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MULTI-RESPONSE PARAMETER OPTIMIZATION OF CNC PLASMA ARC MACHINING USING TAGUCHI METHODOLOGY

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ABSTRACT

This research work focuses on to find out the best possible combination of optimum process parameters in plasma arc cutting system during the machining of 12mm mild steel plate. Plasma arc cutting machine uses different process parameters like cutting speed, arc current, torch standoff distance to perform any cutting operation and response variables like material removal rate (MRR) and a kerf width gets changes corresponding to the input parameters. To optimize of all these process parameters multi responses analysis is done through experimental data obtained by using Taguchi's L9 orthogonal array as design of experiments and all data is analysed by Analysis of mean (ANOM) and Signal to Noise graphical approach using Minitab18 software to observe which input parameter has more effect on response variables.

KEYWORDS: *Plasma cutting, mild steel, Taguchi's L9, S/N Ratio, Analysis of Mean.*

1. INTRODUCTION

The aim of this research work is to attain an optimum combination of process parameters to obtain maximum material removal rate (MRR) and minimum the Kerf width of cutting material. Plasma is the state of matter contains high temperature gas which conducts electricity. When any gas is heated up to very high-temperature plasma gas is formed, during this process gases atom gets ionized help to conduct electricity through it. The difference between a normal and plasma gas is that the particles in a plasma gas can apply electromagnetic forces (EMF) on each other. From the past few years, plasma cutting gets more popular than oxy-acetylene cutting because it allows a wide range of the material which is electrically conductive like stainless steel, aluminium, copper, bronze etc. to a wide range of thickness. The plasma cutting jet extreme hot and narrower than oxy-acetylene cutting flame so cutting by plasma result obtains has smaller kerfs width and cleaner cut. That makes plasma arc cutting most popular and suitable for cutting sheet metal as compare to oxy-acetylene cutting because in oxyacetylene lots of slag formation below cutting edge which is not tolerable on other hand plasma focuses on to kept heat affected zone minimize as possible. From last few decades the improvements in plasma get speed up plasma machine now has integration with the CNC machine controlled by touch screen, minimizing the accessibility of a large number of button making operation simple and less complex. Also, new technology provides flexibility to the machine so that it can be operated through any operating system installed in the machine. For training purpose the operator can learn machine in short period of time with more efficiency, also it makes operator do less work because of auto controlled height console and does not need to make a frequent adjustment for torch consumables. Plasma cutting technology generally uses gases like argon, nitrogen and compressed air to produce a plasma jet and that jet are used to cut electrically conductive metal. S. Srinivasa Raju et al [1] work on a mild steel plate to obtain excellence quality of cut by measuring bevel angle as a quality parameter and the result shows that bevel angle is more affected by cutting speed and least influence by cutting current. Aristidis Tsiolikas et al [2] uses Plasma arc machine for cutting mild steel plate to examine the effect of each individual parameter on surface roughness. Analysis of means (ANOM) and analysis of variances (ANOVA) illustrates that all parameters put an equal effect on the surface roughness and the noise factors cause bigger variance than other process parameters progressively. K. Salonitis et al [3] the research shows that cutting current ampere affect more on heat affected zone while conicity and surface roughness (SR) are mostly affected by the torch cutting height.

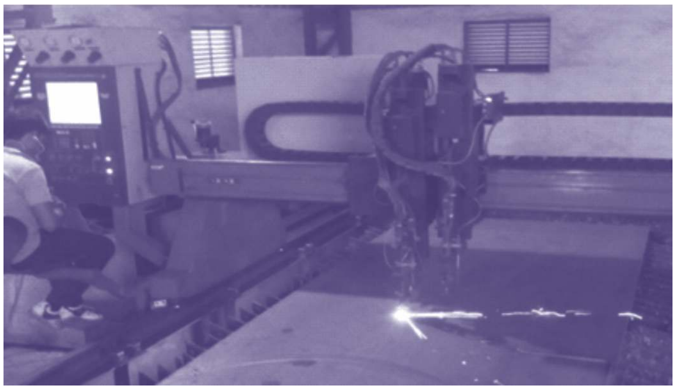


Fig.1. CNC plasma arc cutting machine

2. PROBLEM FORMULATION AND STATEMENT

In plasma machining, there are various problem associate during the operation. The material selection, thickness of material, process parameters, working environment affect the quality of cut, material removal rate, kerf width and surface roughness etc. also the combination of various input parameter influence on the cutting operation, like arc current is more than a limit it raises the temperature due to which heat affected zone area increases, if cutting speed is more it is difficult for plasma arc to penetrate the work material also it leads improper cutting, splashing of molten metal and surface roughness also if torch standoff distance is kept more it does not penetrate the material and less standoff distance leads wide kerf with dross formation. To avoid this problem optimization of process parameters must be done to obtain maximum Material removal rate with Minimum Kerf width..

3. OBJECTIVE OF STUDY

1. To study the impact of input parameters on response variable in Plasma Arc Cutting system during the cutting operation on 12mm mild steel plate.
2. Find out the best combination of the input parameter to improve the cutting process.
3. Optimization of process parameter focuses to maximize material removal rate (MRR) and minimize the kerf width.

4. EXPERIMENTAL DESIGN

The experimental data obtained byperforming numbers of experiments on Hypertherm Powermax105 CNC plasma cutting system. The process parameters considered in this dissertation work for the cutting of 12mm mild steel plate are cutting speed, arc current ampere, torch standoff distance and the response variables considered which to be measured are material removal rate and kerf width. Air & Nitrogen is taken as a plasma gas to cut 12mm Mild steel plate.

Table 1.Different levels of parameters

S. No.	Factors	Level 1	Level 2	Level3
1	Cutting Speed (mm/min)	1000	1500	2000
2	Arc Current (amp)	65	85	105
3	Torch standoff (mm)	2.5	2.0	1.5

To design the experiments, orthogonal arrays are one of the method that requires only a few experimental trials to find which factors effects mainly on output. Here at least 9 experiments are conducted for the 3 factors 3 level process parameters, from Minitab18 software the Taguchi orthogonal L9 arrays shown in the table:

Table 2. Taguchi orthogonal L9 array

Number of Experiment	Cutting speed	Arc current	Torch standoff
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	2
5	2	2	3
6	2	3	1
7	3	1	3
8	3	2	1
9	3	3	2

4.1 Material Selection

Material selection for this dissertation work is 12mm mild steel plate. This steel is considered to provide superb welding and cutting properties also it provides considerable potentials to save material costs, processing cost, and handling the cost. Mild steel which contains small percentage of carbon are known as low or plain carbon steel generally it compromises 0.05 to 0.25 % of carbon which provides it great malleability and ductility also relatively low tensile strength. Low-carbon steels are the best choice in to minimize deflection or failure also it is easier to be easier to handle.

Table 3. Mechanical Properties of Mild Steel [6]

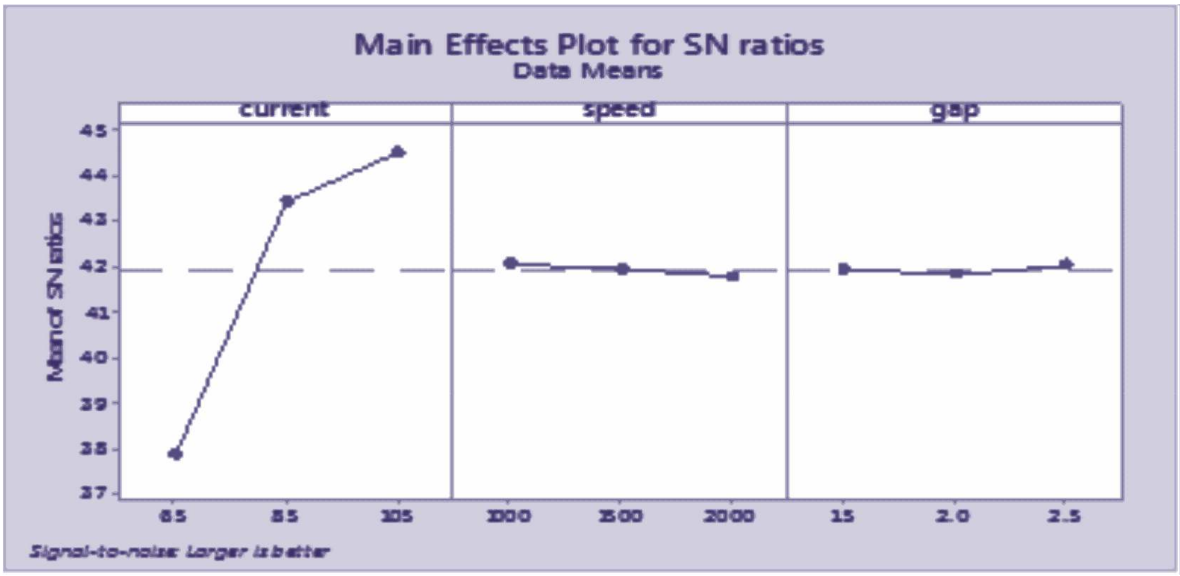
Yield strength	Tensile strength	Elongation	Density
350Mpa	490Mpa	22%	7.7 g/cm^3

5. RESULT AND MEASUREMENT

5.1 ANALYSED DATA FOR HIGHER MRR

Table 4. S/N &Mean data for MRR

Process Parameters			Response Variables		S/N Ratio	Mean
Arc current (amp)	Cutting speed (mm/min)	Torch standoff (mm)	MRR (g/min) Trail 1	MRR (g/min) Trail 2	Larger-is-Better	
65	1000	2.5	80	81.67	38.150	80.835
65	1500	2.0	78.33	76.67	37.784	77.500
65	2000	1.5	75	78.33	37.685	76.665
85	1000	2.0	151.67	145	43.418	148.335
85	1500	1.5	156.67	143.33	43.496	150.000
85	2000	2.5	146.67	148.33	43.375	147.500
105	1000	1.5	175	166.67	44.643	170.835
105	1500	2.5	168.33	170	44.565	169.165
105	2000	2.0	163.33	165	44.305	164.165



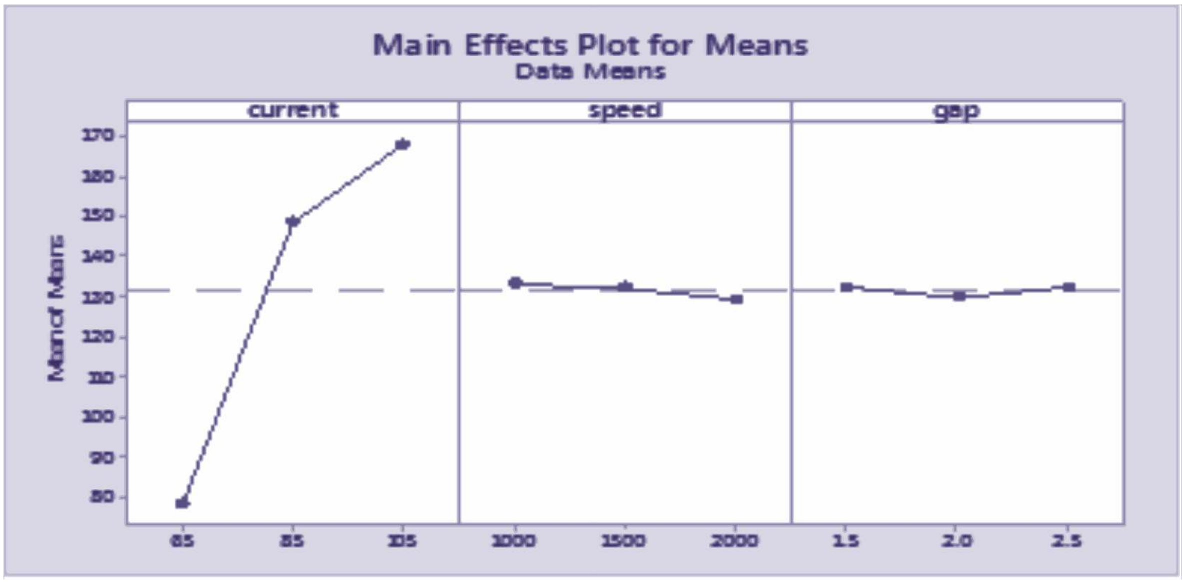


Fig.2. Main effect plot of S/N ratio Mean for higher MRR

Table 5. Response table for S/N Larger-is-better MRR

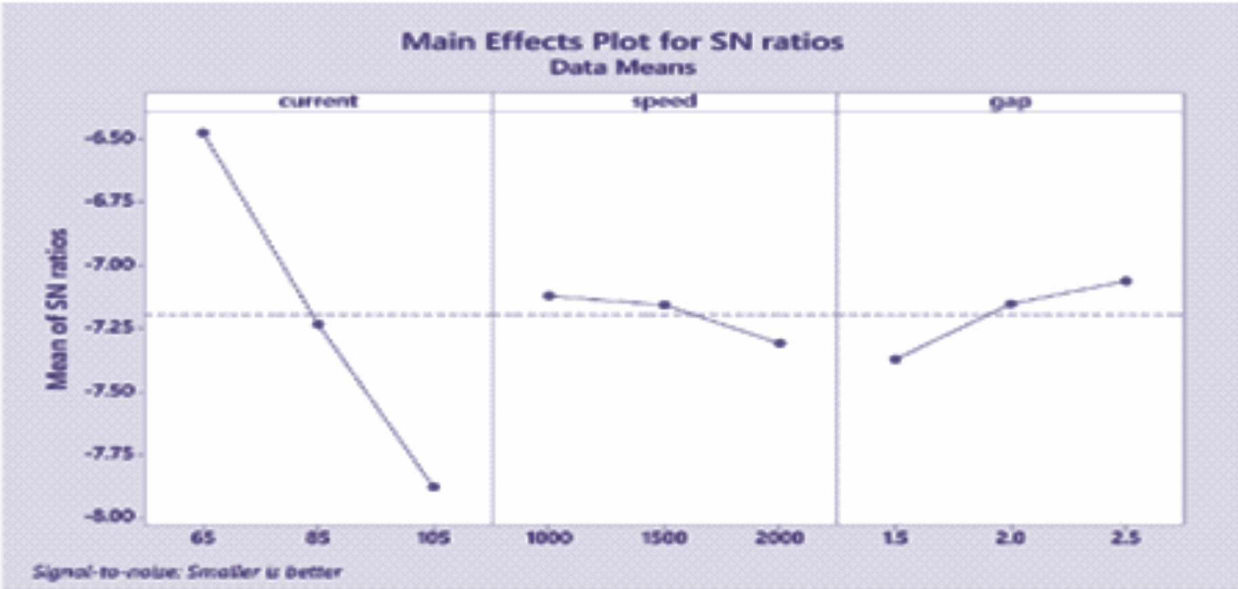
Level	Arc current	Cutting speed	Torch standoff
1	37.87	42.07	41.94
2	43.43	41.95	41.84
3	44.50	41.79	42.03
Delta	6.63	0.28	0.19
Rank	1	2	3

5.2 Analyzed data for smaller KERF

Table 6. S/N & Mean data for KERF width

Process Parameters			Response Variables		S/N Ratio	Mean
Arc current (amp)	Cutting speed (mm/min)	Torch standoff (mm)	KERF Width (mm) Trail 1	KERF Width (mm) Trail 2	For Smaller-is-better	
65	1000	2.5	2.00	2.12	6.281	2.060
65	1500	2.0	2.10	2.05	6.340	2.075
65	2000	1.5	2.20	2.18	6.808	2.190
85	1000	2.0	2.30	2.26	7.159	2.280

85	1500	1.5	2.35	2.33	7.384	2.340
85	2000	2.5	2.25	2.31	7.159	2.280
105	1000	1.5	2.50	2.48	7.924	2.490
105	1500	2.5	2.42	2.46	7.748	2.440
105	2000	2.0	2.48	2.52	7.959	2.500



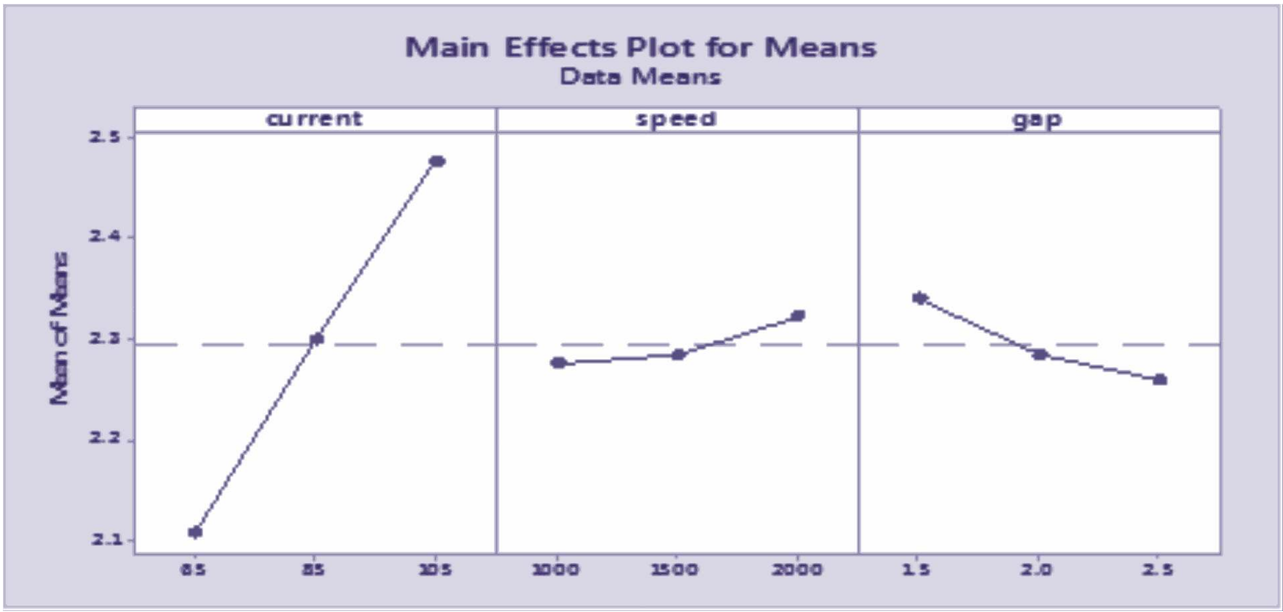


Fig.3. Main effect plot of S/N ration & Mean for smaller KERF

Table 7. response table for means of smaller kerf

Level	Arc current	Cutting speed	Torch standoff
1	2.108	2.277	2.340
2	2.300	2.285	2.285
3	2.477	2.323	2.260
Delta	0.368	0.047	0.080
Rank	1	3	2

5.3 Multi-Response Parameter Optimization

To examine the effect of process parameter for getting minimum kerf width and maximum MRR simultaneously up to the satisfactory level upper limit and the lower limit is set in the minitab18 software as shown in the table. And graph for the multiple optimizations is plotted on the basis of the weight and importance provide to each parameter.

Table 8. Target table for multi-response optimization

Response	Goal	Lower	Target	Upper	Weight
KERF	Minimum		2.06	2.5	1
MRR	Maximum	76.667	170.833		1

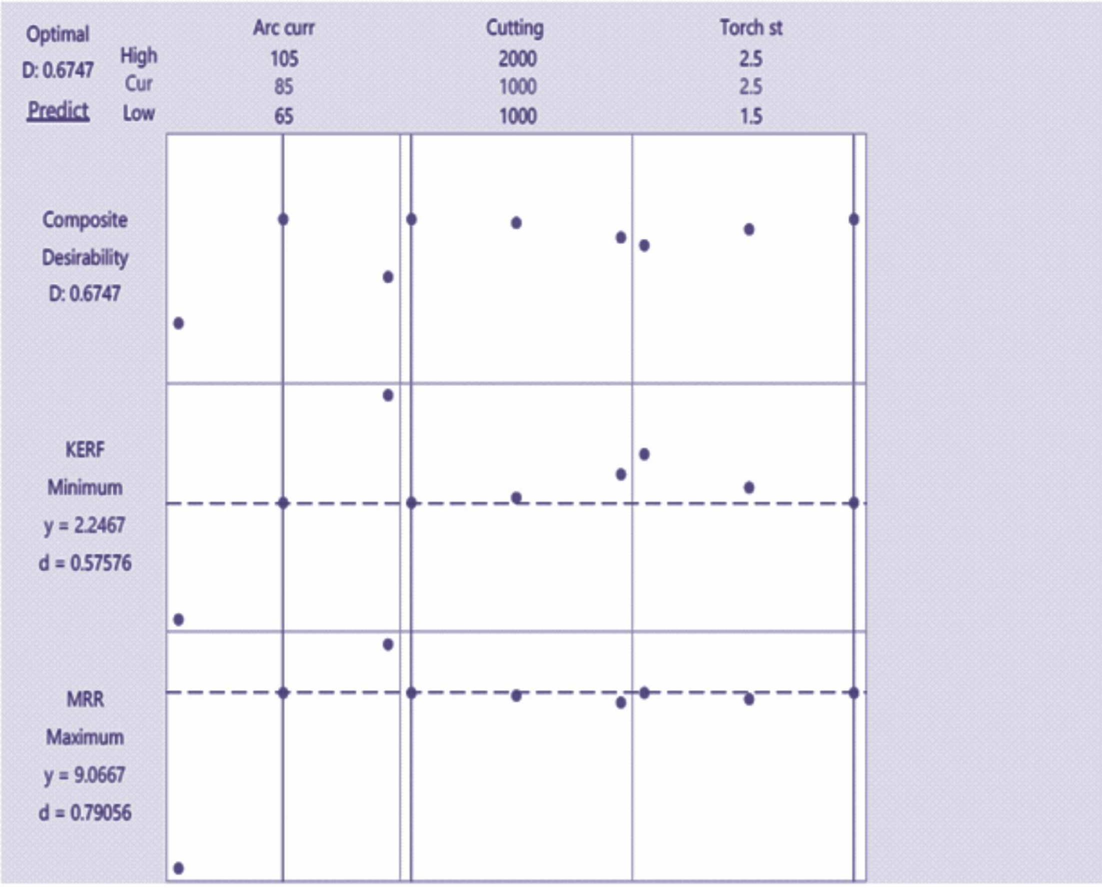


Fig. 4. Graph for Multiple response optimization

From the above graph and prediction table, to get minimum kerf width and maximum material removal rate the cutting current must be 85A, cutting speed 1000mm/min and torch standoff 2.5mm and the result obtained from this combination of parameter are kerf width is 2.2467mm and material removal rate is 151.11 g/min which is the optimum result obtain.

Table 9. Optimize Result for Multiple response

Arc current	Cutting speed	Torch standoff	KERF Fit	MRR Fit
85	1000	2.5	2.24667	151.11

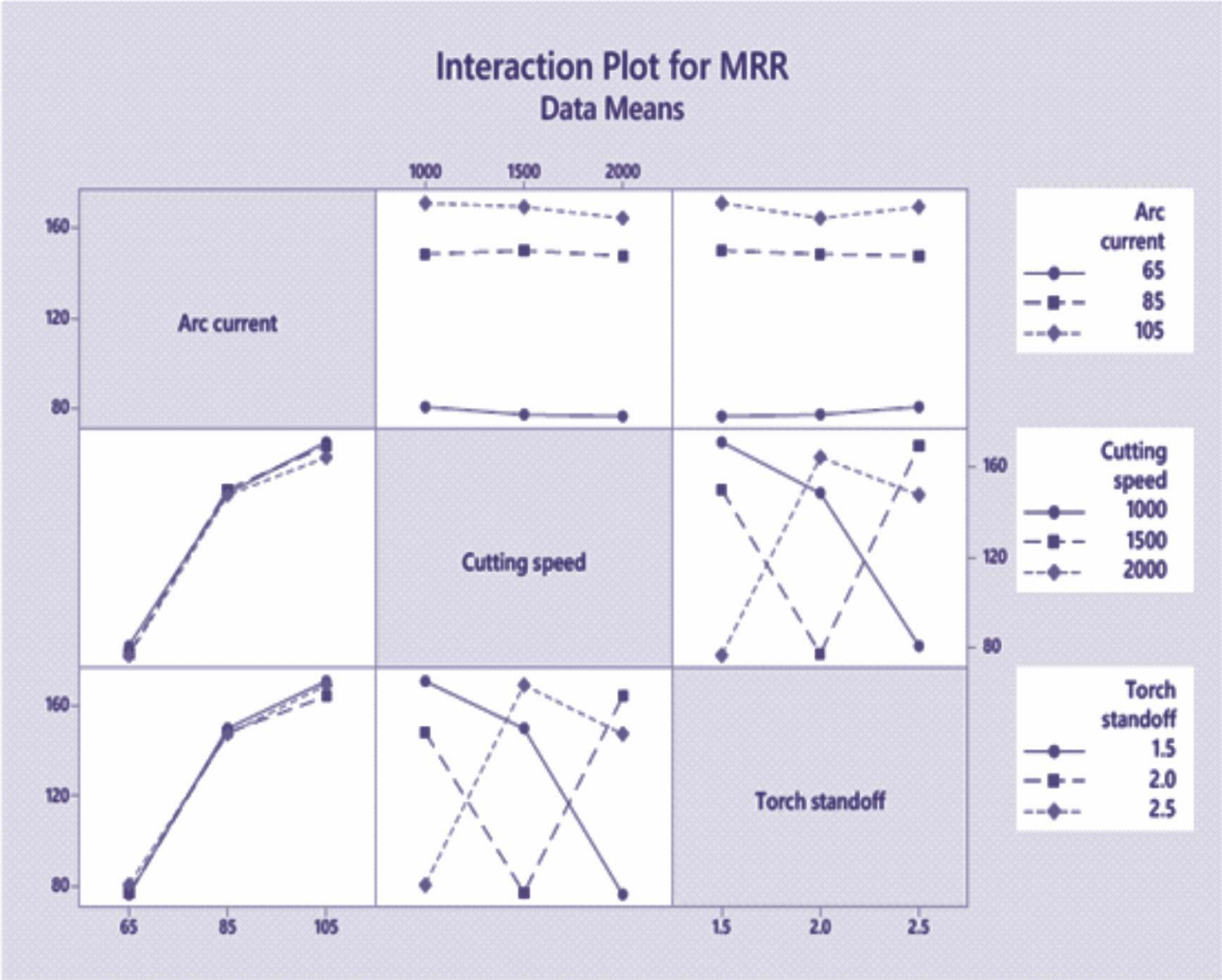


Fig.5. Interaction effect plot for MRR

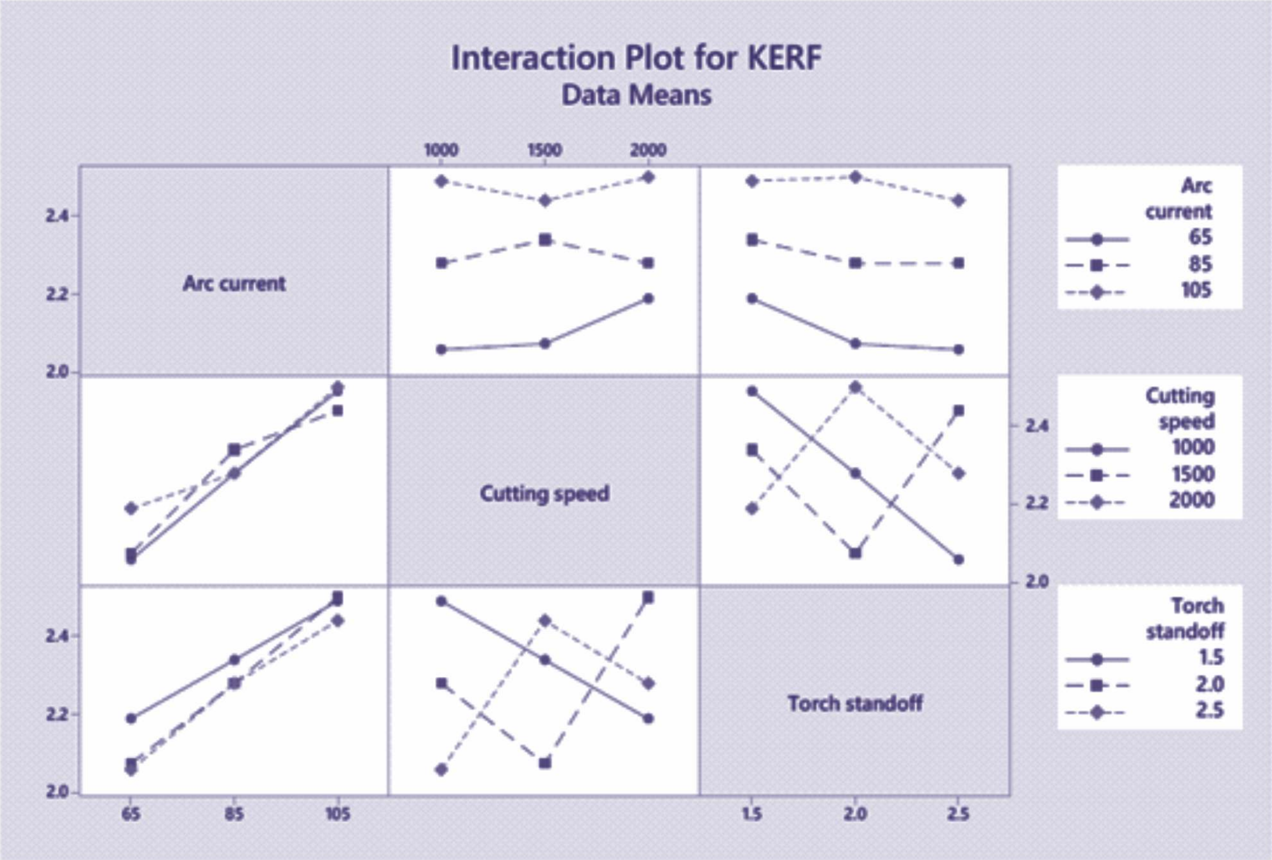


Fig.6. Interaction effect plot for Kerf

6. CONCLUSIONS

From the above all experimental work and study on 12mm mild steel cutting by the Hyperthermpowermax 105 plasma cutting machine the result obtain on the basis of changing the cutting input parameter such as cutting speed, arc current, and torch standoff distance and their effect on the response variable (MRR & KERF) and it is concluded that:

1. Arc current has a maximum effect on material removal rate (MRR) than cutting speed and torch standoff distance. The result concludes that to get maximum material rate cutting arc current, cutting speed and standoff distance should be 65 A, 2000 mm/min, and 2.0 mm.
2. Kerf width has great influence by Torch standoff distance after arc current and least affect by cutting speed, for minimum kerf width the arc current, speed and gap should be 65A, 1000 mm/min and 2.5 mm.
3. The cutting arc current, cutting speed and standoff distance should be 85A, 1000 mm/min, and 2.5 mm to get both MRR and KERF maximum or minimum simultaneously for the satisfactoryoptimized cutting process.

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