The Effects of Process Parameters of Plasma Arc Cutting on Cutting Quality of SS410

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Abstract— Now a day this advance non-conventional machining processes is the life line of any industry. One of the most important non-conventional machining methods is plasma arc machining. Its high accuracy, finishing, high speed and ability to machining any hard surface it become a very preferable for industry. According to available review it has been proved that by selecting proper process parameters we can cut any material by plasma arc machining with high MRR, lower kerf width, bevel angle and high surface finish. But the current technology in the field of PAC is steel insufficient to find out the most favorable parameters to cut any specific material with desired cutting quality. In this research paper the various process parameters of plasma arc cutting machine and their influence on the cutting quality of SS410 is to be studied. For this study the current, standoff distance, cutting speed and gas pressure are referred as process parameters. And material removal rate, kerf width, bevel angle and straightness were selected as response parameters. The trial cut experiment was performed to find out the range of process parameters for detail experiment. The detail experiment was performed on the basis of Response Surface Method (RSM). A regression analysis was performed to find out the best suitable mathematical model which gives the relation between input and output parameters. The Analysis of Variance (ANOVA) was performed to find out the percentage contribution of each process parameters.

Key words: plasma arc cutting, material removal rate, Kerf width, standoff distance, current, gas pressure, Cutting speed, bevel angle

I. INTRODUCTION

Nowadays, the different types of thermal cutting techniques have been applied for cutting materials in different fields of mechanical engineering, process technology and shipbuilding. Plasma arc cutting (PAC) is one of them a very important thermal cutting process. An advanced Plasma arc cutting technique was developed at the end of the 1970s for cutting stainless steel, manganese steel, titanium alloys, copper, magnesium, aluminium and its alloys.

Today metal cutting is characterized by higher quality demands and are expected to exhibit maximum dimensional accuracy. Plasma arc cutting have indirect competition with other techniques such as conventional hacksaw cutting oxy-fuel cutting, laser cutting and water jet cutting. However it can also be an alternative to the mechanical processing techniques such as punching and drilling.

II. PLASMA ARC CUTTING (PAC)

Plasma arc cutting is the process that cuts through electrically conductive materials by means of an accelerated jet of hot plasma. The basic plasma arc cutting process involves creating an electrical channel of ionized gas i.e. plasma from the plasma cutter itself, through the work piece to be cut, thus forming a completed electric circuit back to the plasma cutter via a grounding clamp. This is accomplished by a compressed gas (oxygen, air, inert and others depending on material being cut) which is blown through a focused nozzle at high speed toward the work piece. The block diagram of plasma arc cutting is shown in figure 1.

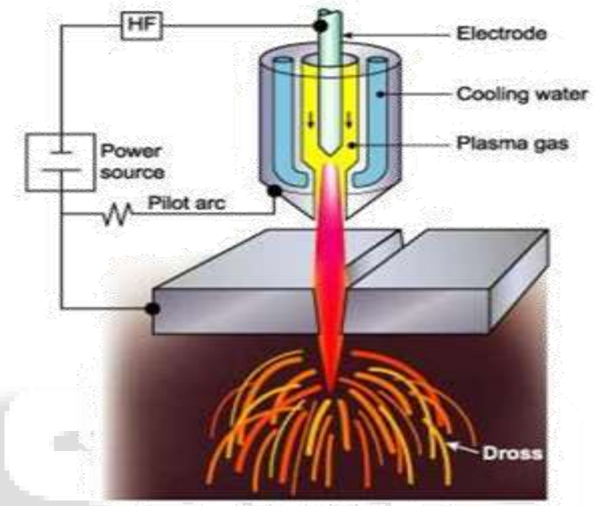

Fig. 1: Plasma arc cutting

Types of plasma arc [9]

1) Dual Gas PAC
2) Water Injection PAC
3) Water Shroud PAC
4) Air PAC

III. MAJOR AREAS OF EXPERIMENTAL RESEARCH IN PLASMA ARC CUTTING

"S. M. LLII et al." [1] Analyze the plasma arc cutting (PAC) process, by using the systemic approach method. They select cutting speed, current intensity and plasma arc voltage as process parameters for their analysis. They found that the cutting speed parameter (vt) is analysed as an evaluation factor of the cutting process machinability. The cutting speed (vt) represents one of the most important parameters in the case of plasma cutting process, due to the fact that this parameter has a direct influence on the productivity of the process and on the quality of the obtain surfaces also.

"K. Salonitis and S. Vatousianos" [2] the aims of their work had to investigation and determination of the most important parameters that influence the cutting quality on oxygen plasma cutting. They were select processing parameters, such as current; cutting speed, torch height and plasma gas pressure. They were performed their experiments on a CNC plasma with a dual flow torch. They were used 15 mm thick S235 mild steel sheet as working material and oxygen as primary and air as secondary gas.

They had selected the Taguchi method for the DOE based on Orthogonal Array (OA). The Taguchi method employs a generic signal-to-noise representing the magnitude of the mean of a process compared to its variation. These data were analyzed using ANOVA techniques as to identify percentage contribution of each process parameters. With the S/N and the ANOVA analyses, the optimal combination of the process parameters can be predicted.

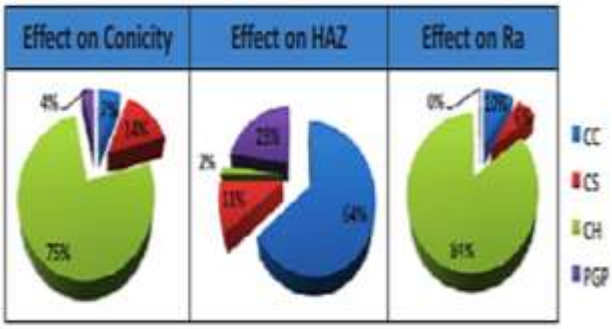

Fig. 2: Effects of process parameters on conicity, HAZ and Ra [2]

On the basis of their experiment they were concluded that the cutting height is the parameter with the greatest influence on the quality characteristics of the process. This has resulted in an on-going research on the development of automatic and adaptive torch height control systems.

"K. P. Maitry and Dilip Kumar Bagal" [3] They were optimized the process parameters of plasma arc cutting of AISI 316 stain less steel having a thickness of 120mm. The whole experiment of plasma arc cutting process was carried out by the MESSER Company built CNC plasma machine named as BURNY 1250, where the cutting process was conducted in Hypertherm environment. The parameters of oxygen supply, fuel gas supply and power supply were fixed at 20 MPa, 1.2MPa and 400 VDC, respectively.

Response surface method coupled with grey relational analysis and principal component analysis had been carried out to optimize plasma arc cutting processes with multi-objective criteria.

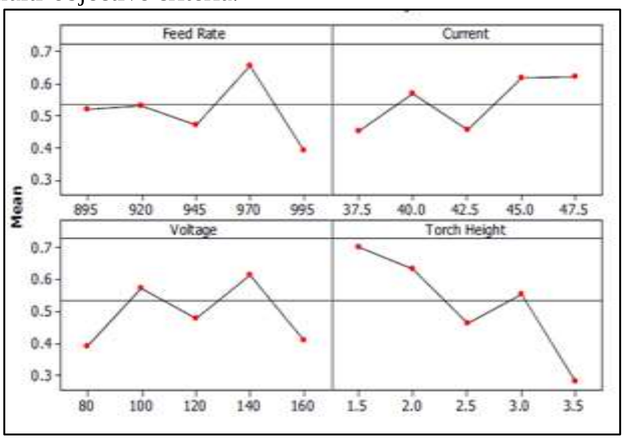

Fig. 3: Main Effects Plot for Overall Grey Relational Grade

"Kulvinder Rana et al." [4] The aim of their work was the optimization of PAC of mild steel thin plates, both in terms of cut quality and performances of the consumables, to achieve cut quality standards and productivity levels usually obtainable through laser cutting processes. The temperature of the plasma arc melts the metal and pierces through the work piece while the high velocity gas flow removes the molten material from the bottom of the cut.

According to their analysis they were conclude that The current has maximum effect on the process after that torch travelling speed and stand-off distance and air pressure have minimum effect on the process. The overall optimum values of each parameter give the calculation was, the optimum current is 65 A optimum air pressure was 65 psi, optimum torch travelling speed was 3.0 m/min, optimum stand-off distance was 3.0 mm of having and Heat Affected Zone. As from the observation they found that it is cheaper than laser cutting for thick plates and from oxy-acetylene for thin plates. PAC has better cut quality and minimum Heat affected zone.

IV. EXPERIMENTATION

A. *Selection of Material:*

For current study a 6 mm thick SS410 plates was selected due to its magnetic properties and has good application properties like resistance against corrosion, heat and chemicals. The trial cut experiment was performed to find out the range of process parameters which gives through cut on workpiece.

So that on the basis of result concluded by trial cut, for the detail experiments the cutting speed for lower current range was 1.1250 to 1.2857 m/min and for the high current the speed was 1.200 to 1.3846 m/min can be adopted. The pressure level for all range of current was 3 to 4 bars and SOD was 2.5 to 3.5 mm can be adopted.

B. *Experimental Setup:*

Fig. 4: Experimental setup for detail experiment

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 1.

Ex. No	Pressure	Current	SOD	Speed	MRR	TKW	BKW	Bevel angle	St
Units	*(bar)*	*(amp)*	*(mm)*	*m/min*	*(mm^3/min)*	*(mm)*	*(mm)*	*(deg.)*	*(mm)*
1	3.5	35	2.5	1.38	4508.6	2.48	1.51	3.61	0.31
2	3.5	40	3	1.38	4951.9	2.3156	1.81	2.43	0.32

3	4	35	2.5	1.28	3696.6	2.1195	1.60	2.34	0.32
4	3	35	2.5	1.28	4022.9	2.4160	1.59	4.28	0.31
5	3	30	3	1.20	2251.5	2.1159	1.83	2.87	0.30
6	3.5	30	2.5	1.20	2402.6	2.0043	1.63	2.1	0.34
7	3.5	35	3.5	1.38	3825.0	1.9594	1.76	2.49	0.39
8	4	30	3	1.20	2221.1	2.3308	1.92	2.07	0.45
9	4	35	3	1.20	2678.0	2.5520	2.02	2.64	0.31
10	3.5	40	2.5	1.28	3573.8	2.2187	2.14	0.82	0.33
11	3.5	35	3	1.28	2945.3	2.09	1.48	3.85	0.35
12	3.5	30	3	1.12	1486.1	2.48	2.52	0.46	0.43
13	3.5	35	3	1.28	3478.9	2.18	1.53	3.55	0.35
14	3	40	3	1.28	3414.0	2.20	1.61	2.58	0.26
15	3.5	30	3.5	1.20	2035.9	2.24	1.98	2.22	0.46
16	3.5	35	3.5	1.20	2366.8	2.49	1.69	4.39	0.34
17	3.5	35	2.5	1.20	2535.1	2.04	1.95	1.25	0.32
18	4	35	3	1.38	4224.1	2.18	1.67	3.08	0.32
19	3	35	3.5	1.28	3150.0	2.03	1.46	3.73	0.31
20	3	35	3	1.38	4425.3	2.43	1.69	3.54	0.27
21	4	40	3	1.28	4168.7	2.37	1.82	3.32	0.20
22	3.5	35	3	1.28	3657.9	2.16	1.58	3.68	0.31
23	3.5	30	3	1.28	2722.9	1.97	1.48	2.62	0.35
24	3.5	40	3	1.20	2162.4	2.25	1.93	1.54	0.18
25	4	35	3.5	1.28	3754.2	2.40	1.58	5.28	0.39
26	3.5	40	3.5	1.28	4077.1	2.09	1.23	4.82	0.22
27	3	35	3	1.20	2451.5	2.23	1.83	2.77	0.29

Table 1: Detail experiment runs

D. Modeling Using Regression Analysis:

Regression analysis is a statistical process for estimating the relationships among input and output variables. The regression analysis generates the mathematical model which gives the correct relation between predictor and the response variable. The mathematical model for various parameters are as per below.

MRR =	112.98P + 336.23C – 90.93SOD + 1438.26S + 165.34P2 - 215.17C2 +101.68SOD2 – 367.01S2 +258.58P*C + 232.63P*SOD - 188.72P*S + 300.88C*SOD + 723.58C*S – 252.58SOD*S + 3049.23
TKW =	0.0726P + 0.09578C + 0.0411SOD – 0.1698S + 0.0998P2 – 0.0866C2 -0.0129SOD2 + 0.2163S2 + 0.0544P*C + 0.1664P*SOD – 0.2008P*S + 0.0132C*SOD + 0.0855C*S – 0.3128SOD*S + 2.1778
BKW =	0.0601P + 0.0880C - 0.0915SOD – 0.4167S + 0.0458P2 + 0.0385C2 -0.0164SOD2 + 0.4530S2 + 0.0545P*C + 0.0.282P*SOD – 0.0781P*S - 0.03825C*SOD + 0.0701C*S – 0.2038SOD*S + 1.60843
BA =	-0.0662P + 0.1280C – 0.9248SOD – 1.1556S + 0.2070P2 – 0.8808C2 + 0.0593SOD2 – 1.5873S2 + 0.4284P*C + 0.8698P*SOD – 0.1413P*S + 1.4569C*SOD + 0.49178C*S – 1.4773SOD*S + 3.4621
ST =	0.0190P - 0.0687C + 0.01083SOD + 0.0183S - 0.0217P2 – 0.0374C2 + 0.0154SOD2 – 0.0263S2 - 0.0553P*C + 0.0174P*SOD – 0.0099P*S – 0.0647C*SOD + 0.1027C*S + 0.0242SOD*S + 0.3400

E. Analysis Of Variance (ANOVA):

The analysis of variances is performed to get the percentage contribution of each process parameters. The contribution of each parameters and their interaction are shown in table 2.

PARAMETERS	Percentage contribution				
	MRR	TKW	BKW	BA	ST
PRESSURE	2%	9%	2%	6%	7%
CURRENT	40%	1%	13%	20%	51%
SOD	1%	1%	5%	19%	4%
SPEED	48%	25%	49%	18%	4%
PRESSURE*CURRENT	1%	2%	0%	2%	11%
PRESSURE*SOD	1%	15%	1%	9%	1%
PRESSURE*SPEED	0%	10%	1%	0%	2%
CURRENT*SOD	2%	5%	25%	13%	14%
CURRENT*SPEED	2%	1%	0%	0%	5%
SOD*SPEED	0%	30%	4%	13%	1%
ERROR	1%	1%	0%	0%	1%
TOTAL	100%	100%	100%	100%	100%

Table 2: ANOVA Table

V. RESULT AND DISCUSSION

From the comparison of experimental data and model generated data it is observed that the residual and adjusted residual for the MRR is relatively 98.1 % and 95.8%, for TKW it is 97.4% and 94.3%, for BKW it is 98.8% and 97.5%, for bevel angle it is 99.3% and 98.5% and for straightness it is 97.6% and 94.8%. This percentage shows that all the data is very close to the residual line.

Here for all the response parameters have approximately more than 95 % Residual Square and adjusted residual square value which is under the acceptable level. So that the mathematical model used for give the relationship between input parameters and output parameters is good up to acceptable level.

CONCLUSIONS

In this paper, it is concluded that

The regression analysis model conclude that the second order non-linear mathematical model is best suited to give the relation between process parameters and various response parameters. By the comparison of experimental data and model predicted data it is observed that the experimental data is highly fitted with regression model line and for all response parameters the value of R square and adjusted R square are above 95% which is tolerable.

From the results of analysis of variance the current and cutting speed contributes 40 and 48 percent in material removal rate. For the top kerf width the speed, SOD*speed and pressure * SOD contributes respectively 25%, 30% and 15% followed by all other parameters. The contribution of speed in bottom kerf width is 49% followed by current and SOD having 25%. There are equal contribution of current, SOD and cutting speed for bevel angle. And for straightness the most influencing parameters is speed which contribute the 51% in straightness.

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