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FACTORS AFFECTING QUALITY OF PLASMA ARC CUTTING PROCESS: A REVIEW

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ABSTRACT

Now a day's metal cutting process demands high quality cut surfaces and good dimensional accuracy with no further processing. Plasma arc cutting process employs a high temperature and high velocity constricted arc through a quantity of gas between the electrode and the work material to be cut. There are various process parameters such as arc voltage, arc current, gas pressure, cutting speed, standoff distance and gas flow rate that affect the quality characteristics of plasma cut like kerf generated, chamfer (bevel angle), heat affected zone (HAZ) and surface finish. Other factors such as bore diameter of nozzle and gap between electrode and nozzle are also important which limits the cutting parameters. It is very important to have a good knowledge of process to get better quality cut. This paper highlights recent research work and results obtained by using plasma arc cutting process based on experiments and various optimisation techniques that have been used for optimisation of plasma cutting process.

Keywords: Double Arcing, Magnetic Arc Blow, Plasma Arc Cutting, Pilot Arc

I INTRODUCTION

There are number of thermal cutting techniques which are applied for material cutting used in different field's viz. shipbuilding, construction and bridge building and the welded structures of industrial plant. The use of plasma arc cutting offers substantial advantages in terms of cutting speed and cost when compared to oxy-fuel cutting and water jet cutting. Laser cutting has the advantages over plasma cutting of being more precise and consumes less energy when cutting sheet metal. However, most industrial lasers cannot cut through the greater metal thickness that plasma can [1]. This process has been used successfully for cutting of stainless steel, high hardness and, high melting point metals and, other difficult to machine alloys [2, 3]. The main objective of this paper is to review recent theories and practices related to plasma arc cutting process.

1.1 Brief Introduction to Plasma Arc Cutting Process

Plasma is called as the fourth state of matter which is produced when substantial heat is added to a gas and is the term used to describe a mass of gas in which enough atoms are ionized [4]. Fig. 1 shows schematic representation of plasma arc cutting process. The basic plasma cutting system consists of a power supply, an arc starting circuit and a torch [5]. Torch comprises of nozzle and electrode assembly with shielding and retaining cap. In this process electrode has a negative polarity and the work piece a positive polarity so that the majority of arc energy used is approximately two thirds for cutting [6]. There are two modes of operation of this process transferred arc mode and non transferred arc mode. In transferred arc mode the pilot arc is formed between the electrode and the nozzle which is transferred to the workpiece for cutting, where as in non-transferred mode the arc is formed between electrode and nozzle, which is used for cutting. When the plasma gas flow is increased, deep penetration of plasma arc is obtained which cuts through the material and removes the molten material from the kerf generated [7].

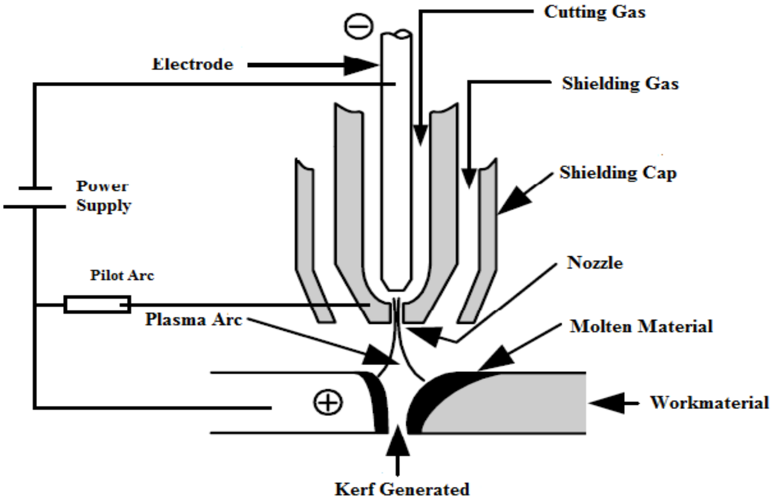

Fig.1 Schematic Representation of Plasma Arc Cutting Process

In the conventional system using a tungsten electrode the plasma is formed using either argon or nitrogen. However, the inert or non reactive plasma forming gas can be replaced with oxidising gas like air but this requires a special electrode of hafnium or zirconium mounted in a copper holder [8]. Quality of cut and dimensional accuracy produced by plasma arc cutting process can be accessed by measuring kerf width, bevel angle (conicity), heat affected zone (HAZ), surface finish and, material removal rate etc. Following Fig. 2 shows quality characteristics of plasma cutting [9].

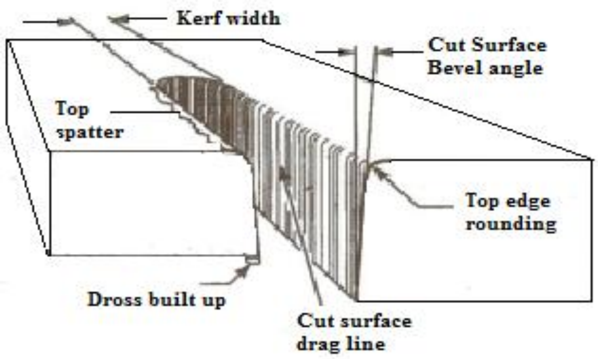

Fig.2 Quality Characteristics of Plasma Arc Cutting Process

During the process of plasma cutting the magnetic field is generated around the arc because of flowing current through it. There may be a difference in magnetic field along the length of the arc because of variation in

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pressure from electrode to the workpiece, which produces a resultant force on ionised particles of gas. This resultant force blows the arc in opposite direction to the concentration of magnetic field [10]. Not all the arc blow is disadvantageous. Sometimes small amount of arc flow can be used for benefit, help to form the bead shape, control molten slag and control penetration. When arc blow is causing defects such as undercut, inconsistent penetration, beads of irregular width, porosity, wavy beads, and excessive spatter, it must be controlled.

1.2 Parameters of plasma cutting process

Arc voltage, arc current, gas flow rate, gas pressure, cutting speed and, standoff distance etc. are the different parameters which affect the quality of the cut produced by using plasma arc cutting process [2-10]. A lower value of arc current and arc voltage was found to produce better responses as the increase in thermal content of the arc was observed to spoil the surface finish and increase the kerf width with increase in HAZ. They are required to be kept at higher side to cut work material having greater thickness. Cutting speed mainly depends on thickness of work material which is to be cut. As the thickness of the work material increases lower value of cutting speed tend to produce better cut quality [11].

Gas pressure plays an important role in removing the molten material from the kerf generated. Lower level of gas pressure will result in formation of spatter at the top side where as higher level will result in dross formation at the bottom edge. Standoff should be kept at lower side; higher standoff distance affects surface roughness and taper angle of the cut surface [12-13]. The plasma gas flow rate must be set according to the current level and the nozzle bore diameter. If the gas flow is too low for the current level or the current level too high for the nozzle bore diameter, the arc will break down forming two arcs in series, electrode to nozzle and nozzle to workpiece, which may result in melting of nozzle and electrode [14].

II LITERATURE REVIEW

This literature review highlights development and problems associated with various aspects related to plasma arc cutting such as effect of magnetic arc blow and nozzle geometry i.e. length of nozzle, bore diameter of nozzle etc. and the various optimisation techniques which are used to optimise process parameters with respect to response parameters.

2.1 Effect of Nozzle Geometry and Magnetic Arc Blow

Zhou et al. [15] analysed effects of nozzle length and process parameters on highly constricted oxygen plasma cutting arc. Long nozzle torch can provide high velocity plasma jet with high heat flux. Strong mass flow has pinch effect on plasma arc inside the torch enhances the arc voltage and power and therefore increases plasma velocity, temperature and heat flux. L Prevosto et al. [16] also investigated the effect of nozzle length on arc properties. The temperature and density profiles of arc were measured for different nozzle length by an electrostatic probe sweeping across arc formed. It is found that nozzle with shorter length produces a thinner and hotter arc than the nozzle with larger length. Bini et al. [17] carried out investigation to identify effect of nozzle geometry and process parameters on energy distribution across argon transferred arc. They used two nozzle geometries straight bore cylindrical and a convergent nozzle. A nozzle with convergent opening results in higher

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powers generation in the discharge for the same applied arc current, as compared to the case of a straight opening nozzle.

Takeru et al. [18] Examined relationship between operating condition and occurrence of abnormal discharge when an external magnetic field is applied to plasma jet with or without using magnetic shielding cap on a torch. It is found that higher value of arc current increases the magnetic flux density because of more deflection of plasma due to higher value of resultant force. Magnetic flux density also found to be decrease with decrease with decrease in gas flow rate. Deflected arc plasma tends to contact with nozzle wall if the nozzle is of smaller diameter. Hence in order to minimize occurrence of abnormal discharge the plasma arc should be driven at lower current, higher cutting gas flow rate and with larger nozzle diameter.

An Experimental study of magnetic arc blow for plasma arc cutting is being carried out by Yamaguchi et al. [19] in which they have studied the effect of magnetic field concentrated around the cutting front and the electromagnetic force induced by leak magnetic field which deflects the plasma jet, which causes poor cutting quality and may causes damage to the electrode and the nozzle by a double arc. Double arcing due to electromagnetic force can be eliminated by using a strong magnetic cap to the torch tip.

2.2 Optimisation of Process Parameters of Plasma Arc Cutting

A 200 A high tolerance plasma arc cutting (HTPAC) system is utilised by Bini et al. [20] to cut plates from 15mm thick mild steel sheets metals. Arc voltage, cutting speed, plasma gas flow rate, and shield gas flow rate and shield gas composition are included in the analysis. Their effects on kerf position and shape are evaluated. It was found out that the arc voltage is the main parameter and it influences all the aspects related with the cut quality. Unevenness of cut surface can be reduced by reducing cutting speed. Teja et al. [21] carried plasma arc cutting process on mild steel material to study impact of machining parameters on cut quality which is measured by kerf generated and surface finish. The machining parameters considered by him are arc current, arc voltage, cutting speed and plate thickness. From the analysis, it is found that the most significant parameters that affect the plasma arc cutting process are plate thickness followed by current.

Effect of process parameters on cut quality of stainless steel of plasma arc cutting using hybrid approach was done by Maity and Bagal [22]. A new composition of response surface methodology and grey relational analysis coupled with principal component analysis is used to evaluate and estimate the effect of machining parameters on the responses. Responses selected for the analysis are kerf, chamfer, dross, surface roughness and material removal rate. The corresponding machining parameters considered are feed rate, current, voltage and torch height. Torch height as well as interaction of torch height with feed rate is the most influencing parameters in plasma arc cutting machining. The plasma cutting process is investigated experimentally on S235 Mild steel sheets by Chamarthi et al. [23] investigated the effect of plasma arc cutting parameters on the Unevenness surface of Hardox-400 material. High tolerance voltage, cutting speed and plasma gas flow rate included as main parameters in the analysis and their effect on unevenness of cut surface is evaluated. The design of experiments (DoE) techniques is used in order to outline the main parameters which define the geometry of the cut profile, as well as its constancy. It was found out that the arc voltage is main parameter and it influences all the aspects related with the cut quality. Results obtained in the experimental stage shows that unevenness can be reduced by reducing the cutting speed.

Das et al. [24] found out optimal combination of MRR and Surface Roughness in PAC of EN 31 Steel Using Weighted Principal Component Analysis. For surface roughness characteristics five different surface roughness parameters centre line average roughness (Ra), root mean square (Rq), skewness (Rsk), kurtosis (Rku) and mean line peak spacing (Rsm) are considered. Three process parameters gas pressure, arc current and torch height are considered. Weighted principle component analysis is applied to compute a multi-response performance index (MPI) and then MPI has been optimized using Taguchi method.

Kechagias et al. [25] developed an Artificial Neural Network (ANN) in order to predict the bevel angle (response variable) during CNC plasma arc cutting of St37 mild steel plates. The four input parameters are selected plate thickness, cutting speed, arc ampere, and torch standoff distance. It found that bevel angle goes on decreasing with increase cutting speed, arc ampere and decreasing standoff distance.

III CONCLUSION

The present work just gives an overview of previously done researches and also for new research, it gives a direction for optimisation of plasma arc cutting using different optimization techniques. The conclusions drawn are discussed below,

- i The quality of cut produced by using plasma arc cutting process depends on arc voltage, arc current, standoff distance, gas pressure, gas flow rate, and cutting speed.
- ii Kerf width, heat affected zone, bevel angle, surface finish, dross and spatter formation are the different parameters which determines cut quality.
- iii Effect magnetic arc blow which results in arc deflection can be reduced by using proper combination of process parameters i.e. lower level of arc current, higher cutting gas flow rate and nozzle diameter.
- iv Arc current and arc voltage are found to be most significant parameter which affects cut quality of plasma arc cut.
- v The bevel angle or chamfer produced is mainly affected by the cutting speed. It decreases with decrease in cutting speed.
- vi Proper gas pressure is required to be maintained since lower value will result in formation of spatter at the top surface and higher value lead to dross formation at the bottom.
- vii Lower values of gas flow rate may result in double arcing which reduces the life of consumables i.e. electrode and nozzle.

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