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ANALYSIS OF PROCESS PARAMETERS AND THEIR OPTIMIZATION OF CNC PLASMA ARC CUTTING

Engineering

KEYWORDS: MRR, Taper, Kerfs, Cutting Speed and Standoff-distance.

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ABSTRACT

Automated CNC plasma cutting is an effective process for building complex two dimensional metallic parts in a short period of time. The research and development in the precise and accurate machining technology of hard metals (Ferrous and non-ferrous etc) is gaining much importance in the industry since last many years. Due to the tremendous competition and cost factor, the non-conventional machining technology is becoming the first choice of the engineers and technicians. In this era of advanced technological processes the CNC plasma arc machining is gaining tremendous ground in the industry. The main objective and targets of this practical experiment is based to achieve the best possible setting and parameters of operation on a CNC plasma arc machine to maximize the Maximum material removal rate (MRR) and to minimize the TAPER.

INTRODUCTION

Automated equipment and good shop layout normally improves speed, precision and quality regardless of which type of fabrication is performed.

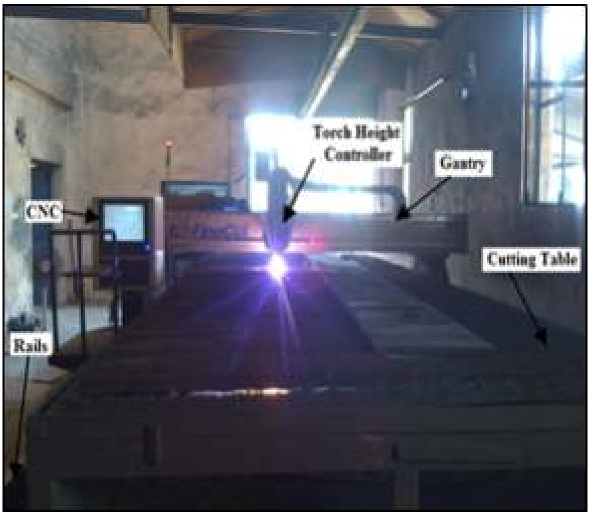

Figure 1.1 CNC Plasma Arc Cutting Machine.

Plasma arc cutting (PAC) is a non-conventional machining process. This is most suitable for machining quite a number of metals like Mild steel, stainless steel etc. This technique is also employed for machining, field steel as well as non ferrous metals and alloys i.e. (Copper, Aluminum, Tin, magnesium and there alloys). Plasma arc machining or plasma arc cutting is a process that is used to cut precision profiles patterns, sheets of different metals by the help of a plasma torch or Plasma gun.

An inert gas as a mixture is blown through a nozzle at a very high speed along with an electric arc formed between the electrode and workpiece. A very high temperature is produced by the arc which is used to cut the metal by melting it and by removing away the molten metal efficiently by gas pressure. This Process is also used for plasma arc cutting, machining, welding and some other specialized applications.

OBJECTIVES

The main purpose of this experimental work was to study the plasma arc cutting parameters in smooth cutting using straight polarity process. The objectives of this work are listed below:

[1] To study about the influence of Plasma Arc Cutting Parameters on Mild Steel material.

[2] To design a series of experiments with the help of Design of Experiments (DOE) technique layout in order to study Plasma Arc Cutting (PAC).

[3] To derive the best combination of solution for maximizing the Material Removal Rate (MRR) and for minimizing the Taper with Taguchi Method.

EXPERIMENTATION

In this work of plasma machining, the plasma is usually initiated by a high voltage pulse which creates a conductive path for a continuous electric arc to form between the hot tungsten cathode and anode. The working gas flows around the tungsten cathode and through a constricting tube or nozzle. The temperature, in the narrow orifice around the cathode, reaches 28,000°C which is enough to produce a high-temperature plasma arc. Under these conditions, the metal being machined is very rapidly melted and vaporized. The stream of ionized gases flushes away the machining debris as a fine spray creating flow lines on the machined surface. The removal rates by this method are substantially higher than those of conventional single-point turning operation.

The effect and optimization of process parameters for plasma arc cutting on 10mm mild steel plate. Three process parameters Kerfs, cutting speed and standoff distance are considered and experiments are conducted based on L9 orthogonal array (OA). Process responses i.e. material removal rate and Taper was observed for various sets of experiments with different combinations of process parameters based on L9 array. For maximum material removal rate (MRR) and for minimum Taper, Characteristics process parameters are optimized based on Taguchi method. Analysis of variation (ANOVA) is performed to get the contribution of each process parameter on the performance characteristics and it observed that cutting speed is significant process parameter that affects the response i.e. material removal rate and kerfs is significant process parameter that affects the response i.e. Taper.

RESULTS & DISCUSSION

Experimental design strategy, using Taguchi orthogonal arrays concept as used. The following L-9 orthogonal array was applied:

Table 1.1 L-9 Orthogonal array with actual values

Mass 1 (Before Cutting)	Mass 2 (After Cutting)	Mass Loss (g)	Time Taken (Sec)	MRR (g/Sec)	Width1 (mm)	Width2 (mm)	Taper Width (W1-W2)
783	161.5	621.5	10	62.15	30.90	29.58	1.32
786	160.7	625.3	09	69.48	30.78	29.60	1.18
770	159.0	611	08	76.38	30.80	29.76	1.04
793	160.7	632.3	10	63.23	30.92	29.34	1.58
789	159.3	629.7	09	69.97	30.88	29.40	1.48
770	158.9	611.1	08	76.39	30.76	29.62	1.14
798	159.4	638.6	10	63.86	30.82	28.99	1.83
788	158.7	629.3	09	69.93	30.56	29.04	1.52
775	157.8	617.2	08	77.15	30.68	29.28	1.40

Observations in Taguchi Analysis: MRR versus kerfs, cutting speed, standoff distance

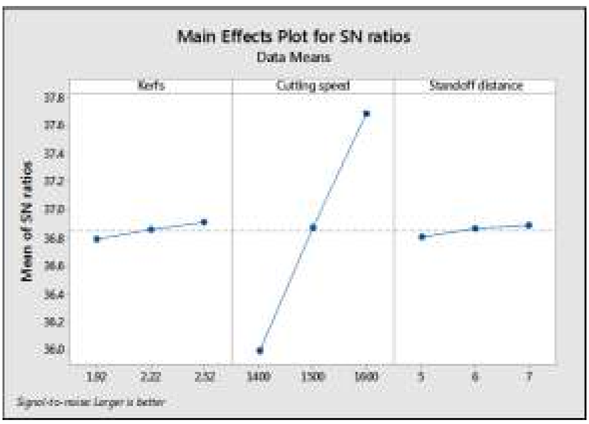

Figure 1.2 Main effects plot for S/N Ratio (MRR)

The SN ratio graph figure1.2 was made using 3 variables i.e. kerfs, cutting speed and standoff distance. As observed from graph, it is clear that at 2.52mm of kerfs, 1600mm/min cutting speed and 7mm Standoff distance gives the best output in terms of Material removal rate will be maximize.

ANOVA Test results for Material removal rate

Table 1.2 General linear Model (ANOVA) for MRR

Source	DF	SS	MS	F	P	Contribution %
Kerfs	2	1.434	0.717	40.25	0.024	0.516
Cutting speed	2	275.81	137.90	7742.9	0.000	99.26
Standoff distance	2	0.565	0.282	15.85	0.0595	0.203
Residual Error	2	0.036	0.018			
Total	8	277.85				

From the ANOVA model for the above experimentation, the calculations are done at 95% confidence level. In an analysis of variance table, the P value determines the most significant factor. The factor whose P value is less than 0.05 will be most effective factor. The ANOVA table clearly indicates that Kerfs and Stand of distance parameter is not significant parameter for defining the MRR. Cutting speed parameter are significant, means that these terms influence the model to a great extent. Cutting speed has the greatest effect on MRR and is followed by Kerfs and Standoff distance.

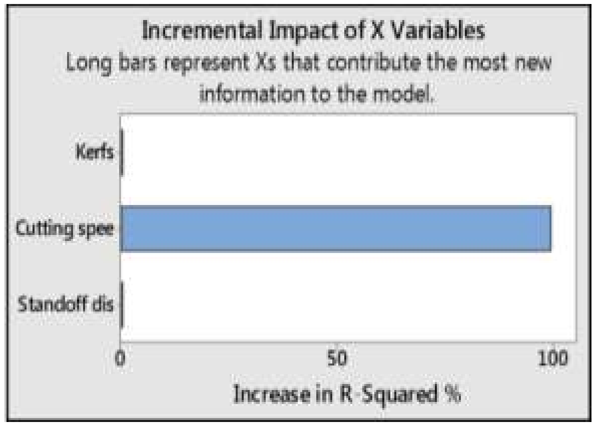

Figure 1.3: Impact of variables

General Regression equation for MRR versus Kerfs, Cutting speed and Standoff distance

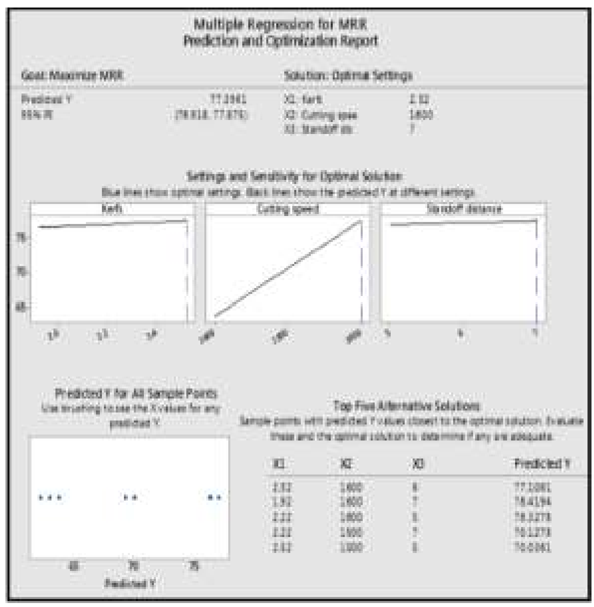

Figure1.4 Multiple Regressions for MRR (Prediction and optimization report)

The above figure 1.4 indicate that the optimal settings for maximum material Removal Rate (MRR).

The following model equation in the figure below has been formed with the help of software MINITAB version 17:

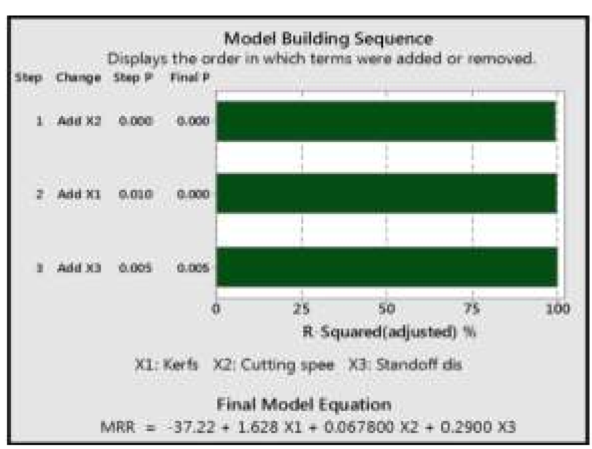

Figure 1.5 Model Equation

Model Adequacy Check: The P-value of Regression equation (0.050) indicates that the regression model is significant. The coefficient of determination (R2) which indicates the goodness of fit for the model so the value of R2=99.96% which indicate the high significance of the model.

Optimized Parameters Combination

As Material Removal Rate is the "larger is better: type quality type characteristic, from the figure 1.2 it can be seen that the third level of kerfs(A3), third level of Cutting speed (B3) and third level of Standoff distance (C3) results in maximum value of Material Removal Rate.

Table 1.3 Optimal value of Material Removal Rate.

Sr. no.	kerfs	Cutting speed	Standoff distance	Material Removal Rate.
1	2.52	1600	7	77.40

Contour plots for MRR

Contours along with three dimensional surfaces are shown in figure 1.6, 1.7 and 1.8 with the help of these contours the value of response can be calculated at any point in the designed region. The figure 1.6 shows the response MRR between cutting speed and kerfs. In this the other parameter Stand of distance kept constant to the higher value. Figure 1.7 shows response MRR between the Cutting speed and Standoff distance. In this the other parameter applied Kerfs constant to the higher value. Figure 1.8 shows response MRR between the Standoff distance and kerfs. In this the other parameter applied cutting speed constant to the higher value.

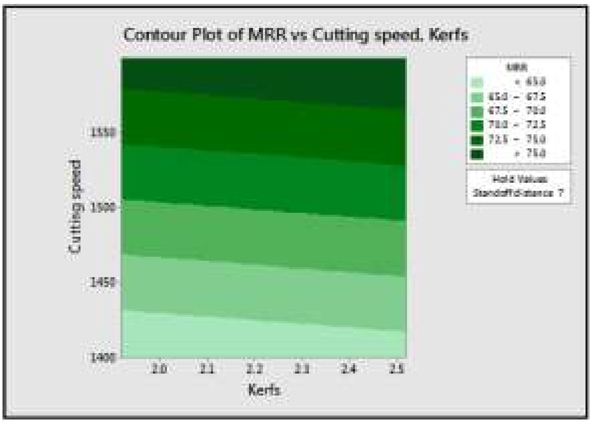

Figure 1.6 Contour plot of MRR for Cutting speed and Kerfs

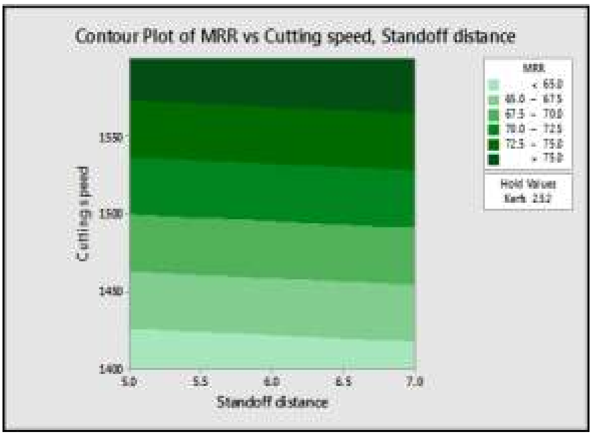

Figure 1.7 Contour plot of MRR for Cutting speed and Standoff distance

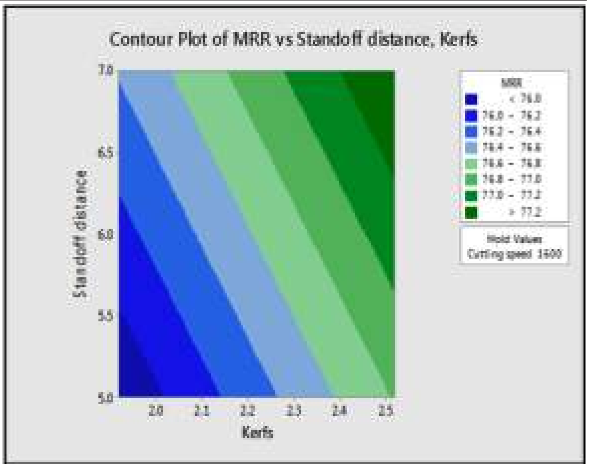

Figure 1.8 Contour plot of MRR for Standoff distance and Kerfs

Observations in Taguchi Analysis: TAPER versus kerfs, cutting speed, standoff distance

The Means graph was made using 3 variables i.e. kerfs, cutting speed and standoff distance. As observed from graph, it is clear that at 1.92 mm of kerfs, 1600 mm/min cutting speed and 5mm standoff distance gives the best output in terms of minimize the TAPER.

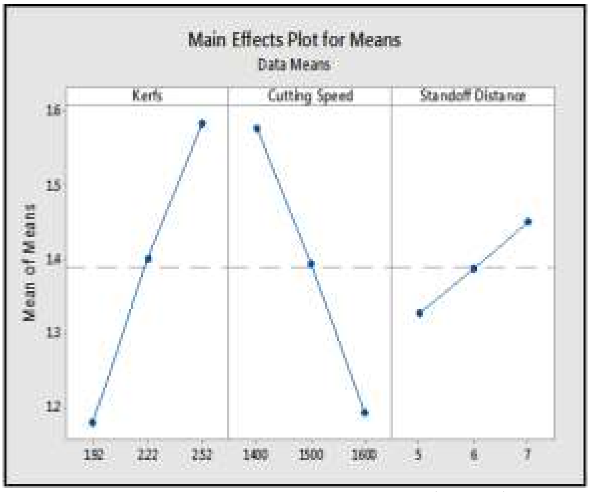

Figure 1.9 Main effects plot for Means (TAPER)

ANOVA Test results for TAPER.

From the ANOVA model for the experimentation, the calculations are done at 95% confidence level. In an analysis of variance table, the P value determines the most significant factor. The factor whose P value is less than 0.05 will be most effective factor. The ANOVA table clearly indicates that Stand of distance parameter is not significant parameter for defining the Taper. Cutting speed and kerfs parameters are significant, means that these terms influence the model to a great extent. Kerf has the greatest effect on TAPER and is followed by cutting speed and Standoff distance.

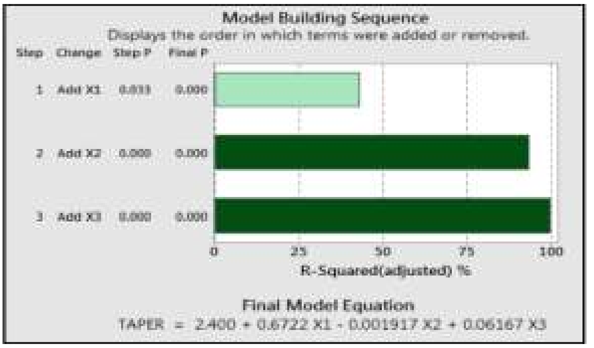

Figure 2.1: Model Equation

Model Adequacy Check: The P- value of Regression equation (0.050) indicates that the regression model is significant. The coefficient of determination (R2) which indicates the goodness of fit for the model so the value of R2=99.69% which indicate the high significance of the model.

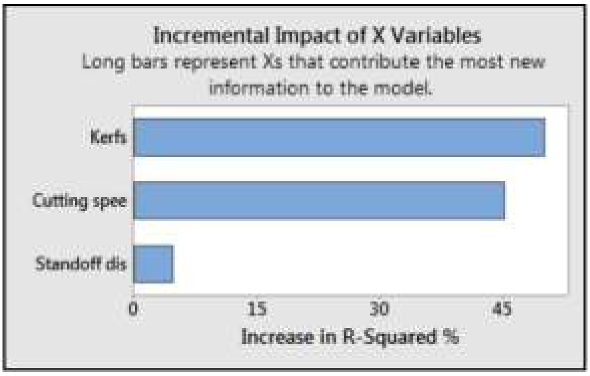

Figure 2.2: Impact of variables

Optimized Parameters Combination

As Taper is the "Smaller is better" type quality type characteristic, from the figure1.9 it can be seen that the first level of kerfs(A1), third level of Cutting speed (B3) and first level of Standoff distance (C1) results in minimum value of Taper.

Table 1.5 Optimal value of TAPER.

Sr. no.	kerfs	Cutting speed	Standoff distance	TAPER
1	1.92	1600	5	0.931774

Contour Plots for Taper

Contours along with three dimensional surfaces are shown in figure 2.3, 2.4 and 2.5 with the help of these contours the value of response can be calculated at any point in the designed region. The figure 2.3 shows the response Taper between kerfs and cutting speed. In this the other parameter Stand of distance kept constant to the smaller value. Figure 2.4 shows response Taper between the Cutting speed and Standoff distance. In this the other parameter applied Kerfs constant to the smaller value. Figure 2.5 shows response Taper between the kerfs and Standoff distance. In this the other parameter applied cutting speed constant to the smaller value.

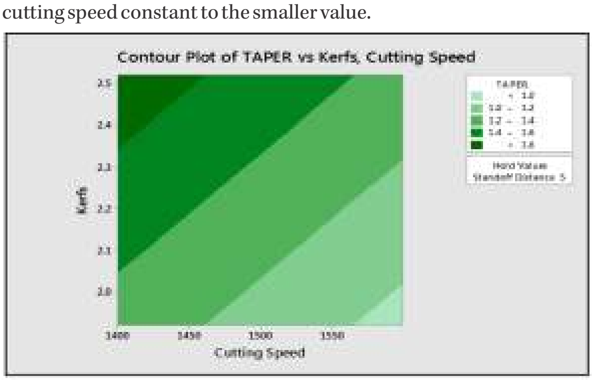

Figure 2.3 Contour plot of TAPER for Kerfs and Cutting speed

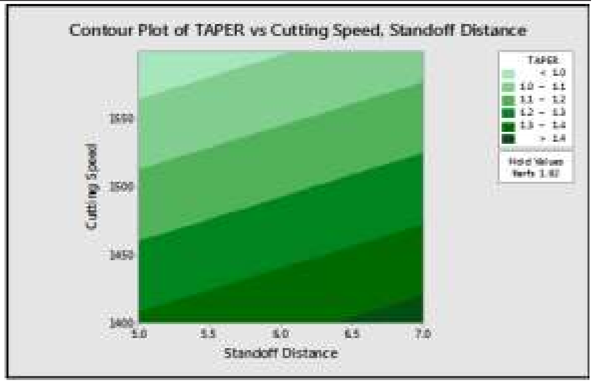

Figure 2.4 Contour plot of Taper for Cutting speed and Stand-off distance

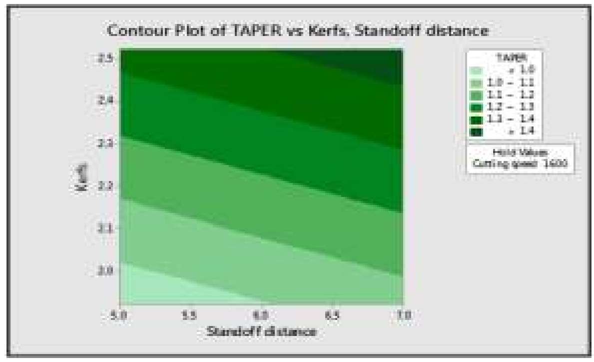

Figure 2.5 Contour plot of Taper for Kerfs and Standoff distance

CONCLUSION

This work presents an application of the Taguchi method to the optimization of the machining parameters of CNC Plasma Arc Cutting Machine. As shown in this study, the Taguchi method provides a systematic and efficient methodology for determining optimal parameters with far less work than would be required for most optimization techniques. The confirmation experiments were conducted to verify the optimal parameters. It has been shown that Material Removal Rate (MRR) and Taper can be significantly improved in the CNC Plasma Arc Cutting process using the optimum level of parameters. From ANOVA of MRR we can say that some parameters are not making any significant effect. This is because we must take large number of observations either by considering L27 or L32 orthogonal array with 3 level designs. From experimental analysis done on MILD STEEL, it was concluded that:

[1] In CNC plasma arc machining the cutting Speed is the parameter has a significant effect on MRR whereas the other parameters viz. Kerfs and standoff distance are less effective.
[2] Taper is mainly affected by the kerfs and cutting speed. The kerf is directly proportional to the Taper and the cutting speed is inversely proportional to the Taper.
[3] The steam as the plasma gas will generate more energy than other gases for the same current value and the plasma jet generated is much narrowed when Oxygen and air is used as plasma gases.
[4] For Maximum Material removal rate the cutting speed play a very important role. Higher the value of cutting speed more is the MRR.

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