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PARAMETRIC STUDY ON PLASMA ARC CUTTING OF AL – 6063

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Abstract —: *Plasma arc cutting is the thermal cutting process that developed at the end of the 1950s for cutting high-alloy steel, non-alloy steels, low-alloy steels and aluminium. Plasma arc cutting makes use of a constricted jet of high temperature plasma gas to melt and separate metal. The effect of process parameters like cutting speed, cutting current, gas pressure and stand-off distance will be studied on the response parameters like material removal rate, kerf width, bevel angle, by designing and performing the detailed experiments using orthogonal array (OA). Process performance data for various parameters will be analyzed using ANOVA. In this paper, the research and progress in plasma arc cutting process parameters of different materials are critically reviewed from different perspectives.*

Keywords*- Plasma Arc Cuttingl, Process Parameters,Response parameter, MRR, Design of experiment, ANOVA.*

I. INTRODUCTION

Plasma arc cutting is a thermal cutting process that makes use of a constricted jet of high-temperature plasma gas to melt and separate cut metal. Plasma arc cutting is a thermal non-traditional cutting process. It was designed to be used on all electrically conductive metals which, due to their chemical composition, could not be subjected to oxy-fuel cutting owing to its extremely high cutting speeds especially with thin materials and narrow heat-affected zone. The technique is also used today for cutting non-alloy steels and low-alloy steels.

Figure 1 shows plasma arc cutting process operates on direct current, straight polarity having electrode negative with a constricted transferred arc.

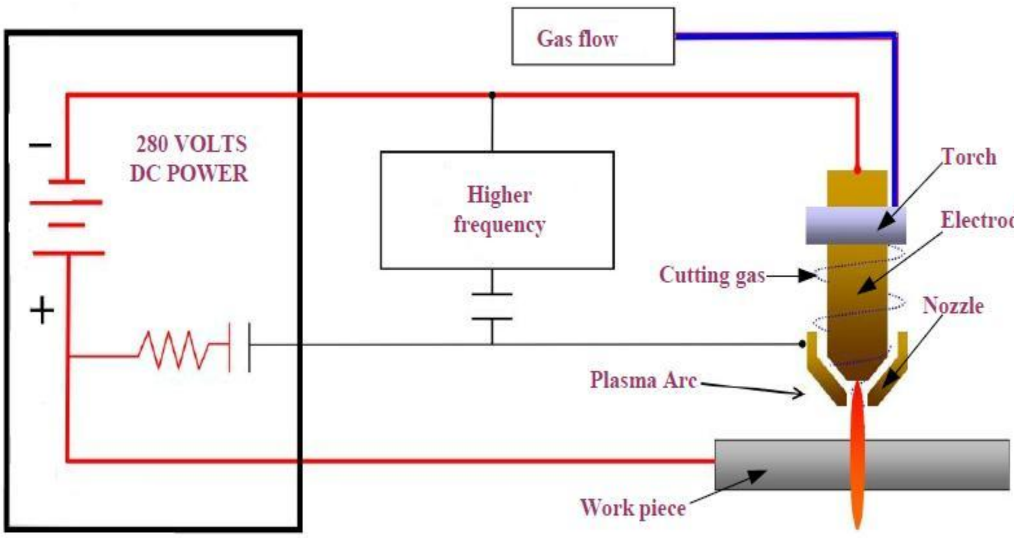

Figure 1: Schematic Diagram of Plasma Arc Cutting

In plasma arc cutting process, heated gas is transformed into a plasma gas, resulting in extremely high temperatures. To establish the arc, a low-current pilot arc is initiated by a higher voltage high-frequency discharge between electrode and nozzle of the torch. Air/Gas from the power supply is used to force the pilot arc out of the nozzle orifice. Once the pilot arc has been established, the work piece needs to be brought into the circuit. The most important step is converting the pilot arc between the electrode and nozzle into a transferred arc between the electrode and the work piece. As the torch approaches the work piece and the pilot arc contacts the plate, the nozzle and work piece start to share the plasma current. The power supply forces all current to go through the work piece and increases the current to the cutting level and melting specific area of metal with heat of a constricted arc, then removing the molten material with high-velocity jet of hot ionized gas expelled from the nozzle orifice of the cutting torch and cut the material. Plasma cutting arc is removed from the work piece after the cutting is completed and the electrical circuit is open which stops flowing current.

II. LITERATURE REVIEW

Maulik K. Bhalodiya[1] studied various process parameters of PAC machine and their influence on the cutting quality of SS410. For this experimental study the current, standoff distance (sod), cutting speed and gas pressure are referred as input process parameters. And material removal rate (MRR), kerf width, bevel angle and straightness were selected as output or response parameters. Response Surface Method was use for detail experiment. A regression analysis was performed to find out the best suitable mathematical model which gives the relation of input and output parameters. The Analysis of Variance was performed to find out the percentage contribution of each process parameters. From the results of ANOVA the current and cutting speed contributes 40 and 48 percent in material removal rate. The contribution of speed in bottom kerf width is 49% followed by current and SOD having 25%. For the top kerf width the speed, SOD speed and pressure SOD contributes respectively 25%, 30% and 15% followed by all other parameters. And for straightness the most influencing parameters is speed which contribute the 51% in straightness.

K. P. Maity and et.al [2] PAC on AISI 316 stainless steel conducting a hybrid optimization method has been carried out. RSM and GRA coupled with principal component analysis have been proposed to evaluate and estimate the effect of machining parameters. The optimum conditions of this process are the following: 970 mm/min of feed rate, 47.5 A of current, 140 V of voltage and 1.5 mm of torch height. Torch height as well as interaction of torch height with feed rate is the most affecting parameters in plasma cutting.

H.Ravi kumar and et.al[3] work is focused towards assessing the quality of cut surface like surface roughness and bevel angle of cut obtained with 21Cr ferritic stainless steel. Taguchi L9 OA was employed to design the cutting trials and grey based technique for order of preference by similarity to ideal solution TOPSIS analysis GTA was presented for designing the cutting parameters. The GTA was found to enhance the responses observed in PAC process permitting its usage in experimental cutting optimization. Optimal setting of cutting parameters for 21Cr Stainless steel as - air pressure: 5.5 bar, cutting speed: 1000 mm/min, arc current: 60 A and sod: 1 mm using PAC process. Analysis of variance was performed on GTI to reveal the major cutting parameters affecting the responses as cutting speed 46.88%, followed by the arc current 27.60% and air pressure 14.92%.

K. Salonitisa and et.al [4] study the plasma arc cutting on S235 mild steel was studied. Design of experiment (L9 OA) and ANOVA was used of further analysis. The quality of the cut had been examined by measuring the kerf taper angle (conicity), the edge roughness and the size of the heat-affected zone. Cutting power, scanning speed, cutting height and plasma gas pressure are input parameter. The regression analysis has been used for the development of empirical models able to describe the effect of the process parameters on the quality of the cutting. From this experiment it is seen that the surface roughness and the conicity are mainly affected by the cutting height, whereas the heat affected zone is mainly influenced by the cutting current.

J. KECHAGIAS and et.al [5] investigate of influence of input process parameters onto the dimensional accuracy performance of the plasma arc cutting process. The input cutting parameters studied were cutting speed in mm/min, torch standoff distance in mm, and arc voltage in volts. This experiment was carried out on St37 mild steel plates. An orthogonal matrix experiment L18 was conducted and the right bevel angle was measured and optimized according to the process parameters using an analysis of means and an analysis of variances. From this experiment it is seen that the arc ampere is the most important parameter that affects the right bevel angle by 50.89%. The torch standoff distance affects the right bevel angle by 15.9% and the plate thickness by about 6.22%.

Subbarao Chamarthi and et.al [6] In this review 12mm plate thickness of Hardox-400 was cut by high tolerance voltage, cutting speed, and plasma gas flow rate included as main input parameter. The design of experiments and ANOVA was used for analysis. From this experiment it is seen that Unevenness can be reduced by reducing the cutting speed. Very good quality can be achieved for all the sides by varying the cutting speed, plasma flow rate and arc voltage only.

BEGIC Derzija and et.al [7] investigate the effect of the cutting parameters on surface roughness and kerf width in plasma cutting of low alloy steel (EN 10025), and also obtained the optimum ranges of plasma gas pressure and cutting speed. From their experiment they concluded that kerf width decreases with increasing plasma gas pressure, while it slightly changes with increasing in cutting speed and surface roughness decreases by increasing plasma gas pressure and changes very slightly with increasing cutting speed.

Abdulkadir Gullu and et.al [8] investigate the cutting quality of plasma cutting on AISI 304 stainless steel and St 52 carbon steel and they also investigated the variations of structural specifications occurred after cutting. The effect of process parameters cutting speed, cutting height, material type and plasma gas pressure on heat affected zone and hardness was studied and it was concluded that after cutting, in the areas near to outer surface of the part hardness increased, around 250–350 HV, and it decreased towards to the core of the material and the area of 0.399–0.499 mm of stainless steel materials and 0.434–0.542 mm of carbon steel materials were more affected by heat according to cutting speed.

III EXPERIMENTATION

For current study a 6 mm thick AL 6063 plates was selected . The exploratory experiment was performed to find out the range of input process parameters and examine through cut on work piece.

It is observed from exploratory experiments that uniform levels of cutting speed cannot be selected for all current levels. So reduce cutting speed at low value of current. High dross and spatter formed at low speed, low current, low standoff distance and insufficient pressure as shown in figure 4.12 (1) and table. At high current, medium pressure, high speed and less stand-off distance less dross and spatter formation

C. RSM Based D.O.E.:

For this study the three low, medium and high levels of factors was selected and there are 4 factors were considered for the DOE viz. current, pressure, standoff distance and speed . A response surface method based DOE was selected for detail experiment. The observation table for detail experiment was as per table.

Runs	Input Parameters				Response Parameters			
	Current	SOD	Pressure	Speed	MRR mm^3/min	TKW mm	BKW mm	BA Degree
1	-1	-1	0	0	2560.955	1.983	0.852	16
2	1	-1	0	0	5264.545	2.422	1.156	17
3	-1	1	0	0	2131.512	2.597	1.316	17
4	1	1	0	0	5623.263	2.387	1.549	10
5	0	0	-1	-1	2838.008	1.838	1.193	13
6	0	0	1	-1	4077.956	2.062	1.508	10
7	0	0	-1	1	3869.848	1.734	0.828	16
8	0	0	1	1	3033.859	2.017	0.817	18
9	-1	0	-1	0	1835.409	2.301	1.2	18
10	1	0	-1	0	5183.951	2.397	1.35	14
11	-1	0	1	0	1277.505	2.339	1.194	19
12	1	0	1	0	5135.412	2.139	1.385	12
13	0	-1	0	-1	4071.765	2	0.885	17
14	0	1	0	-1	4057.794	1.953	0.938	16
15	0	-1	0	1	4522.067	1.791	0.887	17
16	0	1	0	1	4484.095	1.852	0.79	16
17	-1	0	0	-1	1236.297	2.45	1.276	16
18	1	0	0	-1	4686.753	2.52	1.712	10
19	-1	0	0	1	2200.751	2.219	1.151	20
20	1	0	0	1	4749.941	2.183	1.14	14
21	0	-1	-1	0	4558.922	2.203	0.946	17
22	0	1	-1	0	3996.959	2.169	1.042	14
23	0	-1	1	0	4287.099	1.843	0.671	16
24	0	1	1	0	4169.907	1.985	1.101	16
25	0	0	0	0	3511.317	2.232	1.101	19
26	0	0	0	0	4208.122	2.043	0.9	18
27	0	0	0	0	3693.476	2	0.827	19

Table detail experiment

Analysis Of Variance (ANOVA):

PARAMETERS	MRR	TKW	BKW	BA
Current	85.03	52.06	54.90	44.36
SOD	07.39	07.27	16.91	07.66
Pressure	00.57	04.57	02.04	05.92
Speed	03.61	19.21	09.87	27.28

III. CONCLUSION

1. From the above literature survey, it is seen that work has been done on plasma arc cutting of various materials like S235 mild steel, EN 10025, St37 mild steel and Hardox-400 and other steels like 21Cr ferritic stainless steel, EN 31 Steel, AISI 316 stainless steel, AISI 304 stainless steel and St 52 carbon steel.

2. Based upon the experiments, the effect of selected input parameters on the responses parameters such as bevel angle, unevenness of surface, kerf width, surface roughness, temperature distribution, and heat affected zone and hardness were studied.

3. From the main effect plot and ANOVA table for MRR the current, stand-off distance and speed are more significant parameter follow by pressure. The percentage contribution of current, stand-off distance, pressure and speed on MRR are 85.03%, 07.39%, 00.57% and 03.61% respectively. MRR is increase at pressure slight increase and then decrease and for stand-off distance the effect is reverse as compared to pressure.

4. From the results of analysis of variance for Top kerf width the percentage contribution of current, stand-off distance, pressure and speed on Top kerf width are 52.06%, 07.27%, 04.57% and 19.21% respectively. From main effect plot for top kerf width increase in current top kef width decrease and then increase with increase current. With increase in stand-off distance top kerf width is increase. While increase in pressure and speed cause top kerf width fall off.

IV. GAP IDENTIFICATION

1. From the literature review it is concluded that work was done on plasma arc cutting of different materials like SS 304, SS 410,SS 316, EN 31 Steel, AISI 316, Hardox-400, S235 mild steel, AISI 1017 mild steel, EN 10025, St37 mild steel, AISI 304,etc. and hence it is concluded that very less work has been done on Aluminium material high corrosion resistance which is used window frame, doors, extrusion, shop fitting, irrigation tubing.

2. The effect of input parameters on material removal rate (MRR) can be studied.

3. Optimization of the parameters can be done using Taguchi method, Response surface methodology or Grey Relational Analysis.

V. FUTURE WORK

1. The effect of air plasma arc cutting process parameters on cutting of Aluminium 6063 material.

2. The detailed experiments will be performed on the basis of orthogonal array (L9 OA) and the parameters like material removal rate (MRR), kerf width (top and bottom), bevel angle, straightness will be measured by varying cutting current, cutting speed, gas pressure and stand- off distance.

3. The process performance data will be analyzed for various parameters using ANOVA and the optimum combination of process parameters will be obtained.

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