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EXPERIMENTAL INVESTIGATION OF PLASMA ARC CUTTING PARAMETERS FOR EN19 MATERIAL USING ANOVA AND TAGUCHI METHOD

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Abstract:

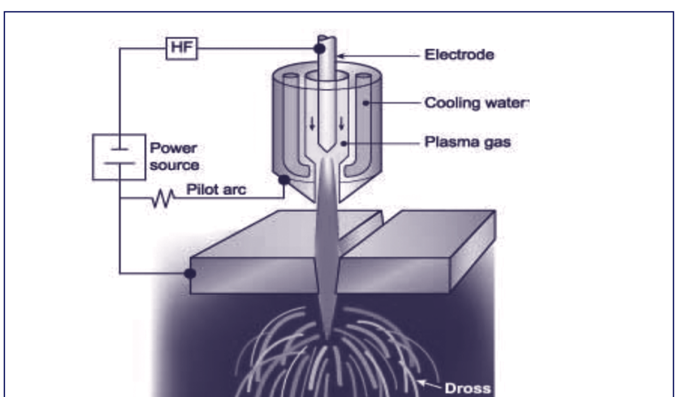
The Last few years there is tremendous research in machining and development in technology. According to present scenario about competition growth in the market and to attain high accuracy now a days the non-conventional machining are become lifeline of any industry. One of most important non convectional machining process is plasma arc cutting process. This paper presents an experimental analysis on the optimization and the effect of the cutting variables on Material Removal Rate (MRR), Kerf Width (KW) and Surface Roughness (Ra) in Plasma Arc Cutting (PAC) of EN19 Material using Taguchi L9 orthogonal array method. Four process parameters i.e. Gas pressure, Current, cutting speed and Arc gap have been selected for the experimental work. Analysis of variance (ANOVA) and Regression analysis have been performed to get effect of each variable on responses and optimization of process variables. From Taguchi's calculation optimum value for each responses has been predicted.

Keywords: Plasma arc cutting (PAC), Mild Steel EN19 Material, Taguchi method, Design of experiment (DOE) and ANOVA.

1. INTRODUCTION

Plasma arc cutting is one of the non-conventional metal cutting process which cuts metal sheets up to 150 mm (6 in) of thickness. This is the type of cutting process which is used not only to cut conductive and hard materials but also used to cut the non-conductive materials by using transferred and non-transferred modes respectively. In conventional plasma arc cutting method is shown in fig. In this method, the arc is constricted by a nozzle only and there is no shielding gas added. Generally, the cutting gas is tangentially injected around the electrode which generate swirling action of the gas causes the cooler (heavier) portions of the gas to move radially outward, which forms a protective boundary layer on the inside of the nozzle bore. This helps to prevent the damage of nozzle and improve its life. Electrode life is also improved. The temperature of the plasma reaches up to 20 000°C and the velocity can approach to the speed of sound. When conventional PAC is used for cutting, the gas flow of plasma is increased so that the deep penetration of plasma jet achieved which cuts through the material and molten material is removed in the efflux plasma. [1]

Figure 1: Conventional PAC process [1]



2. LITERATURE REVIEW

Many works have been done on optimization of plasma arc cutting parameter. Pawar S. S. et al. [2] analyzed SS 316 l pin by plasma arc cutting process and used the grey relational analysis. From the experiment, it was revealed that there is significant improvement in hardness at out of the core parts. It is also shown that stand off distance plays a key role for cut quality. Shovan Bhowmick. [3] In the surface plot the effect of two parameters on the response have been shown by keeping a fixed center value of third parameter. From the plot it is seen that the Ra value of surface roughness decreases with increase of pressure, decrease of speed and decrease of thickness. Also MRR increases with increase of pressure, speed and thickness. Dr. S.V.S.S.Srinivasa Raju [4] The Analysis of Variance (ANOVA) has been conducted to find the percentage contributions of each parameter on the Bevel Angle and it has been found that the Cutting Speed contributes 62.18 %, Arc Gap contributes 15.16 % and the Current contributes 12.08 % with an acceptable error of 10.58 %. Milan Kumar Das et al. [5] propose the responses of MRR and surface roughness are proportional to the gas pressure and current, respectively. The ANOVA and Grey Rational Analysis were used to analyze the plasma arc machining parameters on EN31. Gurwinder Singh et al. [6] used Taguchi L9 to analyze Material Removal Rate (MRR) of mild steel. The process parameters are the Kerf, cutting speed and SOD (Standoff Distance). From the work, authors concluded that the cutting speed has significant effect on MRR. Subbarao Chamarthi et al. [7] The Hardox 400 with 12 mm thickness was used as the work material and oxygen was used as plasma gas. The process parameters are cutting speed, gas flow rate and voltage. The final result is, by decreasing the cutting speed the unevenness is reduced. Tyagi R.K. [8] establishes the plasma cutting process in the concept of velocity unsteadiness on plasma. The experimental end result shows that using velocity shear instability increases the effectiveness of the machine and flexibility of using plasma parameters to control the machining operations. Kulvindar Rana et al. [9] analyzed the 10 mm thickness of mild steel sheet by L9 Taguchi technique. SOD, air pressure, cutting speed and current voltage are taken as the process parameters. The inference observed from this work is the current has maximum influence on HAZ. Salonitis et al. [10] S235 steel with 15-mm-thick material with O2 as plasma gas and air as shield gas was used. This inferences that the HAZ was minimized by lowering of gas pressure, current and SOD. The cutting speed influences on conicity. Sanda Maria llii et al. [11] AISI 304 stainless steel material used to analyze the variation of surface Roughness in plasma arc cutting. From the experiments, concluded that the material thickness has most influential parameter for surface roughness followed by cutting current and cutting speed. The inferences are plasma arc cutting offers productivity and the material thickness has most influence on Ra. Bini et al. [12] composed experimental investigation on kerf in HTPAC. The analysis confirmed that cut quality of the product depends on the cutting speed and the current voltage. K.P. Maity et al. [13] describes the effect of cutting parameters in AISI 316SS. The main responses are kerf width MRR, dross and Ra. The inference from this work was the combination of torch height and feed rate influences much more on machining. From the review, it is shown that plasma arc cutting on EN19 has received less attention to researchers but the application of this material is wide in the automotive, oil and gas sector. The following section elaborates materials and methods and experimental work.

3. EXPERIMENTAL PROCEDURE

A. Material Selection: EN 19 material has been selected for experimental procedure which is alloy steel and very hard material. There is wide application of EN 19 material like, in automotive gears and parts, Shafts, Towing pins, Load bearing tie rods, Oil & Gas industry etc. chemical composition, mechanical properties and fixed parameter shown according to table no. (1) (2) (3) Table 1. [1 to 21].

Table 1: Chemical Composition of EN19 [1][5]

Element	Min.	Max.
Carbon, C	0.35	0.45%
Manganese, Mn	0.50	0.80%
Silicon, Si	0.10	0.35%
Nickel, Ni	-	-
Molybdenum, Mo	0.20	0.40%
Chromium, Cr	0.90	1.50%
Sulfur, S	-	0.05
Phosphorous, P	-	0.05

Table 2: Mechanical Properties of EN19 [1][5]

Heat Treatment	Yield Stress N/mm²	Tensile Strength N/mm²	Proof Stress	Hardness HB
R	495	700/850	480	201/225
S	555	775/925	540	223/277
S	585	775/925	570	223/277
T	680	850/1000	655	248/302
U	755	925/1075	740	269/331
V	850	1000/1150	835	293/352
W	940	1075/1225	925	311/375

Table 3: Fixed Machining Parameters [1] [2][3][5]

Sr. No.	Machining Parameter	Fixed Value
1.	Material Type	EN 19
2.	Material Thickness	10mm
3.	Operating Voltage	110V

B. Design of Experiments (DOE): Design of experiment (DOE) is used to get arrange all the process variables and its levels at minimum number of experiments. Selection of Orthogonal Array: There are four plasma arc cutting parameters at three levels is finalized. The degree of freedom (DOF) of a three level parameter is 2 (number of levels minus 1), hence total degree of freedom for the experiment is 8.

Minimum Experiments – [(L-1) × P] + 1 = [(3-1) × 4] + 1 = 9 = L9 ……….. (1)[19]

Table 4: Process Parameters with Different Levels [5] [6]

Parameters	Level 1	Level 2	Level 3	Unit	DOF
Gas Pressure	4	5	6	Bar	2
Current Flow Rate	40	60	80	Amp	2
Cutting Speed	20	40	60	mm/Sec	2
Arc Gap	4	5	6	mm	2

From equation no. 1, it is finalized that L9 orthogonal array is suitable for 4 variables and 3 level combination. From Minitab 17 design of experiments (DOE) has been generated as shown in table 5. [14]

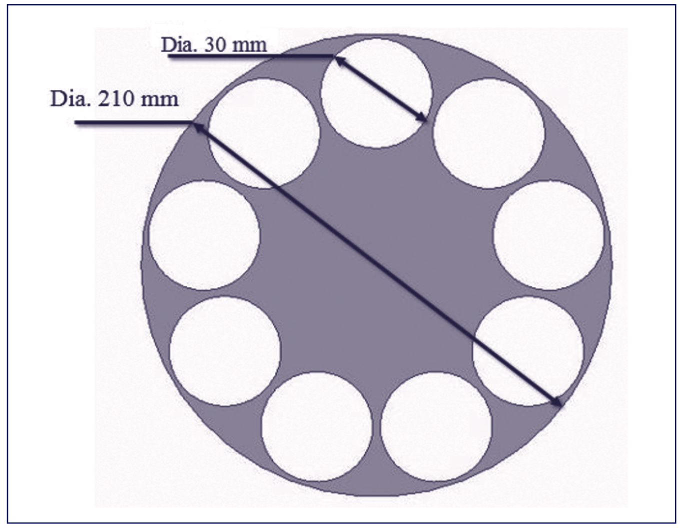
Table 5: Design of Experiment [7] [8] [9][14]

Gas Pressure (Bar)	Current (Amp)	Cutting Speed (In/mm)	Arc Gap (mm)
4	40	20	4
5	60	40	5
6	80	60	6
4	40	40	6
5	60	60	4
6	80	20	5
4	40	60	5
5	60	20	6
6	80	40	4

4. EXPERIMENTAL SETUP

As a part of experimental procedure, first test material was procured i.e. EN 19. 210mm outer diameter plate (Figure 3) with 10mm thickness was selected for experimental purpose and as shown in figure 4, CAD model of EN 19 plate is modelled in CREO software. For the experiments, total nine inner small circles with 30 mm diameter has been modelled which was machined by selected design of experiment combinations. [10] [11][12]

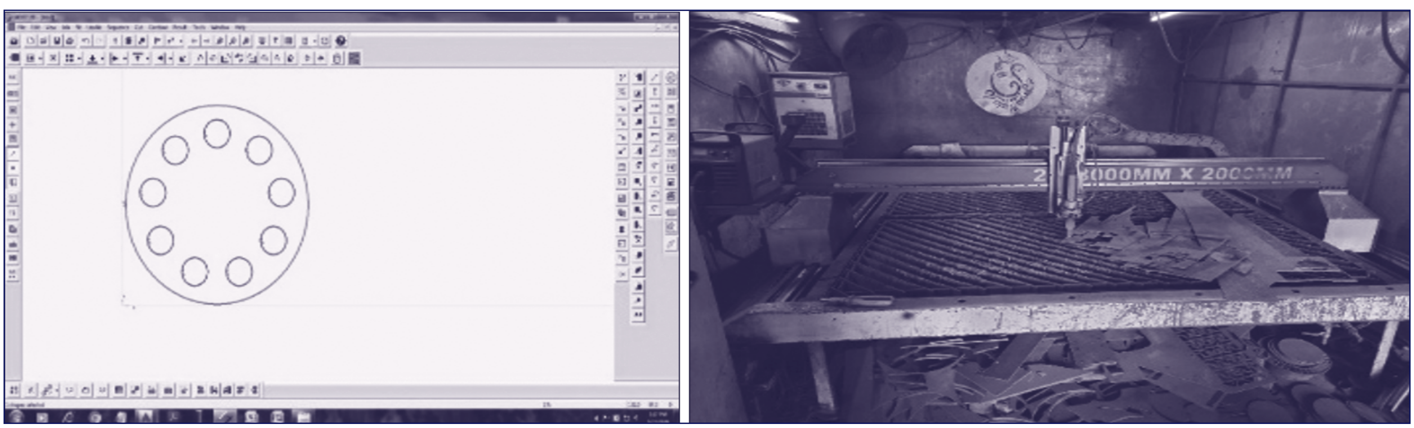
Figure 2: CAD model of EN19 plate



As shown in figure 2, CAD model of EN 19 plate is modelled in “creo” software. For the experiments, total nine inner small circles with 30 mm diameter has been modelled which was machined by selected design of experiment combinations.

Figure 3: Virtual work piece preparation in “Most 2D” software and Plasma Arc Cutting Machine

(a) (b)

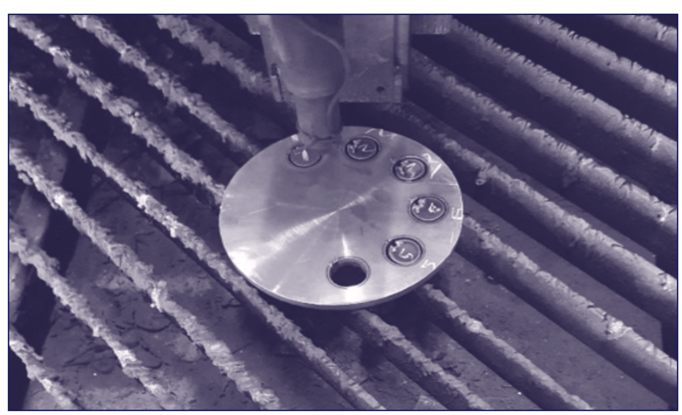


Before cutting the material on PAC machine virtual model of EN19 plate has been generated in “Most 2D” software which is shown in figure 3 (a) and (b).

A. Machine Specifications:

- Air plasma arc cutting
- Single nozzle
- Bed length: 3000 mm
- Bed width: 2000 mm
- Supply voltage: 3X400V – 50 Hz
- Operating pressure: 5 bar
- Power: 30 kW
- Open circuit voltage: 250V
- Primary fuse: 15 A

Figure 5: Material cutting process on PAC machine



5. EXPERIMENTAL RESULTS

After performing the experiments, all the results are combined, S/N ratio for all the responses are calculated. Effect of all process variable is detected through various plots of S/N ratio of responses vs variable and Mean of responses vs process variables.

Table 5: Experimental Results

Sample No.	Cutting Time (sec)	MRR (g/sec)	Kerf Width (mm)	Surface roughness (µm)
1	10.46	0.286	1.66	1.74
2	8.60	0.232	2.86	0.86
3	7.41	0.405	3.08	1.80
4	11.35	0.176	2.93	1.99
5	7.46	0.402	2.87	1.79
6	10.65	0.2817	3.58	1.12
7	7.20	0.694	2.65	2.86
8	10.78	0.278	3.65	0.86
9	8.43	0.474	3.48	2.25

A. Calculation of S/N Ratio: From the experimental results, signal to noise ratio was calculated for all three responses i.e. MRR, Kerf width and Surface roughness. For MRR larger is batter approach ware as for kerf width and surface roughness smaller is better approach was used.

Table 6: S/N Ratio for Material Removal Rate

Exp. No.	Gas Pressure	Current	Cutting Speed	Arc Gap	MRR	S/N ratio for MRR	Kerf	S/N ratio for kerf	Ra	S/N ratio for Ra
1	4	40	20	4	0.286	-10.8727	1.66	-4.40216	1.74	-4.81098
2	4	60	40	5	0.232	-12.6902	2.86	-9.1273	0.86	1.31003
3	4	80	60	6	0.405	-7.8509	3.08	-9.7710	1.80	-5.10545
4	5	40	40	6	0.176	-15.0897	2.93	-9.3374	1.99	-5.97706
5	5	60	60	4	0.402	-7.9155	2.87	-9.1576	1.79	-5.05706
6	5	80	20	5	0.2817	-11.0043	3.58	-11.0777	1.12	-0.98436
7	6	40	60	5	0.694	-3.1728	2.65	-8.46492	2.86	-9.12732
8	6	60	20	6	0.278	-11.1191	3.65	-11.2459	0.86	1.31003
9	6	80	40	4	0.474	-6.4844	3.48	-10.8316	2.25	-7.04365

As shown in table 6, material removal rate has been found for all nine samples and signal to noise ratio is also calculated from Minitab 17 software for same nine samples. For MRR, larger is better type of S/N ratio is used and for all nine experimental samples it was calculated. [13][14][15][16].

Figure 6: Interaction Plot for MRR (a) (b)

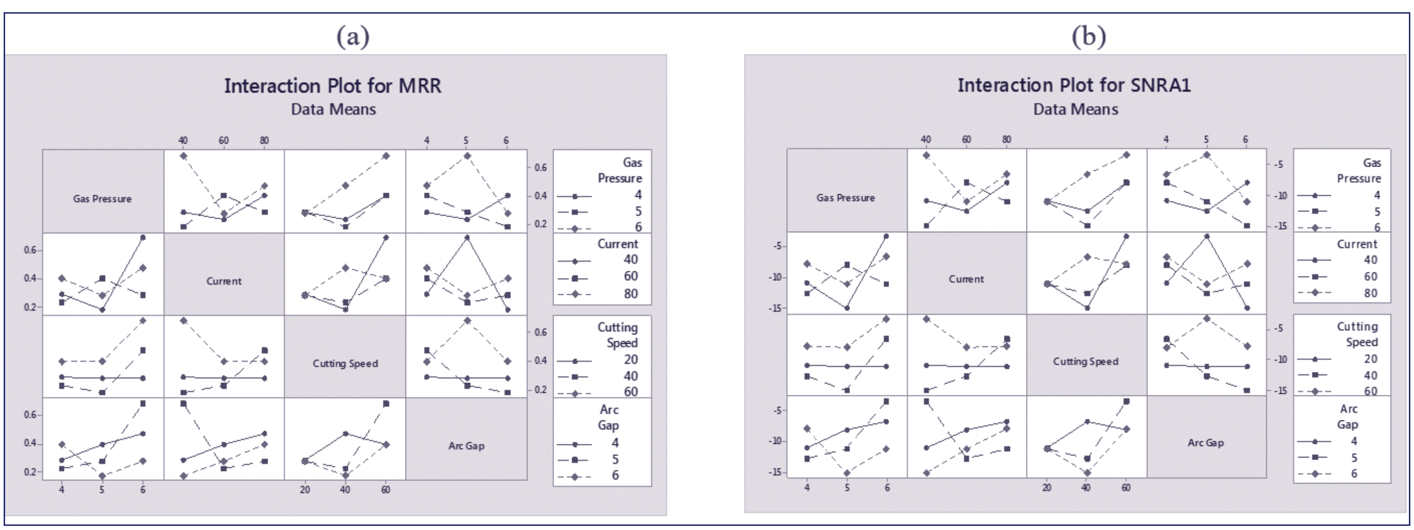


Figure 7: Interaction Plot for Kerf (a) and (b)

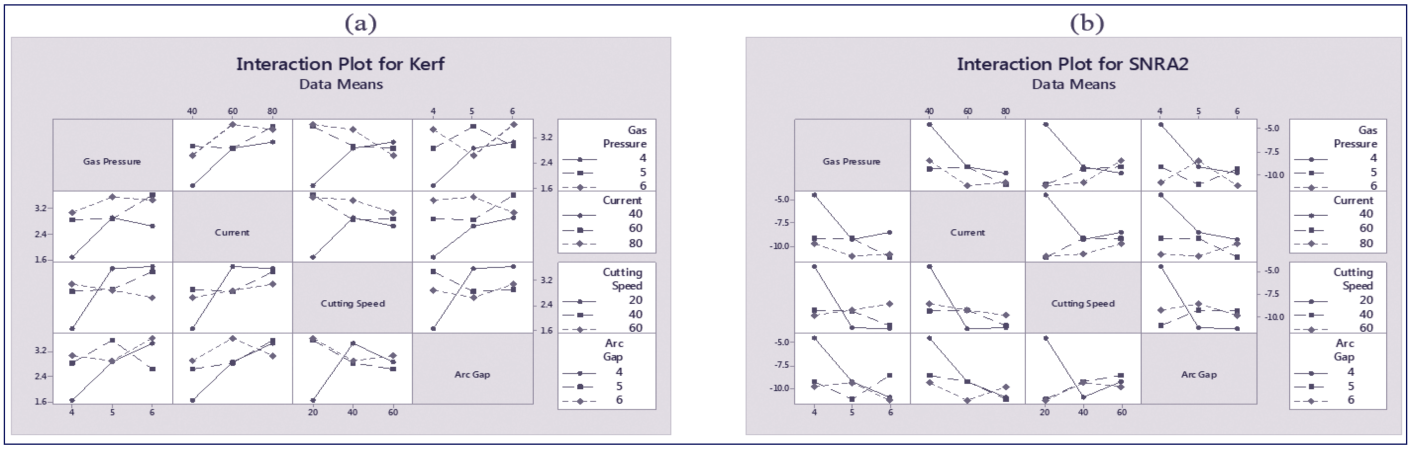
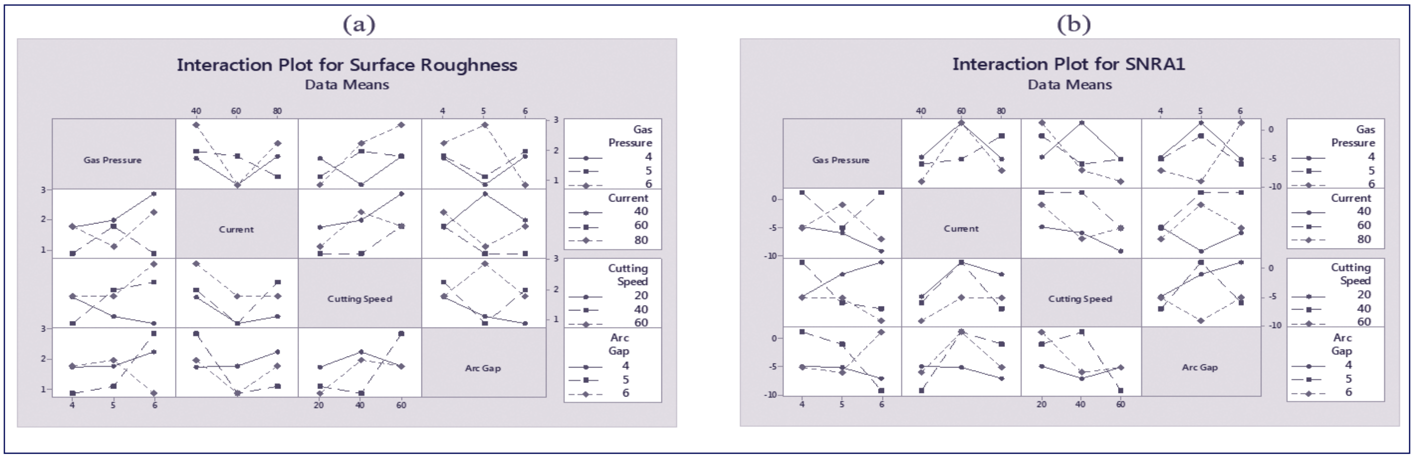
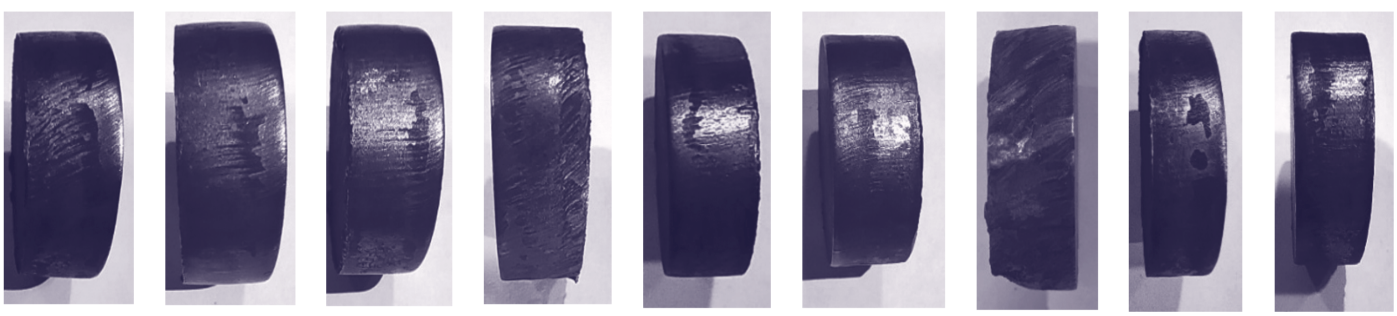


Figure 8: Interaction Plot for surface roughness (a) (b)



As shown in figure 6 (a), (b), 7 (a), (b) and 8 (a), (b) interaction plot for MRR, Kerf and Surface Roughness

Figure 9: Photography view of experiment work piece.



(1) (2) (3) (4) (5) (6) (7) (8) (9)

B. Prediction of response variable's value: After getting the optimal parameters of each responses, the next step of the Taguchi approach is to predict and verify the enhancement of quality characteristics using the optimal parametric combination. The estimated Optimum S/N ratio using the optimal level of the design parameters can be calculated:

$$\hat{\eta} = \eta_m + \sum_{i=1}^{q}(\bar{\eta}_i - \eta_m)$$

Where,

η_m = is the total mean of the multi response signal-to-noise ratio.

$\bar{\eta}_i$ = is the mean of the multi-response signal-to noise ratio at the optimal level.

Q = number of the process parameters that significantly affect the multiple quality characteristics.

B.1 Prediction of optimum value for Material Removal Rate (MRR)

For MRR, η_m = -9.57773
$\hat{\eta}$ = -9.57773 + (-6.925 + 9.57773) + (-8.447 + 9.57773) + (-6.313 + 9.57773) + (-8.424 + 9.57773)
$\hat{\eta}$ = -1.37581

Corresponding value of MRR = $Y_{opt}^2 = \frac{1}{10^{\frac{-\eta_{opt}}{10}}}$ = 0.72848
Predicted Optimum Value of MRR = 0.85351 mm/sec

B.2 Prediction of optimum value for Kerf Width (KW)

$\hat{\eta}$= -4.401809
Corresponding value of Kerf Width = $Y_{opt}^2 = 10^{\frac{-\eta_{opt}}{10}}$ = 2.75526
Predicted Optimum Value of Kerf Width = 1.6599 mm

B3. Prediction of optimum value for Surface Roughness (Ra)
For Surface Roughness, η_m = -3.94286
$\hat{\eta}$ = -3.94286+ (-2.8686 + 3.94286) + (-0.8123 + 3.94286) + (-1.4951 + 3.94286) + (-2.9339 + 3.94286)
$\hat{\eta}$ = 4.24748
Corresponding value of Surface Roughness = $Y_{opt}^2 = 10^{\frac{-\eta_{opt}}{10}}$ = 0.424748
Predicted Optimum Value of Surface Roughness = 0.651727 µm [16][17][18][20][21]

6. MATHEMATICAL MODELLING

The term multiple regression means stepping back toward the average. British mathematician Sir Francis Galton has found this method of data analysis. Regression analysis is a mathematical measure of the average relationship between two or more parameters in terms of the original units of the data. In regression analysis there are two types of variables, one which is influenced or is to be predicted is called dependent variable and second which is the variable which influences the values or is to be used for prediction is called independent variable. Regression analysis can be done in two ways;

(1)Bivariate regression

(2)Multiple regression

A. First Order Linear Model for Material Removal Rate (MRR):

From the minitab17 software, ANOVA table and first order linear model has been generated.

Regression equation for MRR,

MRR = -0.045 + 0.0872 Gas pressure + 0.00004 Current + 0.00546 Cutting speed - 0.0505 Arc gap

Table 6.1: ANOVA table for MRR

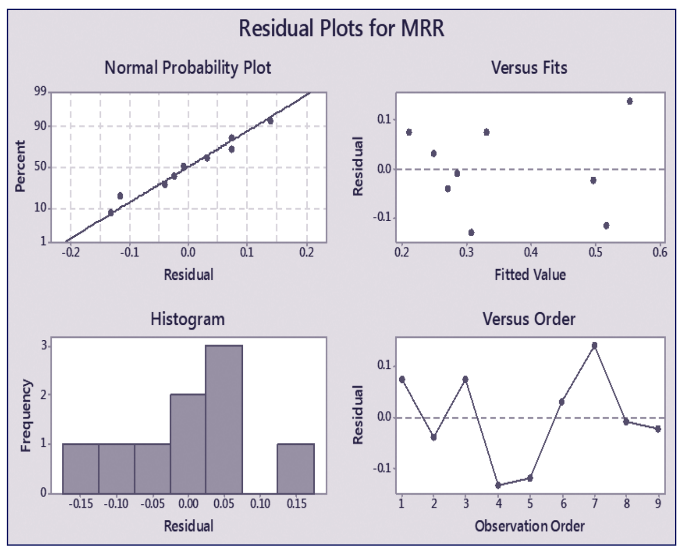
Source	DF	Adj SS	Adj MS	F – Value	P – value
Regression	4	0.132463	0.033116	2.06	0.251
Gas Pressure	1	0.045588	0.045588	2.83	0.168
Current	1	0.000004	0.000004	0.00	0.989
Cutting Speed	1	0.071570	0.071570	4.44	0.103
Arc Gap	1	0.015302	0.015302	0.95	0.385
Error	4	0.64435	0.016109		
Total	8	0.196898			

Model Summary

S = 0.126920 R-sq = 67.28% R-sq(adj) = 34.55% R-sq(pred) = 0.00%

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 = 67.28% which indicate the high significance of the model.

Figure 9 - Normal Probability Plot for Residuals of MRR



This graph indicates that the residual follows a straight line and there are no unusual patterns or outliers. As a result, the assumptions regarding the residual were not violated and the residuals are normally distributed.

B. First Order Linear Model for Kerf width (KW):

Regression Equation for kerf width (KW)

Kerf Width = -1.57167 + 0.363333 Gas pressure + 0.0241667 Current - 0.00241667 Cutting speed + 0.275 Arc gap

Table 6.2: ANOVA table for Kerf Width

Source	DF	Seq SS	Adj SS	Adj MS	F – Value	P – value
Regression	4	2.66150	2.66150	9.2638	0.026628	0.026628
Gas Pressure	1	0.79207	0.79207	11.0277	0.029357	0.029357
Current	1	1.40167	1.40167	19.5150	0.011533	0.011533
Cutting Speed	1	0.01402	0.01402	0.1952	0.681496	0.681496
Arc Gap	1	0.45375	0.45375	6.3174	0.065815	0.065815
Error	4	0.28730	0.28730			
Total	8	2.94880				

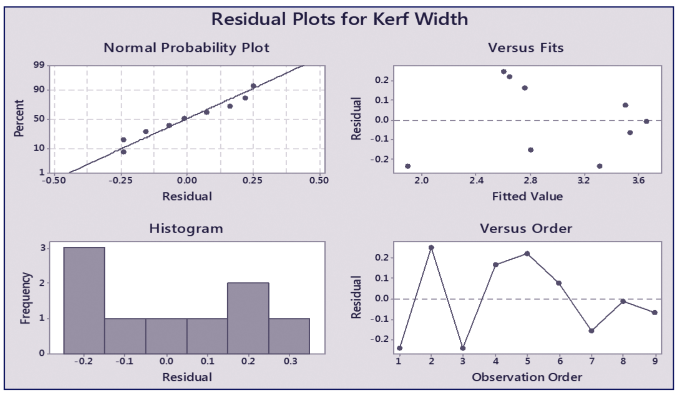
Summary of Model

S = 0.268002 R-Sq = 90.26% R-Sq(adj) = 80.51%

PRESS = 2.90333

R-Sq(pred) = 1.54%

Figure 6.2 - Normal Probability Plot for Residuals of Kerf width (KW)



This graph indicates that the residual follows a straight line and there are no unusual patterns or outliers. As a result, the assumptions regarding the residual were not violated and the residuals are normally distributed.

C. First Order Linear Model for Surface Roughness

Regression Equation

Surface Roughness = 1.13 + 0.262 Gas pressure - 0.0118 Current + 0.0227

Cutting speed - 0.188 Arc gap

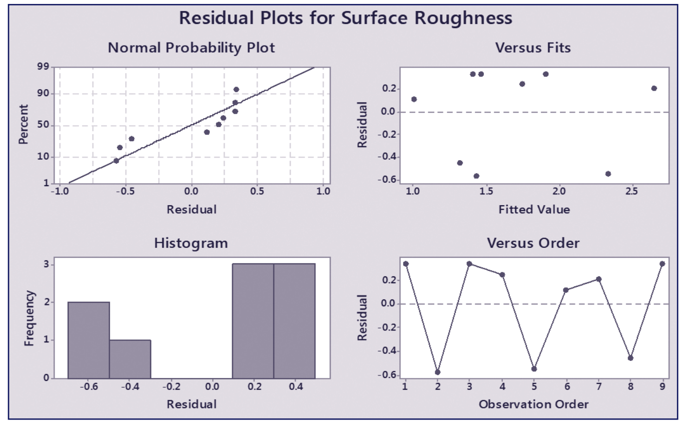
Table 6.3: ANOVA table for Surface Roughness

Source	DF	Adj SS	Adj MS	F – Value	P – Value
Regression	4	2.2018	0.5505	1.70	0.311
Gas Pressure	1	0.4108	0.4108	1.27	0.323
Current	1	0.3361	0.3361	1.04	0.366
Cutting Speed	1	1.2421	1.2421	3.83	0.122
Arc Gap	1	0.2128	0.2128	0.66	0.463
Error	4	1.2975	0.3244		
Total	8	3.4994			

Model Summary

S = 0.569550 R-sq = 62.92% R-sq(adj) = 28.84% R-sq(pred) = 0.00%

Figure 6.3 - Normal Probability Plot for Residuals of Surface Roughness (Ra)



This graph indicates that the residual follows a straight line and there are no unusual patterns or outliers. As a result, the assumptions regarding the residual were not violated and the residuals are normally distributed.

7. CONCLUSION

From main effect plots and response table, it is concluded that:

- Higher value of gas pressure, current and cutting speed
- Will give higher MRR while minimum value or low arc gap is beneficial foe getting better MRR.
- Cutting speed has highest effect on MRR while current has lowest effect on MRR.
- For getting maximum MRR, gas pressure, current, cutting Speed and arc gap must be 6 bar, 80A, 60 mm/s and 4 mm respectively.
- Lower value of gas pressure, current and arc gap is better For getting minimum kerf width.
- Current has highest effect on kerf width followed by gas Pressure, arc gap and cutting speed.
- For getting minimum kerf, gas pressure, current, cutting Speed and arc gap must be 4 bar, 40A, 20 mm/s and 4 mm respectively.
- Current has highest effect on surface roughness which is Followed by cutting speed, gas pressure and arc gap.
- For getting good surface roughness, gas pressure, current, cutting speed and arc gap must be 4 bar, 60A, 20 mm/s and 5 mm respectively.
- Optimum value for material removal rate, kerf width and surface roughness has been calculated i.e. 0.8535 mm/sec, 1.6599 mm, 0.6517 µm respectively.

- From regression analysis, residual plot indicates that the residual follows a straight line and there are no unusual patterns or outliers. As a result, the assumptions regarding the residual were not violated and the residuals are normally distributed.
- R^2 value for MRR, KW and Ra comes 67.28%, 90.26%, 62.92% respectively.

REFERENCES

[1] *Nemchinsky, V.A., Severance, W.-S., 2006, what we know and what we do not know about plasma arc cutting, J. Phys. D: Appl. Phys., 39: 423-438.*

[2] *Pawar S. S, Inamdar K H. "Experimental analysis of plasma arc cutting process for SS 316 1 plates," IOSR Journal of mechanical and civil engineering (2007).*

[3] *Sovan Bhowmick et al., "Experimental study of plasma arc cutting of AISI 304 stainless steel." ICMPC 2017 https://doi.org/10.1016/j.matpr.2017.12.024*

[4] *Dr. S.V.S.S.Srinivasa Raju, "Optimization of Process Parameters of Plasma Arc Cutting Using Taguchi's Robust Design Methodology" IOSR [i- CAM2K16] DOI: 10.9790/1684-1605303124128*

[5] *Milan Kumar das et al. "Optimization of process parameters in plasma arc cutting of EN31 steel based on MRR and multiple roughness characteristics using grey relational analysis," International conference on advances in manufacturing and materials engineering. 5 1550–1559.*

[6] *Singh G et al. "Experimental study and optimisation of MRR in CNC plasma arc cutting," Int J Eng Res Sci App 5(6):96–99*

[7] *Chamarthi S. et al. "Investigation Analysis of Plasma arc cutting Parameters on the Unevenness surface of Hardox-400 material." Int Conf Design Manuf, Procedia Eng 64:854–861*

[8] *Tyagi RK (2014) "A review of few unconventional machining processes based on the concept of velocity shear instability in plasma," Prod Manuf Res, An open access J 2(1):216–227. https://doi.org/10.1080/21693277.2014.899934*

[9] *Rana Kulvinder et al. "Optimization of plasma arc cutting by applying Taguchi method," Int J Enhanc Res Sci Technol Eng 2(7):106–110.*

[10] *Salonitis K et al. "Experimental investigation of the plasma arc cutting process," 45th CIRP Conference on Manufacturing Systems 2012, Procedia CIRP 3 (2012) 287 – 292.*

[11] *Ilii S-M, et al. "Experimental results concerning the variation of surface roughness parameter at plasma arc cutting of a stainless steel work piece." Int J Modern Manufac Technol 2(1):31–36*

[12] *Bini R et al. "Experimental study of the features of the kerf generated by a 200A high tolerance plasma arc cutting system," J Mater Processing Technol 196:345–355.*

[13] *Maity KP et al. "Effect of process parameters on cut quality of stainless steel of plasma arc cutting using hybrid approach" Int J Adv Manuf Technol 78:161–175. https://doi.org/10.1007/s00170-014-6552-6*

[14] *Instruction Manual of Thermal Dynamics Rev. AA.02 Date: July 23, 2007 Manual # 0-2962 www.thermadyne.com (Model SL60, SL100 Hand Torch Model SL100 Machine Torch).*

[15] *Jaypalsinh Rana et al. "Parametric Analysis of EN8 (AISI 1040) Alloy steel on Plasma Arc Cutting" International Journal of Science and Engineering Applications Volume 4 Issue 3, 2015, ISSN-2319-7560 (Online).*

[16] *Pallavi H. Agarwal et al. "Optimizing Plasma Arc Cutting Parameters for Structural Steel using Grey Relational Analysis" International Journal of Engineering Research & Technology (IJERT) ISSN: 2278-0181 Vol. 8 Issue 01, January-2019.*

[17] *Rajnikant C. Bidajwala, et al. "Parametric optimization on plasma arc cutting machine for AISI 1018" Scientific Journal of Impact Factor (SJIF): 3.134 e-ISSN (O): 2348-4470 p-ISSN (P): 2348-6406 Volume 2, Issue 5, May -2015.*

[18] *Pratishtha et al. "Parametric Optimization of MRR in Manual Air Plasma Arc Cutting of AISI 1017 MS using Design of Experiment," Journal of Materials & Metallurgical Engineering ISSN: 2231-3818(online), ISSN: 2321-4236(print) Volume 5, Issue 2.*

[19] *Surender Kumar "Experimental Study on Parameters Optimization in CNC Plasma Arc Cutting (AISI 206 Steel) Using Taguchi Approach," International Journal of Technical Research & Science ISSN No.: 2454- 2024 (online) Volume 3 Issue VI, July 2018.*

[20] *A Parthiban et al. "Experimental Investigation of Plasma Arc Cutting for Stainless Steel Sheet," International Journal of Mechanical and Production Engineering Research and Development (IJMPERD) ISSN (P): 2249-6890; ISSN (E): 2321-8001 Vol. 8, Issue 1, Feb 2018, 907-914 © TJPRC Pvt. Ltd.*

[21] *Sagar B. Patel, Tejas K. Vyas "Parametric Investigation of Plasma Arc Cutting on Aluminium Alloy 6082" International Conference on Ideas, Impact and Innovation in Mechanical Engineering (ICIIIME 2017) ISSN: 2321-8169 Volume: 5 Issue: 6.*

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