Experimental Investigations to Analyse Effect of Process Parameters on Material Removal Rate in Cutting Mild Steel Using Plasma ARC

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Abstract - In this paper the plasma cutting process for the evaluation of the quality of cutting is experimentally examined. Measurement of the material removal rate (MRR) has been monitored for the quality of the cut. This work aims at evaluating three process parameters namely the Kerfs, cutting speed and stand of distance. The results were analyzed statistically to obtain significant parameter. The results have been statistically analyzed so that significant parameters that determine the quality of cut in terms of MRR have been achieved. The study of regression was used to establish mathematical models in order to predict the effect of process parameters on the material removal rates of mild steel samples with PAC. Using analysis of variance, it was found that the MRR was mainly affected by the Kerfs with contributed to 60.06 % followed by stand of distance which contributed 27.37 % and cutting speed contributing 4.14 % towards MRR for selected parametric values.

Keywords: Plasma arc, Kerfs, cutting speed and stand of distance.

I. INTRODUCTION

A lot of metals such as Aluminium, mild steel, stainless steel, high speed steel including non-ferrous metals and alloys of copper tin and magnesium are machined using plasma Arc cutting (PAC) which is a non-conventional machining process. Approximately 30 years ago research suggested that plasma arc cutting can be used for cutting metals, which was previously done by other conventional sources. Oxygen gas arc cutting was applied during those times which had many drawbacks like inaccurate dimensions, low production rates, so much as the equipment itself was not reliable. There were drawbacks such as taper cutting, uneven profile shape, and also deposition of metal below the workpiece in some cases, which were all caused due to problems in the machine setting. So it was found that setting the machine precisely is highly required to achieve the best outcomes. With the demand of precision machining for applications of materials like mild steel, there is need of an optimal set of process parameters for the improvement in responses, like MRR. For this reason, plasma Arc cutting was synchronized with CNC during the 1980s so as to cut even the intricate patterns in a short duration of time, which means the cutting speed was increased.

II. PRINCIPLE AND WORKING

A machining process which uses a plasma torch for cutting metal sheets of varying grade and thickness is known as plasma arc cutting. From the nozzle comes an inert gas such as oxygen, nitrogen, argon, even compressed air at some instances at a very high speed, and electric arc is generated on the workpiece. The arc ionizes the gas transforming it into plasma. The temperature and pressure of the workpiece is so high that it can melt the workpiece and carry the molten metal away from the workpiece. The procedure of cutting precision profile patterns, sheets of different metals of mild steel and stainless steel, aluminum, copper, magnesium, etc. using a plasma torch is known as plasma arc cutting.

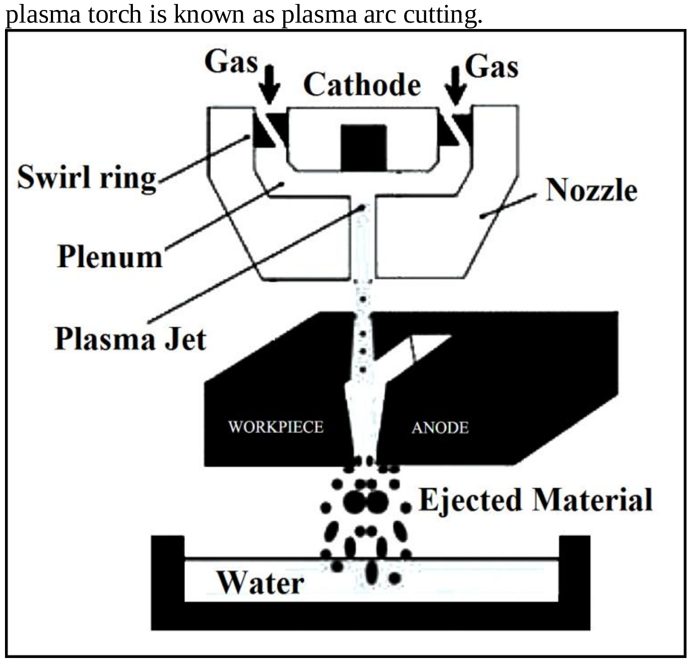

Figure 1: Plasma Arc cutting

An electric arc is formed amid the electrode and the workpiece along with the blowing mixture of an inert gas at very high speed. A very high temperature and pressure is produced which melts the workpiece and carries away the molten metal leading to precision cuts. This process can be used for other applications like machining, welding, and other specialized applications.

III. MATERIAL & EQUIPMENT

Nine samples with dimension 70mm x 30mm x 10 mm were primed for the investigational work. Mild Steel was the material selected for the test specimen. Mild steel contains 0.15% to 0.45% carbon which has tensile strength of 555 N/mm^2 and hardness of 140 BHN.

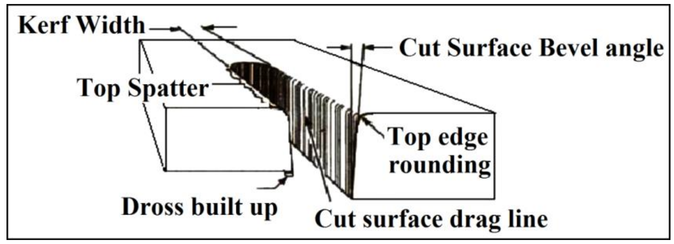

Figure 2: Quality Characteristics of Plasma Arc Cutting Process

Table 1: Mechanical Properties of Mild steel

Type of steel	% carbon	BHN No.	Tensile Strength	Yield Strength	%elongation	%Reduction in area
Mild Steel	0.10-0.30	120-150	420-555	355-480	36-21	66-55

Table 2: Composition range for Mild steel.

C	Si	Mn	P	S	Al	N
0.07	0.01	0.21	0.006	0.012	0.35	0.006

Apparatus for the testing:

1. CNC Plasma arc cutting system EDGE Pro, Hypertherm with Sensor THC.
2. Digital mass balancer equipment.
3. The Taper measured by using height gauge and Magnetic V Block

IV. EXPERIMENTAL PROTOCOL

This is the most important component of the cutting system and can be a laser, oxy-fuel or water-jet system. The plasma gases, the assist gas and its mixture is controlled by this. The other key parameters such as standoff and speed of cutting for cut quality is also provided here

Table 3 Technical Features

Technical Features	Machine
Supply Voltage	100 VAC - 240 VAC
Frequency	50 - 60 Hz
Current	1.85 amps at 100 VAC - 0.65 amps at 240 VAC
Temperature	10^o C - 50^o C
Operating Pressure	5 bar
Pilot Arc Current	50 - 80A
Slow Blow Fuse	2Amp at 100VAC to 220VAC

An L9 OA was found to be satisfactory for the needs of this analysis. For L9 to study the entire parameter area, nine combinations of parameters must be tested. Table 4 sets out the parameters that must be tested and the rates of every parameter.

Table 4: L9 Orthogonal array in terms of actual values

Run No.	Kerfs	Cutting speed	Stand of distance
1	1.50	1400	4
2	1.50	1500	5
3	1.50	1600	6
4	2.00	1400	5
5	2.00	1500	6
6	2.00	1600	4
7	2.50	1400	6
8	2.50	1500	4
9	2.50	1600	5

V. EXPERIMENTAL RESULTS & OBSERVATIONS

Experiments were formulated based on Taguchi's design of experiments with the L9 orthogonal array using Minitab 17 software tool. The construction of empirical models for the Kerfs combined effect, the cutting speed and the stand of distance on the MRR were done via regression analysis.

Table 5 Experimental observations for MRR

Exp No.	Mass 1 (Before Cutting)	Mass 2 (After Cutting)	Mass Loss (g)	Time Taken (Sec)	MRR (g/Sec)
1	783	161.5	621.5	10	78.21
2	787	161.7	625.3	09	69.48
3	780	161.0	619	08	77.38
4	785	160	625	10	76.23
5	782	161.3	620.7	09	68.97
6	789	161.9	627.1	08	78.39
7	787	161.9	625.1	10	62.51
8	789	162	627	09	69.67
9	791	161.3	629.7	08	80.21

The S / N ratio is a tool for evaluating the MRR. The goal is to optimize the three selected characteristics in order to maximize the MRR value. The research criterion chosen was therefore the "higher the better". The quality responsive chart against the three control parameters selected is shown in Fig. 3.

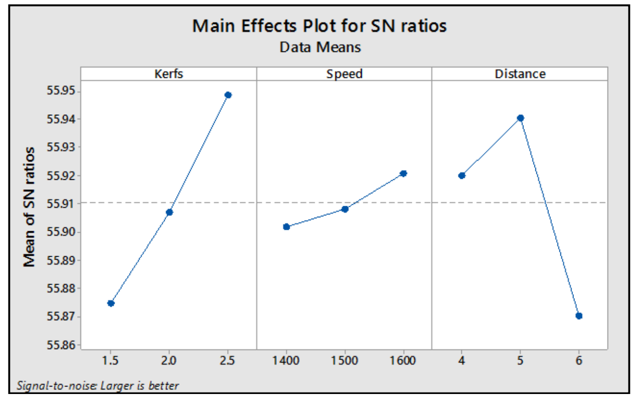

Figure 3 Main effects plot for S/N Ratio (MRR)

Table 6: General linear Model (ANOVA) for MRR.

Source	DF	Seq SS	Contribution	Adj SS	Adj MS	F-Value	% Contribution
Kerfs	1	42.667	44.92 %	42.667	42.667	7.12	60.06
Speed	1	2.940	2.10 %	2.940	2.940	0.49	4.14
Distance	1	19.440	20.47 %	19.940	19.440	2.25	27.37
Error	5	29.942	31.52 %	29.942	5.988		8.43
Total	8	94.989	100.00 %				100

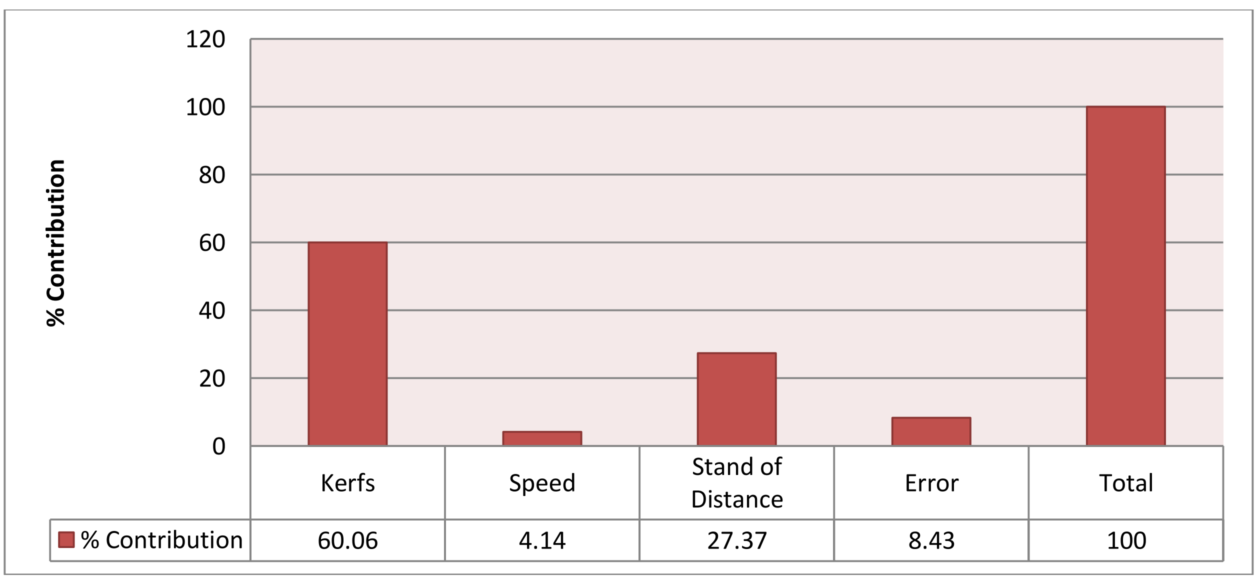

Figure 4: Percentage contribution of process parameters effecting MRR.

Figure 5 shows Contours along with three dimensional surfaces for the response MRR between kerfs and Cutting speed. Figure 6 represents MRR between the responses of kerf and stand of distance.

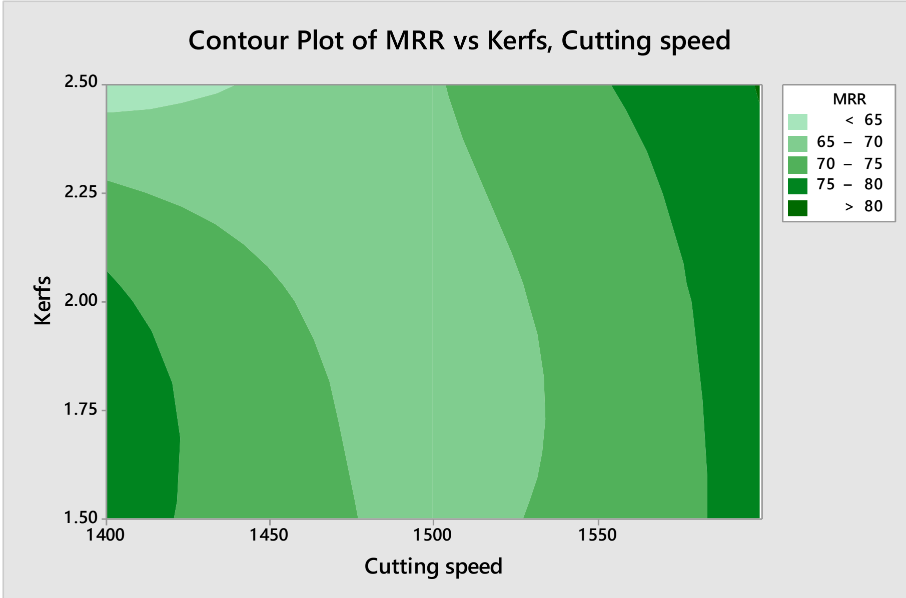

Figure 5: Contour plot of MRR for Kerfs and Cutting speed

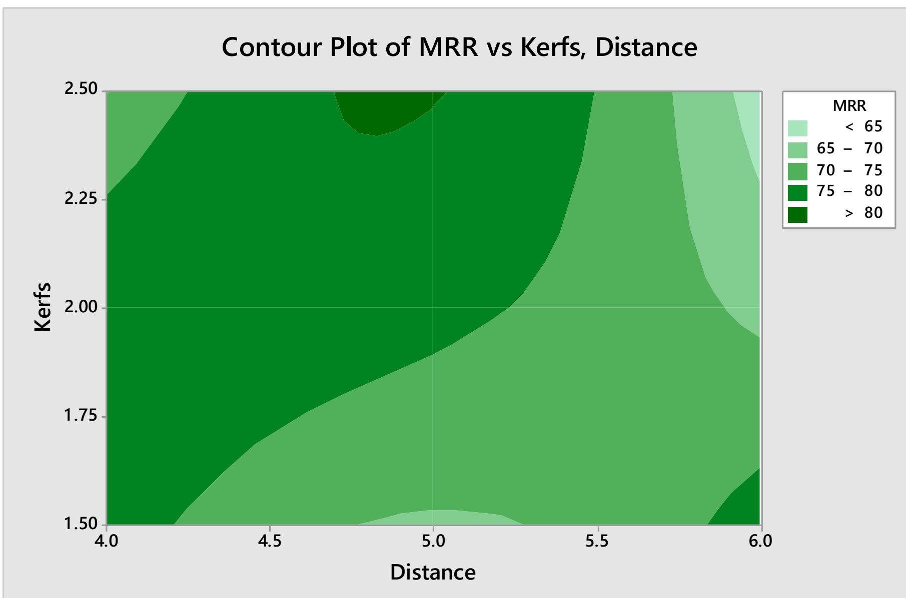

Figure 6: Contour plot of MRR for Kerf and Stand of distance

Based on the above developed experimental model of contour plots, MRR in terms of three most influencing process parameters levels was obtained through regression analysis.

Table 9 Optimal value of Material Removal Rate.

Sr. no.	kerfs	Cutting speed	Stand of distance	Material Removal Rate.
1	2.52	1600	5	78.71

VI. CONCLUSION

The following conclusion can be mentioned from the study:

- Using analysis of variance, it was found that for selected parametric values the MRR was mainly affected by the Kerfs width stand of distance followed by cutting speed.
- For Maximum Material removal rate the kerf width play a very important role. Higher the value of kerf width speed more is the MRR. The Kerfs with contributed to 60.06 % .
- While the oxygen and Air is used as the cutting gas the oxidation reaction will occur and result in width of better quality kerfs.
- The stand of distance which contributed 27.37 %.
- The cutting speed contributing 4.14 % towards MRR.

VII. REFERENCES

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