Plasma Arc Welding - A Review Paper on Weld Quality

[1]Divyesh B Visaveliya, [2]Dhaval k Patel
[1]Post Graduate Student, [2]Assistant Professor
[1]Department of computer aided design and manufacturing
[2]Department of mechanical engineering
[1,2] L D College of engineering, Ahmedabad, India

Abstract: Plasma arc welding is advance form of arc welding process which can be applied to almost any existing metals. The various process parameters in plasma arc welding such as plasma gas flow rate, torch stand-off distances, welding current, welding speed, front weld width, back weld width etc. play an important role in the prediction of the weld geometry and quality. The plasma arc welds have excellent mechanical properties. This paper includes review of various theoretical and experimental studies by different researchers over the years. A section of the paper deals with review on process parameter, weld geometry, weld bead property and importance of filler metal based on existing research and literature content.

Index Terms: **Plasma Arc Welding, Process parameter, Weld Geometry, Weld quality, Filler metal, weld bead property**

I. INTRODUCTION

As the extension of Gas Tungsten Arc Welding (GTAW), Plasma Arc Welding has the advantages of less welding defect and excellent direction control and has been used in space shuttles, airplanes, rockets, etc.[1] In PAW the electric arc generated between a non-consumable tungsten electrode and the working piece is constrained using a copper nozzle with a small opening at the tip. Full setup of plasma arc welding show in figure 1. Arc is generated between electrode and workpiece (transfer PAW) or water cool nozzle (non-transfer PAW) as show in fig 2. By forcing the plasma gas and arc through a constricted orifice, the torch delivers a high concentration of energy to a small area, giving higher welding speeds and producing welds with high penetration/width ratios, thus limiting the HAZ dimensions. For this reason PAW is very useful techniques for welding of austenitic steels, structural steels etc [2]

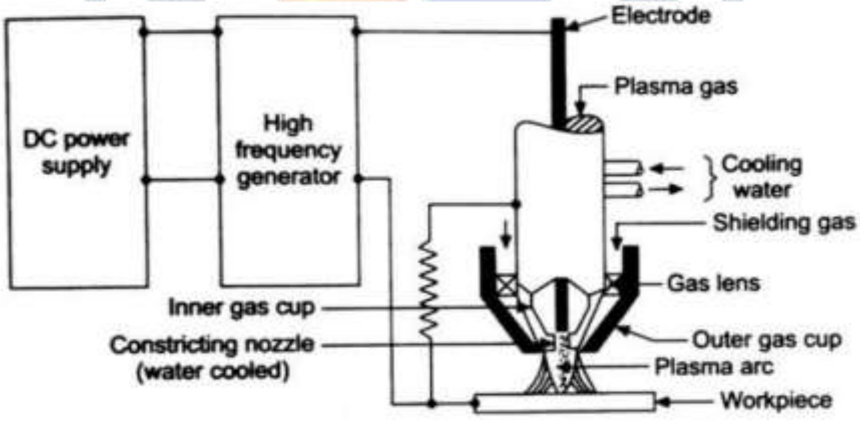

Figure 1 PAW Setup [3]

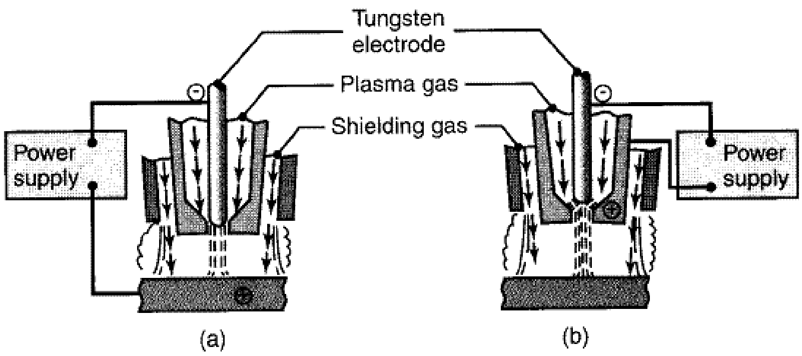

Figure 2 a) Transfer PAW, b) Non-transfer PAW [4]

Plasma Arc Welding Further classify based on range of winding current, following three mode of Plasma Arc Welding used in industry based on application to be weld.

1) Micro plasma (0.1-1 5 A)
2) Medium plasma welding (15-100 A)
3) Keyhole plasma welding (>100 A).

In Micro PAW The concentrated arc enables it to remain stable down to a current of about 0.1 A, which means that the process can be used for welding metal thicknesses down to about 0.1 mm. This makes the process attractive to, for example, the space industry. In medium plasma welding (15-100 A). In this range, the method competes more directly with TIG welding. It is suitable for manual or mechanised welding and is used in applications such as the automotive industry for welding thin sheet materials without introducing distortion or unacceptable welded joints, as are produced by MIG welding, or for the welding of pipes in breweries or dairies. In key hole mode the third type of plasma welding is referred to as keyhole plasma welding, taking its name from the 'keyhole' that is produced when the joint edges in a butt weld are melted as the plasma jet cuts through them. As the jet is moved forward, the molten metal is pressed backwards, filling up the joint behind the jet.[5]

PAW has a number of critical advantages over TIG welding process. The high-power arc that is produced and eliminates the need for time consuming weld preparation work such as: V-type or U-type joint preparation and square cut joint preparation. This preserves around 30% of the filler metal. In turn, increases the welding speed by around 20% in soft-plasma welding. PAW also saves time and costs at the same time as ensuring deeper penetration. The tungsten electrode has a much longer service life because it is enveloped in the protective plasma gas.[6]

II. REVIEW ON PROCESS PARAMETERS

Welding input parameter play a significant role in determining the quality of weld. The weld quality can define in terms of properties such as weld bead geometry, mechanical property, metallurgical property and distortion. In weld bead geometry parameter such as Front melting width, Back melting width and weld reinforcement etc consider for evaluation of weld quality.

D. M. Evans, D. Huang et al (1998), conducted an experimental examination to identify the parameters on which the arc efficiency depended upon. A theoretical model was formulated to compare the results with the experimental answers in order compare the results, and understand how the welding current and voltage affected the heat transfer mechanism thus affecting the arc efficiency. The arc efficiency was measured from the PAW welds made on 6061 Aluminium plate. The arc efficiency was found to vary from 0.48 to 0.66. The arc efficiency was found to decrease with increase with voltage. The efficiency increased with the voltage due the increase in convection caused by the shielding gas used. The arc temperature did not vary with the welding voltage.[7]

Y. F. Hsiao, Y. S. Tarng et al (2007), conducted an experiment to optimised processes parameter by applying the Taguchi method along with the Grey relational analysis. Whole the experiment carried out on 4mm thick SUS316 stainless steel plate. optimal welding parameter is identified base on the undercut, root penetration and the welding groove width. The experimental result conclude that the welding current, welding speed, and plasma gas flow rate are primary factors that affect the welding quality of PAW, while torch stand-off is considered a secondary factor to improve welding quality and utilization of the optimal welding parameter combination enhances a significant improvement of the grey relation.[8]

Kondapalli Siva Prasada et al (2014), in the present study Austenitic stainless-steel sheets (AISI 304L, AISI 316L, AISI 316Ti, AISI 321) of 100 x 150 x 0.25 mm are welded autogenously with square butt joint without edge preparation. From the analysis of the weld quality characteristics, it is revealed that for the same thickness and same welding parameters, AISI 304L has achieved sound weld bead geometry, highest tensile strength and hardness. However, it is noticed that AISI 316L has attained lowest tensile strength, AISI 321 has lowest hardness and grain size. It means to get desired weld quality for different grade of steel plate we have to set different process parameter. There is no any particular formula to identify desired process parameter for different material have a different dimension. It is identify based on experimental study.[9]

Yajuan Jin, Ruifeng Li et al (2016), did similar study on process parameter to weld AISI 304L Stainless Steel and Galvanized Steel Plates. They study the effect of parameters on weld surface appearance, interfacial microstructure, and composition distribution in the joint. The results indicated that good appearance, bead shape, and sufficient metallurgical bonding could be obtained when the process was performed with a wire feeding speed of 0.8 m/min, plasma gas flow rate of 3.0 l/min, welding current of 100 A, and welding speed of 27 cm/min.[10]

Ramesh Kumar, Sandeep S et al (2018), investigated welding of dissimilar metal of austenitic- ferritic stainless steels. PAW has various process parameters in which three major parameter such as welding current, gas flow rate and welding speed is important to predict weld quality.[11]

III. REVIEW ON WELD BEAD GEOMETRY AND WELD QUALITY

Siva Prasad, Srinivasa Rao (2010) et al conducted an experimental investigation to understand the effect of various process parameters like welding current, torch height and welding speed on front melting width, back melting width and weld reinforcement of Plasma Arc Welding on Aluminium alloy is investigated by using standard statistical tool called the Response Surface Method. Different weld bead parameter shown in figure 3. By experimental and theoretical investigations, it was concluded that, when the Torch height and welding speed were kept constant and when the welding current was increased, Front melting width, Back melting width and weld reinforcement decreased Similarly when the welding current and welding speed were kept constant and the Torch height was increased, Front melting width and Back melting width increased, while weld reinforcement decreased. In another scenario where the welding current and torch height were kept constant and the welding speed was increased, then Front melting width and Back melting width decreased whereas the weld reinforcement increased.[12]

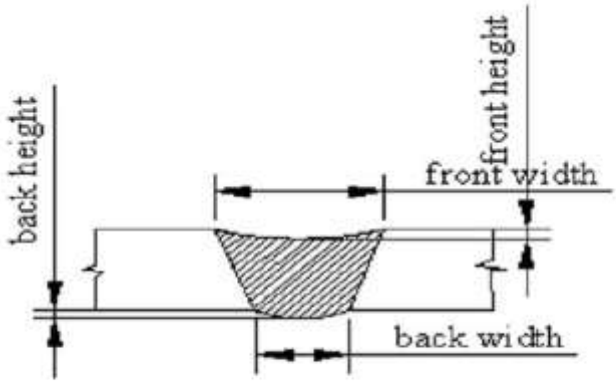

figure 3 weld bead parameters [12]

Siva Prasad, Srinivasa Rao et al (2011), did a similar study on weld bead quality by using factorial design approach. In this study, two levels and four input process parameters were taken and experiments were conducted as per design matrix considering full factorial design. In this study the plasma gas flow rate was also include as one of the process variables. The results were similar to the previous experiment conducted. Though it was noted in the experiment that as the number of process variable increased the accuracy of the weld bead quality would also improve.[13]

Kondapalli Siva Prasad et al Prasad (2012), presented a detailed literature review on the advances in PAW, based on has survey earlier most of the works in Plasma Arc Welding and associated phenomena are towards modelling of plasma arc, temperature & heat transformation and process parameter optimization to get the desired weld quality. In most of the works welding current, arc voltage, welding speed, magnitude of ionic gas, torch stand of are considered for predicting and optimizing the weld bead geometry ,many works were carried out on Stainless Steels, Aluminium, Nickel based alloys, Titanium etc.[14]

M. H. Park (2016) et al, investigated the relationship between the process parameters and the bead geometry in Plasma arc welding (PAW). The quantitative effect of process parameters on bead geometry was calculated using sensitivity analysis. Experimental result show that change of process parameters (variable parameter: welding current, welding speed and shielding gas) affects the bead width more strongly than bead height.[15]

IV. REVIEW ON FILLER METAL AND WELD BEAD PROPERTY

Emel Taban, Alfred Dhooge et al (2009), conducted an experiment on 6mm thick modified stainless-steel plate weld by using PAW without filler metal and with filler metal (AISI 316L austenitic type of consumable filler wire). Photo macrography of weld bead with and without filler metal show in fig 4. It was noticed that hardness value at the HAZ is higher by using filler metal as compare to without filler metal.[16]

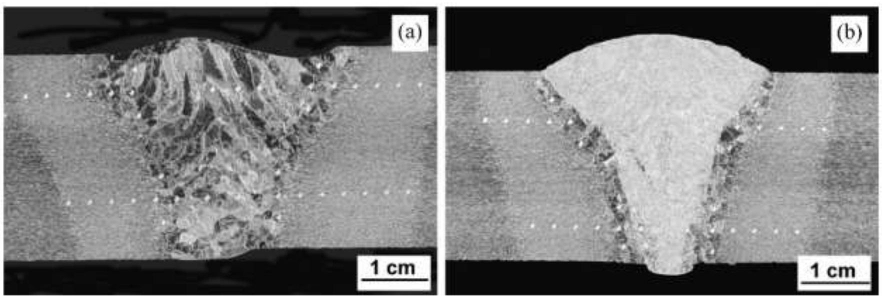

Figure 4: Photo macrographs of (a) Weld 1 without filler metal and (b) Weld 2 with AISI 316 filler metal [16]

Birendra Kumar Barik, P. Sathiya et al (2014), investigate the mechanical and metallurgical properties of welds made AISI 410S plates of 6 mm thickness without filler metal. It was noticed that the higher tensile properties were obtained than the base metal and the impact energy value for welded joints is more than base metal at room temperature.[17]

S Mandal, S Kumar et al (2014), study investigates the role of thermal energy in deposition of thick layer of powder material by PTAW process Stainless steel plates of grade SS316 with size of length 150 mm, width 110mm and thickness 7 mm were used as substrate. Material powder of grade SS304L was used for deposition and conclude that the energy distribution between the powder and the substrate is found to be very important for continuous and thick deposition of powder materials with low dilution.[18]

Selva R Bharathi, S M Sadham et al (2014), investigate the effect of various welding process parameters on the weld ability of stainless-Steel specimens of grade 312 having dimensions 75mm× 55mm× 6 mm, by using SS316 powder form of filler metal and to optimised processes parameter by applying the L25 Taguchi method. Result conclude that by using powder form of filler metal welding defects like cracks which are eliminated to 100%, there is no lack of fusion in the welded portion and the gas holes or porosity on the weld are completely eliminated and welding penetration observed in 3mm.[19]

Shiming huang, daqian sun (2015) et al investigation carried out using powder as filler metal for coating on base metal for improving wear resistances, corrosive resistance property. The results indicate that the powder coatings have a full metallurgical bond in substrate interface.[20]

V. FUTURE PROSPECTS AND CONCLUSIONS

Continuous experimental studies are going on the field of PAW, in order to optimize the process to extend the range of materials it can weld. It was understood from the earlier works that most of the works in plasma arc welding carried out to improve weld bead quality by changing process parameter such as welding current, welding speed, torch stand of distances etc. As from literature survey wire form of filler metal used in welding and powder form of filler metal used in coating purposed. Studies are being made in order to improved weld quality using powder as a filler metal in welding purposed and developed new technology powder plasma arc welding and characterised has mechanical and metallurgical property.

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