A Literature Review on Plasma Arc Welding

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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.

1.INTRODUCTION

Plasma arc welding (PAW) is an arc welding process similar to gas tungsten arc welding (GTAW). The electric arc is formed between an electrode (which is usually but not always made of sintered tungsten) and the workpiece. The key difference from GTAW is that in PAW, the electrode is positioned within the body of the torch, so the plasma arc is separated from the shielding gas envelope. The plasma is then forced through a fine-bore copper nozzle which constricts the arc and the plasma exits the orifice at high velocities (approaching the speed of sound) and a temperature approaching 28,000 °C (50,000 °F) or higher. Arc plasma is a temporary state of a gas. The gas gets ionized by electric current passing through it and it becomes a conductor of electricity. In ionized state, atoms are broken into electrons (−) and cations (+) and the system contains a mixture of ions, electrons and highly excited atoms. The degree of ionization may be between 1% and greater than 100% (possible with double and triple degrees of ionization).

Such states exist as more electrons are pulled from their orbits. The energy of the plasma jet and thus the temperature depends upon the electrical power employed to create arc plasma. A typical value of temperature obtained in a plasma jet torch is on the order of 28000 °C (50000 °F), compared to about 5500 °C (10000 °F) in ordinary electric welding arc. All welding arcs are (partially ionized) plasmas, but the one in plasma arc welding is a constricted arc plasma. Just as oxy-fuel torches can be used for either welding or cutting, so too can plasma torches.

2.WORKING PRINCIPLE

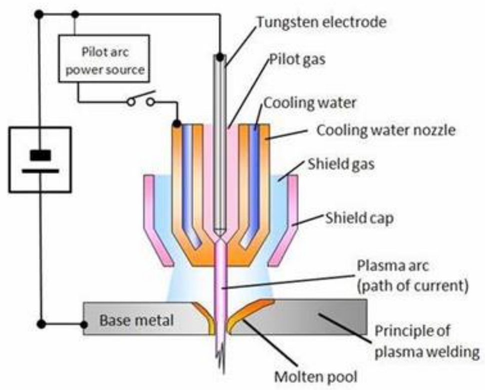

Figure.1 Schematic diagram of working principle

The hot ionized gases are known as plasma. When a sufficient amount of energy provided to any inert gas, some of its electrons breaks free from its nucleus but travel with it. After the electrons leave, the atoms are converted into hot ionized state. It is most common state of matter which is known as fourth state of matter. These ionized atoms have high heat contain which is further used to join two plates. This is basic principle of plasma arc welding. This welding is extended form of TIG welding in which, a non-consumable tungsten electrode is used to produce arc. This arc heats up the inert gases which are provided from inner orifice around tungsten electrode. The heating temperature is about 30000 degrees centigrade at which the gas converts into ionized form. This hot ionized gas further used to create a welding joint by fusion.

3.TYPES OF PLASMA ARC WELDING

Following are the two types of plasma arc welding:

1. Transferred PAW
2. Non-transferred PAW

1)Transferred Plasma Arc Welding

In this welding process, the tungsten electrode is fixed to the negative terminal and the workpiece is fixed to the positive terminal. It also uses a DC current. An arc is generated between the tungsten electrode and the workpiece. In this process, both plasma and arc are transferred to the workpiece it improves the heating capacity of the process. It is employed to weld thick sheets.

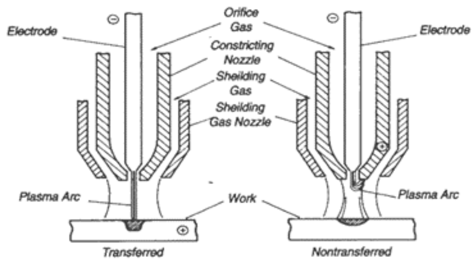

Figure.2 Schematic diagram of transferred and non-transferred PAW

2) Non-transferred Plasma Arc Welding

In this welding process, DC current is used. In which, the tungsten electrode is attached to the negative and the nozzle is attached to the positive pole. An arc is produced between the tungsten electrode and nozzle inside the torch. This will increase the ionization of the gas inside the torch. The torch transfers this ionized gas for further processing. It is employed to weld thin sheets.

4.ADVANTAGES AND DISADVANTAGES OF PLASMA ARC WELDING

Following are the advantages of PAW:

- Requires less operator skill due to good tolerance of arc to misalignments.
- High welding rate.
- It has a high penetrating capability (keyhole effect).
- High energy is available for welding. It can easily weld hard and rough workpieces.
- The distance between the tool and the workpiece does not affect the arc formation.
- It has low power consumption for welds of the same size.
- The more stable arc produced by the plasma arc welding.
- It can operate at low amperage.

Following are the disadvantages of PAW:

- Expensive equipment.
- High distortion and wide as a result of high heat input.
- It is a noisy operation so there is a chance of noise pollution.
- It has more radiation.
- Plasma arc welding is required high skilled labour.
- The maintenance cost is high.

5.LITERATURE SURVEY

[1] Dinakaran et al (2014) conducted an experimental investigation on the numerical simulation of plasma arc welding of 2 mm thick Ti-6Al-4V alloy using the Finite Element code-COMSOL. A Modified Three-Dimensional Conical (MTDC) heat source model and a newly developed heat source model were considered for the numerical simulation to predict the temperature distribution on thin sheets of titanium alloy. The temperature dependent material properties of Ti-6Al-4V such as thermal conductivity, specific heat and density are used for performing the numerical analysis.

[2] Prasad et al (2010) 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 Aluminum alloy is investigated by using standard statistical tool called the Response Surface Method. Variable Polarity Plasma Arc Welding is used for welding Aluminum alloy. Trail experiments are conducted and the limits of the input process parameters are decided. 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.

[3] Prasad et al (2011) did a similar study on weld bead quality by using factorial design approach. In this study, 2 levels and 4 input process parameters were taken and experiments were conducted as per

typical design matrix considering full factorial design. In this study the plasma gas flow rate was also include as one of the process variables. 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.

[4] Evans et al (1998) conducted an experimental examination to identify the parameters on which the arc efficiency depended upon. The arc efficiency is defined as the ratio of Heat absorbed in the workpiece/unit time to the Power of the arc produced by the electrode. 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.

[5] Michalec and Maronek (2012) conducted a comparative study of PAW and laser Beam Welding (LBW) of steel sheets after nitro-oxidation. Steel sheets treated by nitro-oxidation in comparison to material without surface treatment possess increased mechanical properties and enhanced corrosion resistance. The study was conducted to find ways to reduce the high initial costs of LBW and to find an adequate counterpart from the arc welding sphere. The visual inspection of the joints welded by PAW revealed a significant presence of undercuts, whereas the macroscopic analysis confirmed the absence of porosity in the weld joint. But the tensile tests proved that PAW joints had great mechanical properties. The LBW joints had more consistent micro-hardness trend along the measured length, whereas the PAW joints exhibited a continuous decrease of the micro-hardness towards the base material. The macroscopic analysis proved a three-times-wider HAZ in PAW joints.

[6] Bharathi et al (2014) explains that PAW has much better penetration capabilities than TIG welding does. Because of which, the process is often used for seam welding components as high as 12mm in thickness. TIG welding isn’t capable of welding thicker plates due to the wider arc cone. When thin components need penetration, a special process called micro-plasma can be used to bring the current down as low as 5amps. A major advantage of PAW over TIG welding is the increased life of the tungsten. One of the reasons for the longer life is that a pilot arc allows starts to be more constant and reliable and also due to the presence of the shielding gas.

[7] Liu and Jiang (2009) conducted a study on new welding technology called plasma arc weld bonding (PAWB) was designed by combining the plasma arc welding and adhesive bonding process in the lap welding of magnesium alloy. AZ31B extrusive plates with dimensions of 250mm X 100mm X 2.5mm were used in the study. The adhesive used in this experiment was a kind of structural epoxy adhesive, which would decompose above 230 Degree Celsius. During PAWB, the major difficulty was the presence of porosity in the welding joint. The study analyzed the formation mechanism of pores and the effect of welding parameters on pores behaviors during the PAWB process of magnesium alloy by optical microscopy and electron probe microanalysis. The results showed that pores joined easily due of the existence of adhesive layer. The decomposition of adhesive in both the sides of welding seam was the main cause for the formation of pores. The regular-shape pores were formed by CO and CO_2, and the anomalous-shape pores were formed by the low molecular weight hydrocarbons. The pores behaviors were affected evidently by the heat input. A clean, defect free joint was obtained when the heat input was about 396 kJ/m.

[8] Mendez and Eeager (2001) prepared a review which stated that, PAW was selected for the Advanced Solid Rocket Motor. A variation of PAW called the Variable Polarity Plasma Arc Welding (VPPAW) was developed by the aerospace industry for welding thicker sections allow aluminium which were used for the external fuel tanks of space shuttles.

[9] 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.

[10] 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.

[11] 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.

[12] 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.

[13] 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.

[14] 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.

[15] 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.

6. CONCLUSION

Continuous and extensive experimental studies are going on the field of PAW, in order to optimize the process to extend the range of materials it can weld. PAW has been adopted in the field of aviation and electronics due to its easy setup and comparatively cheaper setup costs to LBW and Electron Beam Welding. The keyhole mode of PAW is widely used in industries due the deep penetration characteristics and also the ability to impart superior quality to the weld joint than the base metal. The Various Process parameters are being constantly studied on, to improve the characteristics of the process. The literature review points that most of the studies done by researchers in the field plasma arc welding, the materials on which the studies were conducted were mostly steel, aluminium and tungsten alloys.

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