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PARAMETRIC OPTIMIZATION ON PLASMA ARC CUTTING MACHINE FOR AISI 1018

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Abstract —*In this study we choose plasma cutting machine as our main machine tool and AISI1018 material also used .with the start of globalization there are many company emerges. So, there are more than one company make similar product to sustain this competitive market we must make product which quality is good and must have low price.so with the use of optimization technique we must make our product more economical and also save time coast.so that's why we consider GRA and some other optimize technique issued to find out optimum solution for the machine where it give its best performance.*

Keywords – *PAC, Taguchi, Anova, Grey relational analysis*

I INTRODUCTION

Basically there are three states of matter i.e. solid, liquid and gas. The basic difference between them is of energy. Energy of solid is minimum. If we add energy to solid it is converted into liquid. If we add extra energy to liquid it is converted into gas, when we add extra energy to gas, it becomes plasma. Plasma is highly ionized and electrically conductive. It is much useful to increase temperature as well as to perform cutting. Plasma cutting technology is one in which argon, nitrogen and compressed air are used to generate a plasma jet and then nonferrous metal, stainless steel and black metal are cut by the high temperature of the highly-compressed plasma arc and the mechanical erosion of the fast plasma jet.The plasma arc cutting process is a highly productive method of cutting aluminum and is experiencing rapidly growing application. Cuts can be made from thick foil thickness up to 200 mm although cutting in these thicknesses causes extreme noise levels that have to be taken into consideration when considering the suitability of the process.Plasma cutting was developed in the 1950's for severing steel sheet and plate. Today, it is used on nearly all types of conducting engineering materials. One limiting factor for the plasma process has been the high investment costs. The trend today is that more simple and inexpensive machinery is used, making plasma cutting a realistic alternative to other cutting methods.
Principle of PAC.

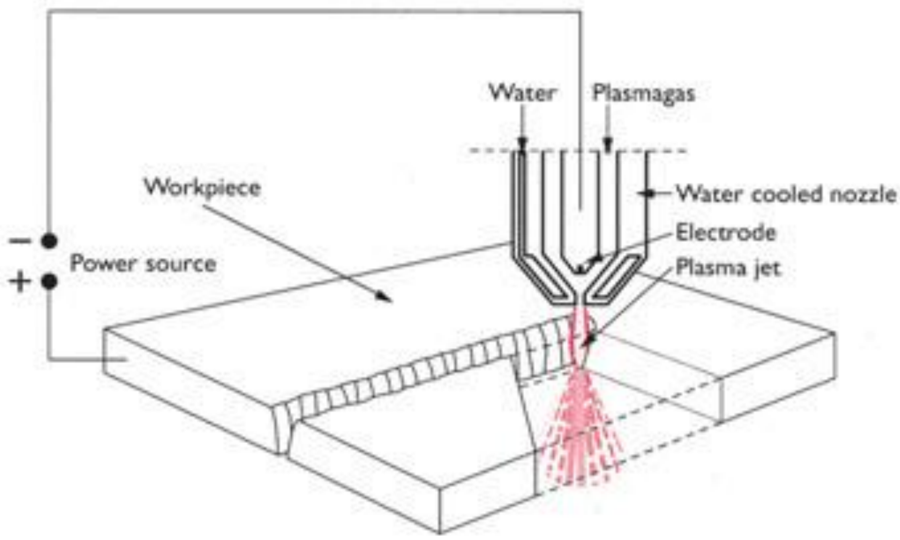

Figure-1. Principle of PAC

The basic principle is that the arc formed between the electrode and the workpiece is constricted by a fine bore, copper nozzle. This increases the temperature and velocity of the plasma emanating from the nozzle. The temperature of the plasma is in excess of 20 000°C and the velocity can approach the speed of sound. When used for cutting, the plasma gas flow is increased so that the deeply penetrating plasma jet cuts through the material and molten material is removed in the efflux plasma. Plasma cutting is a melting process, compared to flame cutting which is a combustion process. A gas jet in the plasma melts and expels the material from the kerf. During the process an electric arc burns between an electrode and the work-piece. The electrode tip is placed in a water or air cooled gas nozzle in the torch. The plasma gas is conducted through the nozzle. The arc and the plasma gas are forced to pass through a very narrow orifice in the tip of the nozzle. The gas is heated and ionized.When the plasma jet hits the work-piece the heat is transferred due to recombination (the gas reverts to its normal state). The material melts and is expelled from the kerf by a flow of gas. To initiate the process, and ionize the gas, a pilot arc must be generated. The pilot arc heats the plasma gas and ionizes it. Since the electrical resistance of the main arc is lower than that of the pilot arc, the main arc ignites and the pilot arc automatically extinguishes.

II LITERATURE REVIEW

[1] Milan kumar das and et all were conducted experiment on EN31 steel using process parameters like gas pressure, arc current and torch height to influence effect on material removal rate and roughness characteristics. They developed empirical graph of response surface methodology and finally they worked on chip morphology. they analyzed their experimental reading through ANOVA and grey relational analysis. They found that highly effective parameter is gas pressure, whereas arc current and torch height are less effective factors for the response

[2] Abdulkadir Gullu and et all were experiment carried out on AISI 304 stainless steel and St 52 carbon steel have been cut by plasma arc and the variations of structural specifications occurred after cutting has been investigated. From the experiment they found that, it has been seen that burning of particulars and distribution amount were increased when the cutting was performed using the speeds which are upper or lower limits of the ideal cutting speeds proposed by the manufacturer of the machine tool. They had determined that the hardness from the outer surface to the core decreased, while the hardness near to the outer surface which affected by the high temperature occurred during cutting increased. Thus they revealed that the area of 0.399–0.499 mm of stainless steel materials and 0.434–0.542 mm of carbon steel materials were more affected by heat according to cutting speed.

[3] W.J.Xu and et all were conducted experiment on ceramic during plasma arc cutting. They measured cutting qualities by varying process parameter the flow rate of injected water and the magnetizing current using nozzles of different diameters. From the experiment they found that both water constriction and magnetic constriction of plasma arc forms a three dimensional constriction with improved shape and uniformity of the arc column and hydro magnetic constriction is capable of improving arc stability

[4] E. Gariboldi and at all were conducted experiment to improved the quality of cuts performed on titanium sheets using high tolerance plasma arc cutting (HTPAC) process. they were investigated under different process conditions like using several feed rates in the dross-free feed rate range and with the adoption of oxygen or nitrogen as cutting and shielding gases. They found that when oxygen was used as cutting gas higher feed rate and geometry attributes (unevenness and kerf width) of better quality were achieved due to the oxidation reaction. The quality features of the cutting edge of HTPAC of commercially pure titanium were integrated with considerations on micro structural features related to the formation of a wide layer severely affected by plasma-induced thermal cycle and by interaction with the cutting gas. They showed that temperature measurements during the passage of the torch defined the thermal cycles of the cutting process in several locations of the sheet. These are characterised by high heating rates (above 2000 K/s within the HAZ) and low cooling rates (150–580 K/s within the HAZ). They were applied to simulate the thermal effects of the material interaction with the torch in the case of slow cuts with oxygen by analytical model. A comparison between predicted thermal cycles, experimental measurements and microstructural observations confirmed the reliability of the estimation in terms of extension of microstructural modificationss.

III METHODOLOGY

TAGUCHI METHOD

A scientific approach to plan the experiments is a necessity for efficient conduct of experiments. By the statistical design of experiments the process of planning the experiment is carried out, so that appropriate data will be collected and analysed by statistical methods resulting in valid and objective conclusions. When the problem involves data that are subjected to experimental error, statistical methodology is the only objective approach to analysis. Thus, there are two aspects of an experimental problem: the design of the experiments and the statistical analysis of the data. These two points are closely related since the method of analysis depends directly on the design of experiments employed.

A. Selection of process parameter

The four process cutting parameters in Plasma Arc Cutting operation are Gas pressure, Current Flow Rate, Cutting Speed and Arc Gap.

Table .1 Process Parameter

Sr no.	Gas pressure (bar)	Current flow rate(amp)	Cutting speed (mm/min)	Arc gap (mm)
1	4	150	2000	2
2	6	200	2500	4
3	8	250	3000	6
4	10	300	3500	8

B. GreyRelational Analysis

Through the grey relational analysis, a grey relational grade can be obtained to evaluate the multiple performance characteristic. As a result, optimization of the complicated multiple performance characteristic can be converted into the optimization of a single grey relation grade. For multiple performance characteristic optimizations using GRA, following steps are followed:

1. Normalization of experimental result for all performance characteristics.
2. Performance of grey relational generating and calculation of grey relational coefficient (GRC).
3. Calculation of grey relation grade (GRG) using, weighing factor for performance characteristics.
4. Analysis of experimental results using GRG and statistical analysis of variance (ANOVA).
5. Selection of optimal levels of process parameters

IV EXPERIMENTAL RESULT AND DISCUSSION

The experiment was conducted in company to measures the value of Material Removal Rate, Surface Roughness, Heat Affected Zone for the various combination of input parameter.

Table .2 L16 orthogonal array with Experimental Readings

NO.	GAS PRESSURE	CURRENT FLOW RATE	CUTTING SPEED	ARC GAP	MRR	SR	HAZ
1	4	150	2000	2	1.98	3.50	0.6803
2	4	200	2500	4	2.50	4.10	0.7477
3	4	250	3000	6	3.50	4.80	0.7547
4	4	300	3500	8	4.50	5.29	0.7846
5	6	150	2500	6	2.10	3.18	0.7083
6	6	200	2000	8	2.85	3.87	0.7284
7	6	250	3500	2	3.99	4.28	0.7221
8	6	300	3000	4	4.80	4.78	0.7534
9	8	150	3000	8	2.80	2.98	0.6917
10	8	200	3500	6	4.50	3.15	0.7083
11	8	250	2000	4	4.26	3.89	0.7284
12	8	300	2500	2	5.24	3.15	0.7477
13	10	150	3500	4	4.90	2.19	0.6724
14	10	200	3000	2	4.98	2.98	0.6658
15	10	250	2500	8	5.74	3.29	0.7284
16	10	300	2000	6	6.26	2.78	0.7394

A. **Main Effects Plot of material removal rate**

Fig.2 shows that higher material removal rate will meet at Gas pressure 10 bar, Current flow rate 300amp, Cutting speed 3500 mm/min and arc gap 4 mm. The graph generate by use of minitab-15 statistical software for material removal rate is shown in fig.From the fig it has been conclude that the optimum combination of each process parameter for higher material removal rate is meeting at Gas pressure [A4], Current flow rate [B4], Cutting speed [C4] and arc gap [D2].

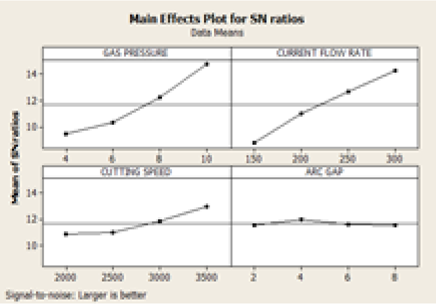

Figure 2. Effect of control factor on material removal rate

B. Main Effects Plot of Surface roughness

Fig.3 shows that lower Surface roughness will meet at Gas pressure 4 bar, Current flow rate 250 amp, Cutting speed 3000 mm/min and arc gap 8 mm From the fig.5.2, it has been conclude that the optimum combination of each process parameter for lower surface roughness is meeting at Gas pressure [A1], Current flow rate [B3], Cutting speed [C3] and arc gap [D4].

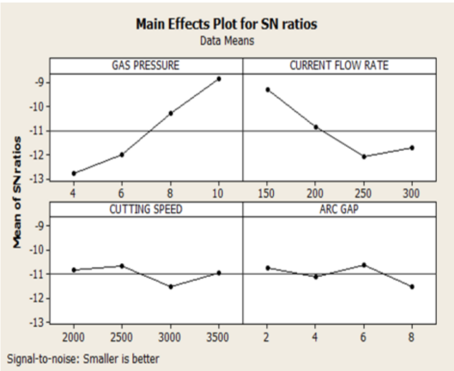

Figure 3. Effect of control factor on Surface roughness

C. Main Effects Plot of Heat Affected Zone

Fig.4shows that lower HAZ will meet at Gas pressure 4 bar, Current flow rate 300 amp, Cutting speed 2500 mm/min and arc gap 8 mm From the fig.5.3, it has been conclude that the optimum combination of each process parameter for lower surface roughness is meeting at Gas pressure [A1], Current flow rate [B4], Cutting speed [C2] and arc gap [D4].

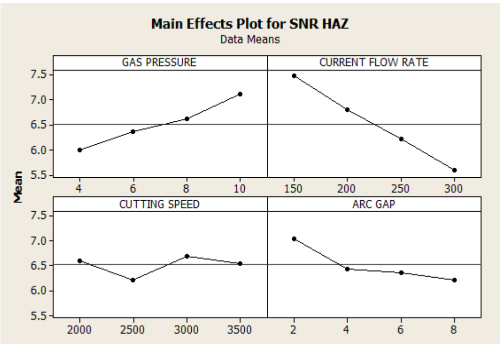

Figure 4. Effect of control factor on HAZ

D. Analysis of Variance for material removal rate

From ANOVA result it is observed that Gas pressure and current flow rate influencing parameter for MRR, while the value of p for cutting speed and arc gap is 0.193 and 0.928 which is greater than 0.05 p value so they are not influencing parameter for MRR.

Table 3. ANOVA table of material removal rate

Source	DF	Seq SS	Adj SS	Adj MS	F	P
gas pressure	3	13.1275	13.1275	4.3758	40.20	0.006
current flow rate	3	11.0587	11.0587	3.6862	33.87	0.008
cutting speed	3	0.9937	0.9937	0.3312	3.04	0.193

arc gap	3	0.0467	0.0467	0.0156	0.14	0.928
Error	3	0.3265	0.3265	0.1088		
Total	15	25.5532				
R-Sq = 98.72%				R-Sq(adj) = 93.65%		

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E. Analysis of variance for Surface Roughness

From ANOVA result it is observed that the Gas pressure and current flow rate influencing parameter for SR,

Table 4. ANOVA table for Surface roughness

Source	DF	Seq SS	Adj SS	Adj MS	F	P
gas pressure	3	6.28842	6.28842	2.09614	22.61	0.015
current flow rate	3	3.12977	3.12977	1.04326	11.25	0.039
cutting speed	3	0.51467	0.51467	0.17156	1.85	0.313
arc gap	3	0.44042	0.44042	0.14681	1.58	0.357
Error	3	0.27817	0.27817	0.09272		
Total	15	10.65144				
R-Sq = 97.39%				R-Sq(adj) = 86.94%		

F. Analysis of variance for HAZ

From ANOVA result it is observed that the gas pressure, current flow rate and arc gap are influencing parameter for HAZ, while the value of p for cutting speed is 0.145 which is greater than 0.05 p values. So, it is not influencing parameter for HAZ.

Table 5. ANOVA table for HAZ

Source	DF	Seq SS	Adj SS	Adj MS	F	P
gas pressure	3	2.6262	2.6262	0.8754	19.47	0.018
current flow rate	3	7.8095	7.8095	2.6032	57.89	0.004
cutting speed	3	0.5299	0.5299	0.1766	3.93	0.145
arc gap	3	1.5538	1.5538	0.5179	11.52	0.037
Error	3	0.1349	0.1349	0.0450		
Total	15	12.6542				
R-Sq = 98.93%				R-Sq(adj) = 94.67%		

V GREY RELATIONAL ANALYSIS

Table 6. Normalization, GRC and GRG of experimental data

No	Normalization data			Grey relational coefficient			GRG
	MRR	SR	HAZ	MRR	SR	HAZ	
1	1	0.531639	0.131687	0.333333	0.484666	0.791531	0.53651
2	0.79741355	0.711048	0.706745	0.385382	0.412865	0.414338	0.404195
3	0.505104362	0.889783	0.762998	0.497461	0.359768	0.395883	0.417704
4	0.28677575	1	1	0.635505	0.333333	0.333333	0.434057
5	0.948882502	0.422919	0.376896	0.345094	0.541759	0.570193	0.485682
6	0.683583163	0.645586	0.546956	0.422446	0.436458	0.477575	0.445493
7	0.391273975	0.759767	0.494277	0.560995	0.396899	0.502878	0.486924

8	0.230708114	0.885048	0.752859	0.684268	0.360998	0.399087	0.481451
9	0.698959614	0.349264	0.232513	0.417028	0.588745	0.682582	0.562785
10	0.28677575	0.412171	0.376896	0.635505	0.548143	0.570193	0.584614
11	0.334390231	0.651431	0.546956	0.59924	0.434242	0.477575	0.503686
12	0.154514169	0.412171	0.706745	0.763925	0.548143	0.414338	0.575469
13	0.212795174	0	0.060071	0.701464	1	0.892743	0.864736
14	0.198726092	0.349264	0	0.715588	0.588745	1	0.768111
15	0.075338571	0.461479	0.546956	0.869054	0.520032	0.477575	0.62222
16	0	0.27049	0.638684	1	0.648938	0.439103	0.696014

The higher grey relational grade value will give optimum value of MATERIAL REMOVAL RATE, SURFACE ROUGHNESS AND HEAT AFFECTED ZONE. Thus it is revealed that response will be optimum at GAS PRESSURE 10 BAR, CURRENT FLOW RATE at 150 A0, CUTTING SPEED at 3500 mm/min and ARC GAP at 2 mm.

A. Main Effect of Factors on Grey Relational Grade (GRG)

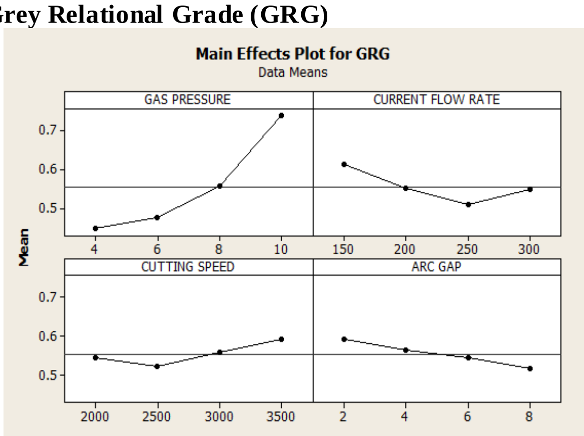

Figure.5. Effect of control factors plot of SNR of GRG

For the combined response maximization or minimization, fig.5. gives optimum value of each control factor. It interprets that level A1, B2, and C1 gives optimum result. The mean of grey relational grade for each level of the other machining parameters can be computed in similar manner.

Table 7. Main effect of factors on Grey Relational Grade

Symbol	Control factor	Level 1	Level 2	Level 3	Level 4
A	Gas pressure	0.448117	0.474887	0.556638	0.73777
B	Current flow rate	0.612428	0.550603	0.507633	0.546748
C	Cutting speed	0.545426	0.521891	0.557513	0.592538
D	Arc gap	0.541753	0.563517	0.546003	0.516139

As we know that higher grey relational grade value will give optimum value of MATERIAL REMOVAL RATE, SURFACE ROUGHNESS AND HEAT AFFECTED ZONE. Thus it is revealed that response will be optimum at GAS PRESSURE 10 BAR, CURRENT FLOW RATE at 150 A0, CUTTING SPEED at 3500 mm/min and ARC GAP at 2 mm.

VI EXPERIMENTAL VALIDATION

For experimental validation, there is L9 Taguchi method used and nine combination generate as per based on Taguchi approach. In this method, combination of GAS PRESSURE, CUTTING FLOW RATE, CUTTING SPEED AND ARC GAP are higher han to combination of which are used in TAGUCHI L27 approach. For this concern GAS PRESSURE are range of 5, 10 and 15 bar, cutting flow rate are range of 300, 350 and 400, cutting speed are range of

3800, 4200 and 4600 mm/min and arc gap are range of 8.0, 9.5 and 11 mm are used. Thus these ranges are intermediate and higher than taguchi L9 combination .

Table 8 – Experimental Validation

GP	CR	CS	ARC GAP	PR.MRR	EX. MRR	PR SR	EXP. SR	PR.HAZ	EXP. HAZ
5	300	3800	8.0	4.787	4.870	5.10	4.87	0.7799	0.7782
5	350	4200	9.5	5.670	5.254	5.62	4.99	0.8080	0.7925
5	400	4600	11.0	6.565	5.995	6.14	5.75	0.8369	0.8254
10	300	4200	11.0	6.860	6.781	3.93	3.87	0.7602	0.7582
10	350	4600	8.0	7.810	7.015	4.23	4.58	0.7683	0.7525
10	400	3800	9.5	8.210	7.992	4.51	4.75	0.7992	0.8012
15	300	4600	9.5	9.003	8.879	2.56	3.02	0.7201	0.7325
15	350	3800	11.0	9.405	8.987	2.81	2.98	0.7510	0.7458
15	400	4200	8.0	10.350	9.897	3.13	3.25	0.7591	0.7584

Table shows experimental and predicted value.this verifies that the experimental result is highly correlated with the estimated result.

VII CONCLUSION

From The conclusions relevant to this investigation are outlined below:

[1] 1.The material removal rate increase with increase gas pressure, current flow rate and cutting speed from 4 to 10 Bar, 150 to 300 Amp and 2000 to 3500 mm/min. when the arc gap parameter are kept constant as well as material removal rate has slightly effect by arc gap.

[2] 2.While studying the effect of the cutting parameters on the material removal rate, it was observed that the effect of the gas pressure and current flow rate far outweighs the effect of the cutting speed and arc gap, which are again roughly equal. The optimum condition for machining to increase material removal rate would be A4 B4 C4 and D1. It has been concluded that higher material removal rate will meet at Gas pressure 10 bar, Current flow rate 300amp, Cutting speed 3500 mm/min and arc gap 4 mm.

[3] 3.The surface roughness decrease with increase from 4 to 10 Bar, but increase with increase with 150 to 300 Amp., when the other two parameter are kept constant as well as surface roughness, but cutting speed and arc gap has not effected on surface roughness.

[4] 4.While studying the effect of the cutting parameters on the surface roughness, it was observed that both the gas pressure play important roles in the effect on the surface roughness. The role of the cutting speed and arc gap given is not crucial to the same extent. The optimum condition for machining to reduce surface roughness would be A4 B1 C2 D1 i.e., the Gas pressure kept at 10 Bar, the current flow rate kept at 150 Amp., cutting speed 2500 mm/min and the gap arc kept at 2 mm.

[5] 5.The effect of change in the cutting speed from 2500 to 3000 mm/min on average surface roughness is slightly raised then after decrease suddenly till 3500 mm/min.

[6] 6.The heat affected zone increase with increase current flow rate from 150 to 300 Amp., when the other three parameter are kept constant as well as heat affected zone decrease with increase gas pressure 4 to 10 Bar, but reversely in case of arc gap and vice versa.

[7] 7.From the ANOVA table, it has been revealed that the current flow rate has effective parameter compare to other process parameter.

[8] 8.Through use of regression equation, engineer can manipulate range of gas pressure, current flow rate, cutting speed and arc gap for this particular work- material and ranges of process parameter combination. Also it has been find out and predicted material removal rate, surface roughness and heat affected zone at any combination of process parameter.

[9] 9.From grey relational analysis, we came to know that the all this responses maximum material removal rate, minimum surface roughness and minimum heat affected zone will obtain at gas pressure kept at 10 Bar, current flow rate kept at 150 Amp, cutting speed kept at 3500 mm/min and arc gap kept at 4 mm.

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