was used as an etchant. For revealing the Microstructure, Electrolytic Etching was done. The Microstructure was measured using Metallurgical Microscope, Make: Carl Zeiss, Model No: Axiovert 40 at a magnification of 100X. The Microstructure of parent metal zone, weld metal zone and fusion zone are shown in Figure 6.

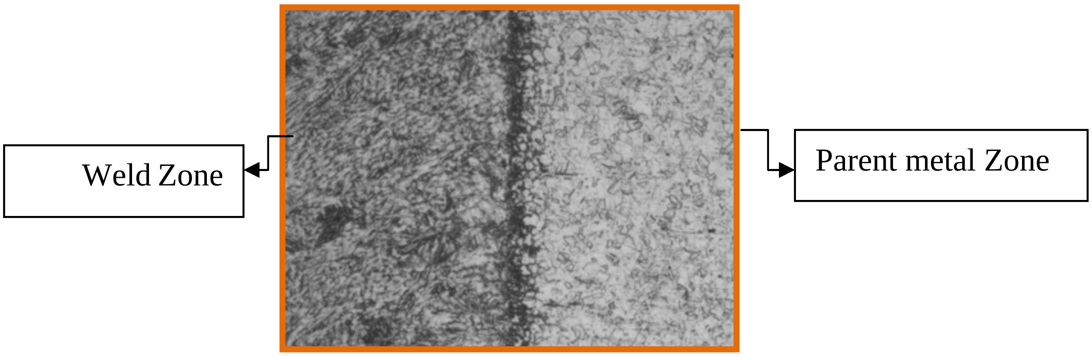

Figure 6: Indicating Parent, Fusion and Metal zone.

3.4 Grain Size

For Grain Size measurement ASTM E112 was followed. Polishing was done according to standard Metallurgical procedure and Etching was done as per ASTM E407. For revealing the grain size Electrolytic was done using Nitric Acid for about 1 minute. Using Metallurgical Microscope, Make: Carl Zeiss, Model No: Axiovert 40 at a magnification of 200X grain structures was captured and compared with ASTM standard grain Size. Figures 7 and 8 indicate the grain structure at weld joint and Parent metal zone.

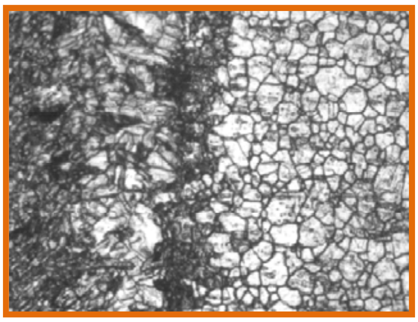

Figure 7: Grain structure at weld joint.

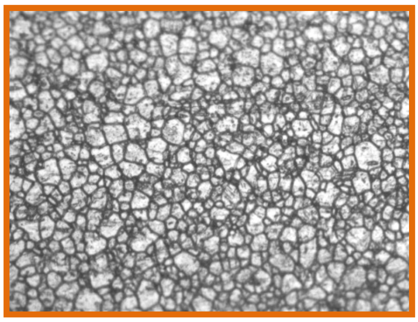

Figure 8: Grain structure at Parent metal.

From Figures 7 and 8, one can only compare with the standard ASTM grain size number. By comparison method it was observed that for parent metal the ASTM grain size number is 8.5 and near to the fusion zone the ASTM grain size number is 8.

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In order to get the exact grain size one has to go for advanced measuring devices like Scanning Electron Microscope (SEM).The grain size of parent metal in heat affected zone is around 45.432µm and near to the fusion zone it is around 43.854µm. The SEM images showing the grain size at the fusion zone is presented in Figure 9.

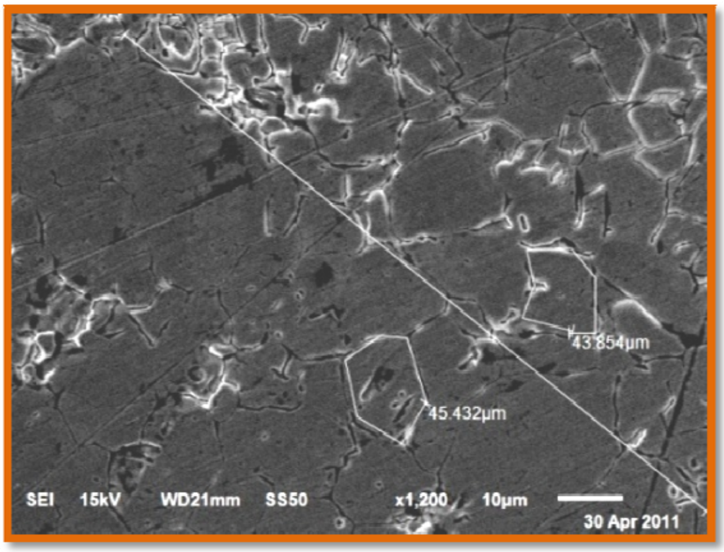

Figure 9: SEM image of SS304L.

3.5 Tensile Properties

The tensile property of the sample was carried out according to ASTM E8. Specimen was cut using wire cut Electro Discharge Machine. Tensing was carried out on a 100KN universal tensile testing machine. The results indicate that the values obtained are better than the parent metal; hence the weld joint is good. The tensile properties of parent metal and welded specimen are shown in Table 5.

Table 5: Tensile properties.

	Parent metal	Welded specimen
Yield Strength (MPa)	254.95	271
Ultimate Strength (Mpa)	677.67	705
% Elongation (50mm gauge length	52.56	59.5

From Table 5 it is very clear that the tensile properties of the weld specimen is better than the parent metal.

4. Conclusions

The study reveals that the sound weld joint is obtained by choosing proper values of Peak current, Back current, Pulse and Pulse as the important process variables. The weld joint obtained is free from surface defects and fused properly. The hardness values of the weld zone are comparatively better than the parent metal zone which indicates better strength of the weld joint. The microstructure of the weld joint indicates the presence of ferrite particles. Fine grains are obtained in the weld zone and fusion zone because of using pulsed current. The grain size of parent metal in heat affected zone is around 45.432µm and near to the fusion zone it is around 43.854µm, which reveals that weld zone is stronger than parent metal. The tensile properties of welded sample are better than parent metal, which indicates better strength of the weld joint.

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