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Optimization of plasma arc cutting by applying Taguchi Method

Kulvinder Rana[1], Dr. Parbhakar Kaushik[2], Sumit Chaudhary[3]
[1]M.Tech. Scholar, U.I.E.T., M.D.U., Rohtak, Haryana
[2]Assistant Professor, ME Dept., U.I.E.T., M.D.U., Rohtak, Haryana
[3]Assistant Professor, ME Dept., MAIT, New Delhi, India

Abstract: Now a day with the increase in competition in market and to achieve high accuracy the non conventional machining like PAC is become life line of any industry. Plasma arc cutting (PAC) is a widely used process for the cutting of different types of metals in several operating conditions. PAC is considered a challenging technology compared to its main competitors: oxy-fuel and laser cutting. Today, because of advances in equipment design and improvement in cut quality, previously unheard of applications, such as multiple torch cutting of mild steel, are becoming common place. The aim of the work is the optimization of PAC of mild steel thin plates, both in terms of cut quality and performances of the consumables, to achieve cut quality standards and productivity levels usually obtainable through laser cutting processes. The temperature of the plasma arc melts the metal and pierces through the work piece while the high velocity gas flow removes the molten material from the bottom of the cut. PAC of mild steel thin plates of 10 mm through a KALI-100 Plasma Arc Cutting Machine is operating in the range 25-120 A. The air is used as plasma gas as well as secondary gas.

Keywords: Taguchi, Plasma arc cutting, ANOVA, HAZAV.

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.

Conventional Plasma Arc Cutting

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.

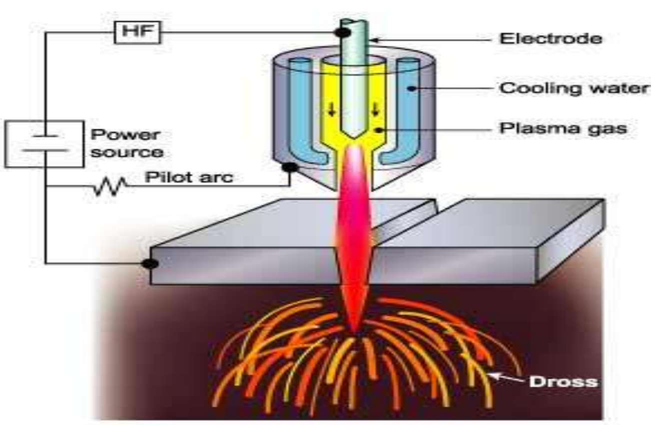

Fig. 1: The plasma arc cutting process

The process differs from the oxy-fuel process in that the plasma process operates by using the arc to melt the metal whereas in the oxy-fuel process, the oxygen oxidizes the metal and the heat from the exothermic reaction melts the metal. Thus, unlike the oxy-fuel process, the plasma process can be applied to cutting metals which form refractory oxides such as stainless steel, aluminum, cast iron and non-ferrous alloys.

The Taguchi method, a systematic application in design and analysis of experiments, is used for Designing and improving product quality. It has become a powerful tool for improving productivity during research and development so that high quality products can be produced and cost is reduced. However, the original Taguchi method was designed to optimize a single performance characteristic. Taguchi designs are balanced, that is no factor is weighted more or less in an experiment, thus allowing factors to be analyzed independently of each other. Minitab provides both static and dynamic response experiments.

Objective of Work

This research is carried out on KALI-100 Model of Plasma Arc Cutter. We can have four variables in this models which are current, torch travelling speed, Torch Stand-off distance, supply air pressure. The output parameter is Heat Affected Zone which is to be minimized to have optimized settings of process parameters.

The statistical tool used in the research is Taguchi Method. Taguchi L9 orthogonal array is used for the calculation of optimum process parameters. The percentage effect of each process variable is also studied.

Input Parameter

1. Flame cutting thickness: 6-150mm.
2. Cutting speed: 50-4000mm/min.
3. Work voltage: 220/380V +-10% 50Hz
4. Cutting air pressure: 1.2MPa
5. Cutting oxygen pressure :< =1.0MPa.
6. Plasma Gas pressure :< =0.25MPa.
7. Work temperature :< =50 C.

Output Parameters

Heat affected zone.

Observations and Calculations

The statistical tool used for determining the optimum process parameters is Taguchi the software which is used for calculation is Qualitek-4 software which is Automatic Design and Analysis of Taguchi Experiments. This software provides the information about the selection of Taguchi design which depends on the number of process variables and the level of their variation. The design of experiment is complete in this stage. The combination of the various process variables is given after the selection of Taguchi orthogonal Array.

In our research the number of variables is four and their level is three so we have the Taguchi L9 orthogonal Array for the study. The levels of the various process variables are given as input to the software. The output parameter which is used for controlling the process is the kerf and Heat Affected Zone. Both are undesirable so we have to minimize both kerf and Heat Affected Zone. So we take the condition of smaller is better for our calculations.
The calculation will be on the basis of average of values.

Heat Affected Zone Response

Analysis using Average of Results:

We will take nine experiments with three runs and we take average of results. The average value of experimental run of heat affected zone is explained in table below.

Table 1: Average Value of Experiment Run (HAZAV)

Experiment no	A	B	C	D	Observations			Average
					First run	Second run	Third run	
1	1	1	1	1	2.04	2.16	2.16	2.119
2	1	2	2	2	1.56	1.44	1.44	1.479
3	1	3	3	3	1.2	1.08	1.14	1.14
4	2	1	2	3	2.64	2.88	2.76	2.76
5	2	2	3	1	2.4	2.28	2.22	2.299
6	2	3	1	2	1.66	1.44	1.5	1.533
7	3	1	3	2	3.72	3.66	3.78	3.719
8	3	2	1	3	3	2.94	3.18	3.039
9	3	3	2	1	2.52	2.58	2.64	2.58

Table 2: Main Effects (HAZAV)

Column # / Factors	Level 1	Level 2	Level 3	L2 - L1
1 current	1.579	2.197	3.112	.618
2 t t speed	2.865	2.272	1.75	-.594
3 air pressure	2.23	2.273	2.385	.043
4 stand off distanc	2.332	2.243	2.312	-.089

With the help of this main effect we can draw multiple graphs keeping the condition small is better. The graphs are shown below:

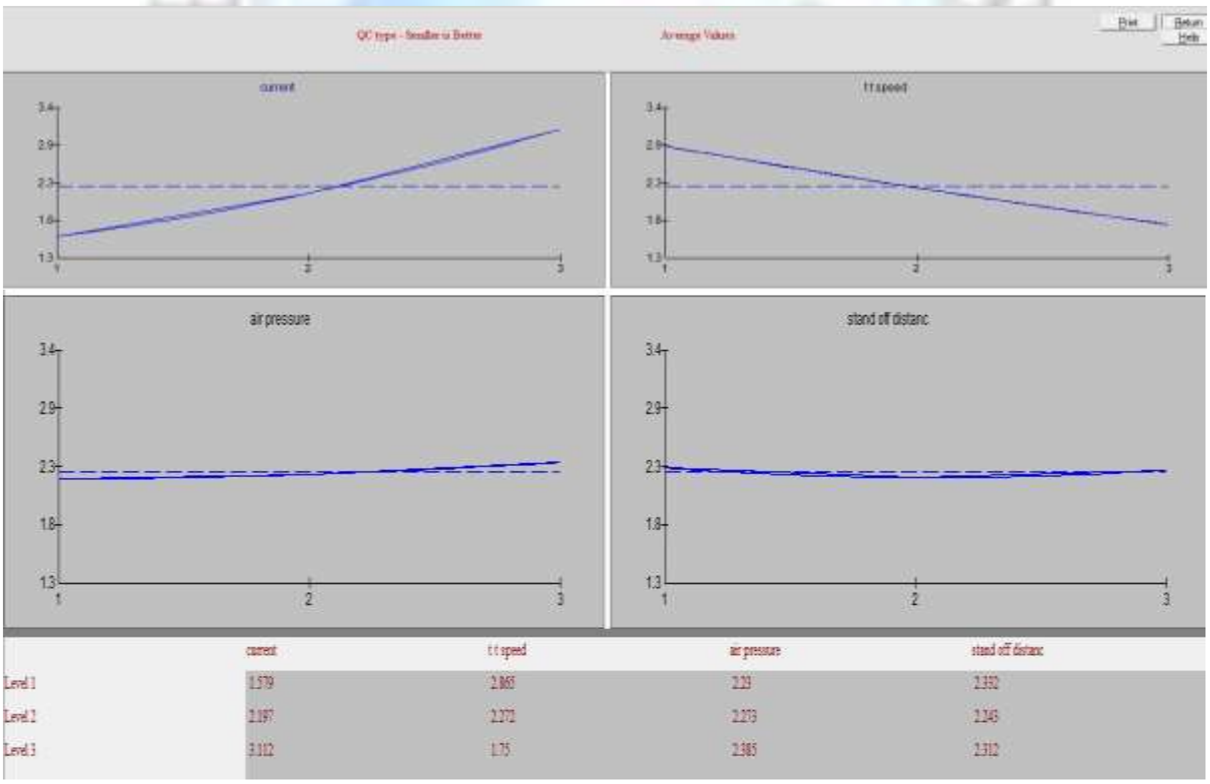

Fig. 2: Multiple Graphs of Main Effects (HAZAV)

The table below is ANOVA table which indicates the percentage contribution of the input parameters.

Table 3: ANOVA Table (HAZAV)

Col # / Factor	DOF (f)	Sum of Sqrs. (S)	Variance (V)	F - Ratio (F)	Pure Sum (S')	Percent P(%)
1 current	2	3.57	1.785	-----	3.57	65.038
2 t t speed	2	1.867	.933	-----	1.867	34.013
3 air pressure	2	.038	.019	-----	.038	.707
4 stand off distanc	2	.013	.006	-----	.013	.238

After obtaining the values from ANOVA table we can show the relative influence of factors and interactions with the help of pi chart.

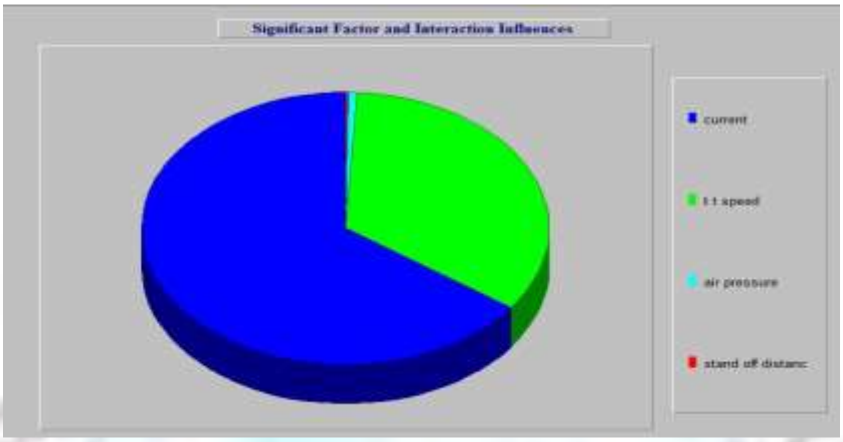

Fig. 3: Relative Influence of Factors and interactions (HAZAV)

At last we show table below which explain the optimum value of inputs and their performance.

Table 4: Optimum condition and performance (HAZAV)

Column # / Factor	Level Description	Level	Contribution
1 current	65	1	-.718
2 t t speed	3.0	3	-.546
3 air pressure	60	1	-.067
4 stand off distanc	3.0	2	-.053

The graph shown below shows the contribution of input factors , i.e optimum performance with major factor contribution.

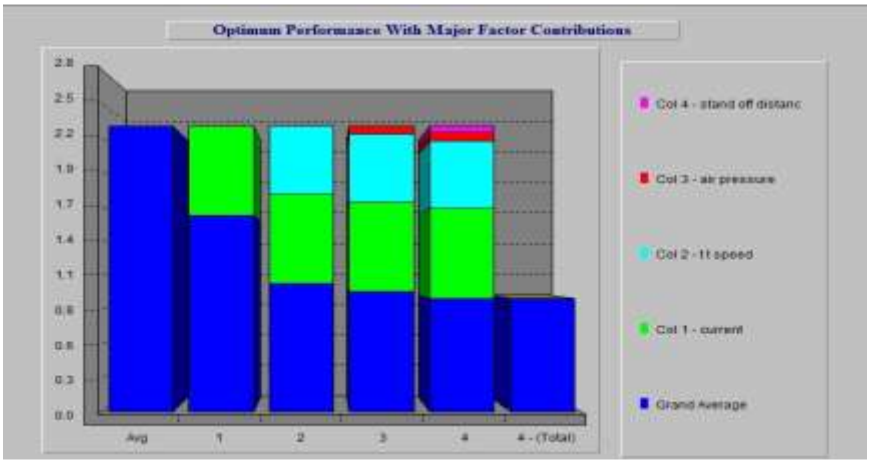

Fig. 4: Factors contribution- stacked group (HAZAV)

Observations

In this research the calculation is done on the basis of average of values. The Main Effect of all the parameters is calculated. The Multiple Graph is plotted which shows the effect of variation of the parameters on a single plot. Moreover it gives the idea about the extent upto which a factor effect the process graphically. ANOVA gives the percentage effect of all the factors i.e. it tells about the percentage or parameters according to their effect on the process. The finally the optimum conditions and performance is given which tell about the optimum value of process variables which gives the best performance according to the desired constraints i.e. smaller is better in our case.

Observation Heat Affected Zone Response using Average of Results

The effect of current is maximum on the process which is more the 65% after that speed have a effect of about 34% and stand off distance and air pressure have minimum effect on the process. Their combined effect is less the 1% on the process. The optimum values of each parameter is given by table 7.8, the optimum current is 65 A optimum air pressure is 60 psi, optimum torch travelling speed is 3.0 m/min, optimum stand-off distance is 3.0 mm of having minimum HAZ which is calculated by average of results.

Conclusions and Future Scope

In this research, the optimum parameter settings were identified for the plasma cutting process by using Taguchi L9 orthogonal array, the number of runs required of this design is 9, in this array we have four variables having three leves so the number of run required if Taguchi orthogonal array is not used are 3^4 i.e. 81 runs. So by using Taguchi method we have reduced our number of runs. The main parameters which effect the process are current, air pressure, stand-off distance, and torch travelling speed. Three levels of these parameters are considered in increasing order. The entire process in this study was conducted for mild steel sheet with 10 mm thickness. The statistical tool used for determining the optimum process parameters is Taguchi the software which is used for calculation is Qualitek-4 software which is Automatic Design and Analysis of Taguchi Experiments. This software provides the information about the selection of Taguchi design which depends on the number of process variables and the level of their variation.

The current has maximum effect on the process after that torch travelling speed and stand-off distance and air pressure have minimum effect on the process. The overall optimum values of each parameter give the calculation is, the optimum current is 65 A optimum air pressure is 65 psi, optimum torch travelling speed is 3.0 m/min, optimum stand-off distance is 3.0 mm of having and Heat Affected Zone. As from the observation we found that it is cheaper than laser cutting for thick plates and from oxy-acetelene for thin plates.pac has better cut quality. Heat affected zone is less or minimum. So we can prefer it inspite of other cutting processes. It can also be used to cut ceramic which results in high accuracy and less cost. Some one can make another study using plasma arc cutting and can implement it for quantitative analysis.

References

[1]. Ramakrishnan S, Shrinet V, Polivka F, Kearney TN, Koltun P. 2000, "Influence of Gas Composition on Plasma Arc Cutting of Mild Steel", Journal. of Physics, 33, 2000 (18).
[2]. Joseph C. Chen, Ye Li, Ronald A. Cox, "Taguchi-based Six Sigma Approach to Optimize Plasma Cutting Process: An Industrial Case Study", International Journal of Advanced Manufacturing Technology, 41, 2009, pp. 760-769.
[3]. Y. F. Hsiao, Y. S. Tarng, and W. J. Huang, "The optimal parameters process of plasma arc welding (PAW) by the Taguchi method with Grey relational analysis is studied", 23, 2008, pp. 51-58.
[4]. Mahapatra, S.S., Amar Patnaik, "Optimization of wire electrical discharge machining (WEDM) process parameters using Taguchi method", Vol. 34, (2007) pp. 911-925.
[5]. John Kechagias, Michael Billis, Stergios Maropoulos, "An optimization of the cutting parameters during CNC plasma-arc cutting of St37 mild steel plates is attempted using robust design", Volume 1 - Issue 4 – 2010, pp.562-571.
[6]. Ryoichi F, "Elimination of various quality nonconformities, reduction in failure and cost by half by using Taguchi design method", Vol. 36 No. 3 October 2003 pp 168-173.
[7]. Fang Yi-Chin1, Tzeng Yih-Fong and Li Si-Xiang, "A Taguchi PCA fuzzy-based approach for the multi-objective extended optimization of a miniature optical engine" vol 41, 2008, pp. 653-661.
[8]. Jia Deli & You, "An intelligent control strategy for plasma arc cutting technology" vol-13, (2011), pp. 1–7.
[9]. Abdulkadir Gullu, Umut Atici, "Investigation of the effects of plasma arc parameters on the structure variation of AISI 304 and St 52 steels", Vol 18, No 2 (2005), pp.-172-180.
[10]. Xu W. J., Fang J. C. & Lu Y. S. October, "Study on ceramic cutting by plasma arc", Journal of Materials Processing Technology, Volume 129, Issues 1-3, (2002), pp.-55-63.