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A Review on Optimization of Plasma Arc Cutting Parameters Using Taguchi Method for EN19

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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 the most important non-conventional machining methods is plasma arc cutting and also considered a challenging technology compared to its similar technology like oxy-fuel and laser cutting. It has high finishing and accuracy ability of machining any materials and to produce complex shape increases its demand in market. Optimization of Plasma arc cutting has always been an open research area for researchers.*

In thesis work literature has been studied in context to optimization of plasma arc cutting parameter. In order to achieve target and optimum results, Taguchi method employed. The suitable orthogonal array has been selected as per number of factors and there levels to perform minimum experimentation. The work pieces of EN19grade materials will be selected for experiment purpose. The optimum value will have been determined with the help of ANOVA Method. The aim of present article is to identify various process parameters and response variables which has significant effect on plasma arc cutting process.

Keywords*: Plasma arc cutting (PAC), Taguchi method, Design of experiment (DOE), ANOVA etc.*

I. Introduction

There are mainly four stages of physical matter and that are: solid, liquid, gas and plasma. By subtracting the energy or by adding the energy, changes are made from one state to another state. Plasma is the fourth state of matter which is resultant of electric arc heating of gas at very high temperature which gives an electrically charged gas due to an adequate number of electron to protons. The major difference between plasma gas and neutral gas is that the molecules in plasma can exert electromagnetic forces on one other. From many years in engineering industry, oxy – acetylene gas cutting has been used for cutting of sheet metal. Over the past few years, plasma arc cutting has pretty much taken over, for some really honourable reasons to perhaps most significantly. Plasma arc cutting can cut any metal that is electrically conductive i.e. steel, stainless steel, copper, bronze and brass etc. there are many advantages of plasma arc cutting over oxy – acetylene flame that, it is hotter and narrower which results in smaller width of kerfs and gives cleaner cuts. Plasma arc is formed between the electrode and the work piece. The temperature of plasma is about 20000oC and the velocity can reach up to speed of sound. There are various types of plasma arc cutting like, conventional PAC in which arc is constructed by a nozzle and there is no shielding gas is used. Second type of PAC is air plasma arc cutting. Extra oxygen in air provides additional energy from the exothermic reaction with molten metal of steel which increases cutting speed by 20%. This process also used for cutting of aluminum and stainless steel. Next is a dual-flow plasma arc cutting which is modification of conventional plasma arc cutting. In dual-flow plasma all the features are same as conventional plasma arc cutting except it has secondary shielding gas passing through nozzle. Cutting speed is slightly higher than conventional plasma cutting but cutting quality is not acceptable. In water injection plasma arc cutting, water is passed inside the nozzle to provide extra arc construction. Two modes of water injection have been used i.e. radial injection and swirl injection. Underwater plasma arc cutting is suitable for numerically controlled cutting machine. Underwater PAC fairly eliminate fumes and ultraviolet radiation. It also produces less noise compared to conventional PAC.

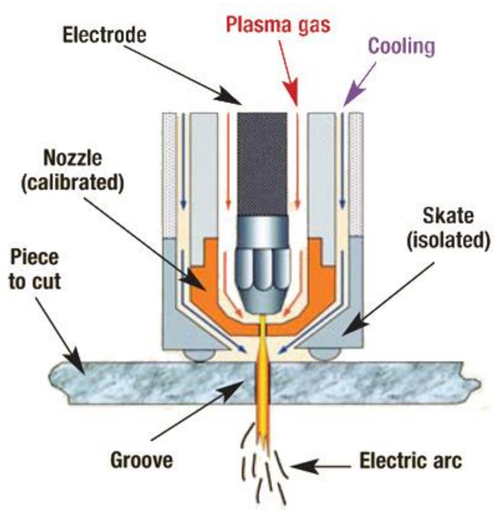

Fig 1: Plasma Arc Cutting

II. Literature Review

In the survey of literature about the material processing using plasma arc cutting and importance is given to finding the work done by different authors in the field of plasma arc material processing of ferrous and nonferrous material with special reference toexperimental data for material removal rates (MRR), kerf, analysis, surface roughness etc.

Ferrous Material

1) Mild Steel

a) Hardox-400 metal plate

Subbarao Chamarthi [1]Plasma arc cutting (PAC) is a thermal cutting process which makes use of a concentrated jet of high - temperature plasma gas which melts and cut the material. Author has done study on 12 mm thick plate of Hardox-400 material which has been cut by considering high tolerance voltage, cutting speed, and plasma gas flow rate included as main parameters in the analysis and their effect on unevenness of cut surface was evaluated. The design of experiments (DOE) method was used to evaluate the main parameters which is define the geometry of the cut profile, as well as its constancy for Hardox-400 material plate. Despite the value selected for these parameters, the analysis shows that Hardox-400 metal plates can have different profiles, depending on the specific side considered. Unevenness can be determined as a result of an experimental investigation aimed at selecting the proper values of process parameters of PAC system. Results of this screening steps were analyzed by means of the Analysis of Variance (ANOVA) technique with use of design expert 8.0.7.1 software in order to identify the main parameters, which define the unevenness quality attribute. The operating conditions have been optimized by adjustment of parameters like plasma gas, cutting speed and arc voltage in order to obtain good surface quality for all the sides of Hardox-400 metal plate. As recorded optimized minimum unevenness for 12 mm Hardox plate is 421 micron at optimum value of 70L/Hr plasma flow rate, 125 V voltage and 2100 mm/min cutting speed.

b) S235 material

K. Salonitis (2012) [2] investigated plasma arc cutting process experimentally. The aim of work is to evaluating process variables like, cutting power, scanning speed, plasma gas pressure and cutting height. Experiment has been conducted on S235 mild steel material with oxygen as primary gas and air as secondary gas. Selected responses were, Heat affected zone, cutting edge roughness and conicity. Standard Design of Experiment procedure has been carried out and on the basis of that results S/N ratio of all the results have been calculated. Three levels of each processing parameters have been selected. Experiment had been conducted on CNC plasma cutting machine and all the results of output parameter were evaluated by using various mechanical instruments. ANOVA was applied on the achieved data and evaluated that, the cutting height has the strongest effect on the quality characteristics and especially on conicity and on the surface roughness of the cut. The cutting current has highest effect on heat affected zone. Surface roughness of edge is strongly affected by cutting height. In general, it can be stated that the cutting height is the parameter with the greatest influence on the quality characteristics of the process.

c) AISI 1017 Steel

R. Bhuvenesh [3]The roughness of the surface area of the material cut by the plasma arc cutting process and the rate of the removed material by the manual plasma arc cutting machine was importantly considered. Cutter Selco Genesis 90 used to cut Standard AISI 1017 Steel of 200 mm x100 mm x 6 mm manually based on the chosen parameters setting. The material removal rate (MRR) was measured by determining the weight of the specimens before and after the cutting process. The surface roughness (SR) analysis were conducted using Mitutoyo CS-3100 to conclude the average roughness value (Ra). Taguchi method was applied to achieve optimum condition for both outputs studied. The microstructure analysis in the area of the cutting surface is achieved using SEM. The results reveal that the SR values are inversely proportional to the MRR values. The quality of the surface roughness depends on the dross peak that occurred after completion of the cutting process. Based on the experiment results various conclusions for manual plasma arc cutting machine can be highlighted as: A) generally the Surface roughness (SR) values are inversely proportional to the material removal rate (MRR) values. B) The dimensions of the dross determine the quality of plasma arc cutting (PAC) in terms of surface roughness (SR).

d) EN31 Material

Milan kumar das et. al. (2014) [4] investigated the influence and parametric optimization of response parameters on EN31 material using grey relation analysis method. Three output parameters, (1) gas pressure (2) Material removal rate and (3) Surface roughness has been selected. L27 orthogonal array had been selected. The maximum material removal rate and minimum surface roughness parameters were optimized based on taguchi's method and grey relational method. The optimal combination of parameters obtained as middle level of gas pressure, highest level of arc current and highest level of torch height. ANOVA was used to get effect of each parameter on the performance characteristics. It was observed that gas pressure had significant effect on output whereas torch height and arc current had less effect on response. Confirmation of the test using optimal setting displays good agreement to the predicted value.

e) EN8 (AISI 1040) Material

Parthkumar M. Patel and Jaypalsinh Rana [5] investigated the effect of selected plasma arc cutting parameters such as current flow rate, air pressure, cutting speed and arc gap etc. and for cutting of EN8 (AISI 1040) material. The experiment was done on the 8 mm thick plate. In the experiment, the main focus was on selection of best process parameters combination for cutting using material surface roughness (SR), removal rate (MRR) and kerf width (KW). It has been conclude that the optimum combination of each process parameter for higher MRR was meeting at high cutting speed, high current flow rate, low air pressure and high arc gap.

f) EN-45A Material

Sahil Sharma et. al. [6] conducted an experimental investigation for the optimization and the effect of the cutting process parameters on Material Removal Rate (MRR) in Plasma Arc Cutting machine (PAC) of EN- 45 material by using Taguchi's L16 orthogonal array method. Four process parameters like, cutting speed, cutting current, plasma gas pressure, stand-off-distance have been selected for the experimental work. Analysis of variance (ANOVA) has been performed for getting the percentage contribution of each process parameter on the response variable i.e. material removal rate (MRR). From the ANOVA, it has been found that the cutting speed, cutting current and the plasma gas pressure were the major factors that affect the response variable. The optimal combination of the cutting process parameters was obtained at highest level of cutting speed and gas pressure and middle level of current and S.O.D). From the ANOVA, the most effective process parameters in descending order were: Cutting speed, gas pressure, current and S.O.D. The S.O.D was the least effective parameter within a specified test range.

g) IS 2062 E250 BR

Pallavi H. Agarwal, Ketulkumar R. Patel [7]have done the experimental investigation on the plasma arc cutting of structural steel (IS 2062 E250 BR) material. The response parameters selected were top and bottom kerf widths, material removal rate (MRR), and bevel angle: while machining variables were pressure, current, standoff distance (SOD) and speed. Experiments were performed using response surface methodology (RSM). Furthermore grey relational analysis was used to optimize the process parameters. For material removal rate (MRR), higher the better output performance characteristic was used whereas lower the better characteristic was used for top kerf width, bottom kerf width and bevel angle.

h) Hot Rolled Drawing Mild Steel

R.Biniand atall [8]were conducted experiment on 15mm thick mild steel sheets metals using process parameters like arc voltage, cutting speed, plasma gas flow rate, shield gas flow rate and shield gas composition. The effect of process parameters were evaluated on kerf position and shape. Experimental results revealed that the cutting speed and arc voltage have most effect on the kerf formation mechanism and their interaction was also important in defining the inclination of the cut. It is also concluded that by reducing the arc voltage, i.e. the standoff distance, the thermal stress on the torch components, especially the electrode and the nozzle, increases, which accelerate their wear. This trade-off can be taken into account by adding some suitable constraints to the parameters domain and beyond the arc voltage, the cutting speed showed a noticeable effect. In particular, results obtained in the last experimental stage allowed one to observe that unevenness can be reduced by reducing the cutting speed. It was shown that very good quality can be achieved for all the sides by varying the cutting speed and the arc voltage only.

i) Mild Steel Thin Plates

Kulvinder Rana [9]has done the optimization of plasma arc cutting (PAC) of mild steel thin plates, both in terms of cutting quality and performances of the consumables, to achieve highest cutting quality standards and best productivity levels usually obtainable through laser cutting processes. PAC of mild steel thin plates of 10 mm thickness through a KALI-100 Plasma Arc Cutting Machine was operating in the range of 25-120 A. The air was used as plasma gas as well as secondary gas. In this research, the optimum process parameter settings were identified for the plasma cutting process by using Taguchi's L9 orthogonal array, the number of runs required of this design was 9, The main process parameters which affect the process were air pressure, current, stand-off distance, and torch travelling speed. Three levels of these parameters were 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 was Taguchi's design. Qualitek-4 software was used for calculation which gives 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 parameters and the level of their variation. Experimental results shows that, 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 was the optimum current (65 A) optimum air pressure (65 psi), optimum torch travelling speed (3.0 m/min), optimum stand-off distance (3.0 mm) of having and Heat Affected Zone.

j) ST37 plates

Kechagias [10]investigated the optimization of cutting process parameters during CNC plasma-arc cutting of St37 mild steel plates by utilizing robust design. Selected process parameters are cutting speed, arc ampere, pierce height, and torch standoff distance utilizing the Taguchi L9 (34) orthogonal array. The effect of each parameter has been examined through ANOM (Analysis of Means) diagrams. Optimum levels for each parameter have been proposed as per performance measures. ANOVA (Analysis of Variances) has been used aiming the importance identification of each parameter variance on the performance measure as a percentage value. Results indicate that the arc ampere has an effect mainly on the bevel angle (58.7%), while the cutting speed and the torch standoff distance have an influence of 19% and 15.7% respectively. The pierce height has an influence about 6.6% and thus its variations do not significantly affect the bevel angle in the experimental region.

k) S235JR Material 16mm thickness

TKavkaetal [11]investigated the effect of nature of gas on the plasma arc cutting of mild steel material. In this paper the study is been carried out on the effect of the nature of gas on the arc behavior and the cutting performance of mild steel material. Usually the plasma arc cutting system is operated on steam has been modified to usage of different plasma gases. Experimental results were obtained from the cutting of 16 mm thick mild steel metal plate at 60 A current with steam, nitrogen, air, and oxygen as the plasma gases. From the experimental results it is revealed that 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 nitrogen and air is used as plasma gases.

l) S235JR Sheet plates (4mm, 6mm and 8mm) material

Yaha hisman selic et al [12]work has been done on cutting the sheet of S235JR material using the CNC plasma arc cutting machine at different process parameters like cutting speed, cutting current, and arc voltage and measured the effect of variation on temperature distribution, hardness, thickness of heat affected zone and surface roughness of the material after cutting. From the results of the experiments it is concluded that the quality of plasma CNC machine depends on the cutting current, cutting speed, arc voltage and material thickness. To get the best surface roughness, the cutting current and the cutting voltage must be kept low and cutting speed must be high for the thin sheet. While the thickness of the cutting sheet increase the cutting current must be increased and cutting voltage is to be decreased. However this leads to decrease in corresponding cutting speed.

m) St-52 Structural steel

Michal Hatala [13]research has been done for definition and evaluation of process factors and parameters of cutting surface while cutting the material ISO Fe510. Using factor experiment method, importance of four factors were observed which are feed rate of plasma torch, plasma gas pressure, nozzle diameter and distance between nozzle mouth and cutting material, that influence the parameter of roughness profile Ra and Rz. On the base of experimental results that were analytically processed by factor analysis method it can be said, that impact of process parameters during the material cutting was different in particular depths. It was found that most significant parameter which affect the machined surface roughness are feed rate of plasma torch and plasma gas pressure. Remaining all factors are less important like diameter of nozzle and distance between nozzle mouth and material.

From the experimental results it can be said, that for achieving higher quality of cut surface it is recommended to use higher pressures of plasma gas and appropriate feed rate of plasma torch.

n) EN 8 Steel Plates

S.Ragul, V.Sakthiseran and J.Santhosh[14]In this experimental work plasma cutting on EN 8 steel plates (30x30x4mm) with different machining process parameters has been conducted. L16 Orthogonal array is used design of experiment with 4 levels and 3 factors design. Gas pressure, current flow and cutting speed are the input parameters and surface roughness and material removal rate is response parameters. After conducting experiment the following the process parameters are the optimized in plasma cutting of EN 8 steel plates.

Surface roughness

The optimized process parameters of EN 8 plates are 4 bar of gas pressure, 30 ampere of current flow and 1400 rpm of plasma cutting g is the best parameters while achieving lower surface roughness in small the better concept of signal to noise ratio. The gas pressure is a dominating parameter of plasma cutting process while machining EN 8 plates. The EN 8 steel provided good machinability in plasma cutting process and provides good machining tolerance.

Material removal rate

The optimized process parameters of EN 8 plates are 4.5 bar of gas pressure, 39 ampere of current flow and 1200 rpm of plasma cutting is the best parameters while higher material removal rates in larger the better concept of signal to noise ratio. The gas pressure is a dominating parameter of higher material removal rate in plasma cutting process while machining EN 8 plates.

o) A Grade Mild Steel

Ashish Sharma[15] In this experimental work plasma cutting on A Grade Mild steel with different machining process parameters has been conducted and important conclusions obtained from present work. Various vital issues of Plasma arc cutting have been analyzed on the basis of an experimental study. The following conclusions have been drawn: Optimal value of Kerfs 1.2 and optimum cutting speed 1350 and optimum stand of distance 5 and taper is 0.57.

p) Mild Steel Material (10mm plate)

Gurwinder Singh*, Shalom Akhai [16] In this investigation application of the Taguchi method to the optimization of the machining parameters of CNC Plasma Arc Cutting Machine. It has been shown that Material Removal Rate (MRR) can be considerably improved in the CNC Plasma Arc Cutting process using the optimum level of parameters. From experimental analysis completed on MILD STEEL, it was concluded that:

[1] In Plasma arc machining the cutting Speed is the parameter has a significant effect while the other parameters viz. Kerfs and standoff distance are less effective.

[2] 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 primary gas, Oxygen and secondary gas, air is used as plasma gases.

[3] For Maximum Material removal rate the cutting speed play a very important role. Higher the value of cutting speed more is the MRR.

q) Mild Steel Plate (200x200x5mm)

Dhiraj Kolhe, Altaf Sayyad, Digambar Nikam, Umesh Patole and Prof. Narkhede J. A[17] From the conversation so far it has been concluded that R&D parameter is better material cutting than other parameter. Al will help in reduction in material removal rate burr, plain surface finishing and better cutting quality than other parameter like machine provider, nozzle provider etc. material Removal rate minimization techniques can be easily implemented in material. The overall conclusions from the investigations are:

- Burr reduction with optimize parameter speed.
- Better surface finish with optimize parameter.
- Important reduction of exit burr with accurately constructed system

r) <u>Hardox-400 Cutting Plate (50mm wide 12mm thickness)</u>

<u>Patel Jitendra Kumar[18]</u> In this experimental Hardox-400 in standard plate supply has a ferrite structure; the chemical composition of this material is given in Table-1.specimens, 50 mm wide, were machined from plates with thickness of 12 mm; are typically used in the construction of pavers &plants. The external surfaces of the specimens were not machined, so as to maintain, as in real constructions, the "as-received" condition of the plates. Plasma Cut Specimens. A group of specimens was obtained by cutting them with a numerically controlled plasma-cutting machine. The torch was water-cooled and had a nozzle with an outlet diameter of 2.5mm the plasma gas was oxygen, 0.05m3/s, at a pressure of 10.bar.a current setting of 130 amps at 135volts was used. The distance between the torch and the plate was 3.3 mm.

Cutting speed increase or decrease inversely proportional thickness of plate. The cutting speed reduces results in an excessive amount of molten metal which cannot be completely removed by the momentum of the plasma jet. Further, at low cutting speeds the shape of the cut front changes resulting in a change in the direction of ejection of molten metal. The unevenness of plate increase with increase of cutting speed, so decrease of speed is very important but the at this speed more dross are produced at bottom of plate. It has been found more value of unevenness is in 16mm plate cutting compare of 12mm plate thickness. It was determined that after cutting, in the areas near to outer surface of the part hardness increased, around 390–480 HV, and it decreased towards to the core of the material.

s) <u>E250 Mild Steel plate (6mm Thickness)</u>

<u>S.Balaganesh, T.Dinesh, B.Dinesh Kumar, S.Hariharan and N.Senthil Kumar[19]</u> In this experiment it is concluded that, In plasma arc cutting process there are various process parameters such as pressure, current, speed and arc height which affect cutting quality. By selecting the proper process parameters we can achieve proper cutting quality. (1) Hardness will be better for maximum pressure and arc height, medium current and speed. (2) Roughness will be better for maximum pressure and arc height, medium current and speed. (3) Machining time will be better for maximum pressure, current and arc height, medium speed. (4) From the above SN graph, it is absorbed that the optimum hardness obtained for the pressure 8.2 bar, current 90 A, arc height 2.5 mm and speed 2800 rpm.

t) <u>Mild Steel Plate (8mm to 16mm thickness)</u>

<u>S.Siva Teja, G.Karthik, S.Sampath, and Md. Shaj[20]</u> The plasma arc cutting experiments were conducted on Taguchi L16 orthogonal array using a CNC plasma arc cutting machine to study the impact of various process parameters on the process. The surface roughness is measured using a profilometer in µm and kerf is measured with the aid of Vernier calipers in mm. The major factors considered are plate thickness, speed, current and voltage. A grey relational analysis is performed to examine the multiple performance characteristics of the plasma arc cutting process. The conclusions of the experimental work can be summarized as follows. Grey relational analysis is an efficient and powerful tool for optimizing the multiple response characteristics. ANOVA is performed on the grey relational grade to ascertain the most important parameter affecting the process. From the analysis, it is found that the most important parameters that affect the plasma arc cutting process are plate thickness followed by current. The optimal parameter found as A4B4C1D3. The productivity of machining process can be improved by machining under optimal parameter settings. It is observed that the grey relational grade is improved by 59.15% from the validation tests.

u) AISI 1018 Material

Mr. Rajnikant C. Bidajwala, Ms.Mili A. Trivedi, Mr.Hiren M. Gajera and Mr. Tejendrasinh S.Raol [21] 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.

v) AISI 1017 Mild Steel Material (10×10×6mm)

Pratishtha and C.S. Malvi[22] This work has presented an application of the Taguchi method to the optimization of the machining parameters of manual air plasma arc cutting machine. The Taguchi method provides a systematic and efficient mean for determining optimal parameters with less work than other optimization techniques. The confirmation experiments were also conducted to verify the optimal parameters. It has been shown through confirmation test that MRR can be significantly improved in the plasma arc cutting process using the optimum level of parameters. The plasma arc cutting (PAC) machining of mild steel (AISI 1017) is performed with the application of combination with DOE. From ANOVA of MRR it can be said that which parameter is most important and which is least important. This is because large number of observations can be taken either by considering L27 or L32 orthogonal array with 3 level designs. On the basis of result and discussion summary, this work had archived its main objective but an improvement can still be done to improve the metal removal rate (MRR). Some suggestions to improve the result include the reproduction of the model which can reduce the variations of the data and increase the reliability. Based on this; many improvements can be met. Following are some suggestions for future work like addition of the parameters such as kerf, voltage, angle; material dimension and change in advance material such as copper, brass and bronze etc. then the comparison of the results are obtained. The introduction of other methodologies in the same material of work to compare the results obtained such as response surface methodology (RSM), grey relational analysis (GRA), and genetic algorithm (GA) and artificial neural network (ANN) etc. In this work no interaction is considered therefore interaction can also be considered in the future research asthis will improve optimum conditions. The effect of side clearance and temperature on material and work can also be considered to study the effect on properties of work piece.

w) <u>ASSAB 760 (equivalent to AISI 1043) steel specimens of 6 mm thickness</u>

<u>L.J. Yang[23]</u> This paper presents the results obtained from the optimisation of the processing parameters to achieve maximum hardened depth of ASSAB 760 steel specimens using a micro-plasma arc and the Taguchi experimental design with a 4-factor 3-level (L9) OA. The factors considered were arc current, torch traversing speed, plasma gas flow rate and arc gap. The hardened depth obtained varied from 0.08 to 0.37 mm, with an average value of 0.193 mm. However, with the optimized processing parameters, the average depth obtained was 0.36 mm. The maximum hardness of the hardened zone observed was 733 Hv. The significance of the optimisation process, in maximizing the depth of the hardened zone in ASSAB 760 steel specimens, is therefore obvious.

x) <u>Mild Steel 200 x 200 x 10mm</u>

<u>Dattu B. Ghane[24]</u> Experimental work has been administrated. From that it is concluded that: 1) MRR and surface roughness values are affected by cutting parameters such as Gas pressure and maintained arc gap. 2) There are different operating parameters suggested by Kalpak industry, Nozzle provider (ESAB), Mass cutting machine provider, operating parameters taken by operator and company expert as per expertise (R & D). So among these parameters advised for right parameters selection as given in detail report and From Dimensional analysis it is concluded that after cutting, sample width varies at different sections as given in analysis report 4) Material removal rate is higher while amount of material removed is less. 5) As the Material removal rate increases the time required to cut the part is less. 6) The surface roughness is having lower value resulting surface finish of part is good that reduces the cost of after processing operations. 6) In nozzle wear analysis found that the 3/64 type nozzle is the best for all results and mentioned in detail report.

y) <u>Mild steel plate (12mm)</u>

<u>S.Mittal and M.D. Mahajan[25]</u> In 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, torch standoff distance & arc current and their effect on the response variable (MRR & KERF) and it is concluded that: 1. Arc current has a extreme 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 effect 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 KERF and MRR maximum or minimum simultaneously for the satisfactory optimized cutting process.

z) <u>Mild steel plate of dimension 200 mm x 30 mm.</u>

<u>Devaki Nandan Sharma and J. Ram Kumar[26]</u>In this investigation on PAC of Mild steel. RSM is selected to optimize the process parameters of cutting variables. The RSM technique was very adequate in predicting the optimum solution of input parameters. Safe cutting zone is useful to find out working environment and optimum solution. The optimum solution is: Thickness _ 2 mm, Current _ 40A, Arc Gap Voltage _146.84 V, Speed _ 700 mm/min and DFR _ 0.0214695 g/s. Obtained experimental results are consistent with theoretical considerations. Error is 8% that is in allowable range.

The biggest problem in PAC is dross formation on work piece during cutting. By selecting optimum parameters, it can be minimized. Minimum or no dross formation will help to find out the best quality cut of PAC. A small amount of dross is also present in the optimum solution obtained. It indicates that in this area have a place for further research and improvements.

aa) <u>IS 2062 (E250) Mild Steel Material</u>

<u>Utsav Desai, Divyesh Barodiya, Santosh Rathod and Anant Lad[27]</u> The Taguchi method has been used, in which the experiments are completed as per standard Orthogonal Arrays (OA) while the optimum level of input process parameters (control factors) are decided on the basis of analysis of the experimental results. Based on the review of the literature, the selected input parameters to be investigated were four namely the stand of distance, cutting speed, current, and voltage. The surface roughness and MRR has been selected as output parameter. This led to the use of an L9 orthogonal array.

From ANOVA analysis it has been conclude that, the most affecting parameter for MRR and surface roughness is voltage and speed respectively. – From Grey relation analysis it has been found that the optimum value of speed, stand of distance voltage and current is 60 mm/min, 3 mm and 130 V, 45 Amp Respectively. – After deciding the optimum value of each parameter it has been say that the 1st run give the best multi-performance characteristic so the 1st run is best.

2) <u>Stainless Steel</u>

a) <u>SS 316L Material</u>

<u>S.S. Pawar [28]</u> response parameters of plasma cutting process for SS 316L plates with different thickness were experimentally analyzed. The quality of the cut had been monitored by measuring the kerf width and taper. Plate with different thickness like, 4 mm, 8 mm and 12 mm were cut with different combination of input parameters as per the Design of experiments. Input parameters used for experimental work were arc voltage, cutting speed, and gas pressure. Effect of each process parameter on quality characteristic of cut was determined by using analysis of variance (ANOVA) method. It was found that arc voltage had the major influencing parameter which affects kerf and cutting speed, and gas pressure were the secondary. Whereas the taper was highly influenced by cutting speed followed by gas pressure and arc voltage. These two quality characteristics were optimized by using Grey Relational Analysis.

(a) From S/N ratio analysis it was found that increment in arc voltage results in increment in kerf width and decrement in taper. Increase in gas pressure causes increase in kerf width and decrease in taper produced. Increase in cutting speed results in decreased kerf width and increase in taper.

(b) ANOVA was done in order to identify influence of process parameters on quality characteristics. It was found that cutting speed and arc voltage were significant for kerf width. Whereas all three input parameters cutting speed, arc voltage and gas pressure are found significant for taper.

(c) Effect of arc voltage was found more for kerf width followed by cutting speed and gas pressure. Cutting speed was effecting more for taper followed by arc voltage and cutting speed.

(d) GRA was used to optimize both the responses taper and kerf width. GRG was found maximum for 4 mm plate at 145 volt, 3500 mm/min and 55 psi, for 8 mm plate at 155 volt, 1500 mm/min and 65 psi, for 12 mm plate at 155 volt, 900 mm/min and 80 psi.

(e) Taguchi method was used to optimize GRG it was found that GRG was maximum for 4 mm plate at 145 volt, 4000 mm/min and 55 psi, for 8 mm plate at 145 volt, 1800 mm/min and 65 psi, for 12 mm plate 155 volt, 1100 mm/min and 80 psi. Better results of quality characteristics were obtained by using these process parameters.

b) <u>AISI 304 Material</u>

<u>Sovan Bhowmick et. al. (2018) [29]</u> the experiment had been performed by taking into consideration of three process parameters and three factor levels for each parameter. Traverse speed, Gas pressure and thickness of material were taken as the input process parameters. Analysis of Variance (ANOVA) had been performed in order to identify the effect of each input process parameters on the material removal rate (MRR) and surface roughness. A multi objective optimization was also done to find the optimum value of surface roughness and MRR for a set of predicted value of input process parameters. From ANOVA it was seen that the speed and the thickness were more significant. It was observed that the MRR was the function of speed and thickness of material. The gas pressure had a less effect on MRR. From ANOVA it was also observed that the pressure was the only significant parameter in case of surface roughness. The multi objective optimization was in well agreement with the result of the confirmatory tests. The percentage error of experimental value with the predicted value for both MRR and surface roughness was less than 10%.

c) AISI 304 Stainless Steel and St 52 carbon steel

Abdulkadir Gullu and Umut Atici (2008) [30] stainless steel (SS) & carbon steel (CS) have been cut by plasma arc cutting machine and the variety of structural specifications made after cutting has been done. From the experimental results, it has been observed that burning of particulars and distribution amount were goes increased when the cutting was performed using the speeds which were upper or lower limits of the ideal cutting speeds proposed by the manufacturer of the machine tool. It was found that the hardness from the outer surface to the core decreases, while the hardness near to the outer surface which was affected by the high temperature during cutting increases. The amount of material removed from cutting area was proportional to the thickness of material. Cutting gap becomes smaller in thin material section, bigger in thick material section. When the graphics shows cutting results which were prepared according to side speeds proposed by the machine tool manufacturer and material type and thickness, it can be seen that these proposed speeds were more suitable. This indicates that the manufacturing company determined these speeds after doing some experimental tests. The least amount of burr occurred when the proposed speeds were used for experiment. 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.

Similar results were observed for the same group of materials having different thickness, mechanical, physical properties. It was found that after cutting, in the areas nearer to outer surface of the spaceman hardness was increased, around 250–350 HV, and it decreased towards to the core of the spaceman. The amount of material removed from cutting area was directly proportional to thickness of spaceman. Cutting gap becomes small for thin material, larger for thicker material. When the graphics showing cutting results which were prepared according to side speeds proposed by the machine tool manufacturer and material type and thickness, it is seen that these proposed speeds are more suitable for spaceman.

d) Stainless Steel (0.25 Inch Thickness)

B.Asiabanpour [31]has applied response surface methodology and desirability functions simultaneously to optimize 18 part quality characteristics. After performing the regression analysis, it is concluded that the effect of torch height, tool type, and cutting direction plays a critical role in surface quality characteristics. Furthermore, cost savings may result of using tool type C, horizontal cut, and a torch height near to 0.3 inches. High values for current (80 A), pressure (90 psi) were recommended to achieve quality results while an intermediate cut speed of 55 ipm was recommended. The entire study was conducted for stainless steel sheet metal with 0.25 inch thickness.

e) AISI 304 Stainless steel work piece

Sanda-Maria Ilii [32] presented some experimental results concerning the surface roughness variation at plasma arc cutting, in case of processing of stainless steel work piece. Thus, some experimental tests were made in an industrial enterprise, on a CNC plasma cutting equipment, KOMPACT3015-HPR130, in order to analyze the surface roughness parameter obtained during the cutting process. In order to establish an empirical model of the surface roughness (SR) found during the plasma arc cutting process the experimental tests were made using different cutting conditions. To measure the surface roughness, HANDYSURF E-35A/B apparatus was used. From the experiment, it is determined that the material thickness, g [mm], has the most influence on the Ra roughness surface followed by the cutting speed parameter v [mm/min] and the current intensity I [A]. The optimal cutting condition in this case is when v = 1000 mm/min, g = 4 mm and I = 130 A; Ra = 1.77 ìm.

f) Stainless steel 304L (600 mm×600 mm×5 mm)

R. Adalarasan M. Santhanakumar and M. Rajmohan [33] Solving a multi-response optimization problem in a multi input multi-output process like PAC is a challenging task. In this work, 304 L stainless steel was cut using the plasma cutter and the GT-RSM was disclosed to predict the optimal combination of the cutting parameters. Unlike the central composite design used along with the traditional RSM, Taguchi's orthogonal array was used to conduct the experiments, and the following conclusions can be drawn: & The technique of GT-RSM was effective in predicting the optimal setting of cutting parameters for 304 L stainless steel as follows: air pressure 5 bar, cutting speed 2335 mm/min, arc current 60 A and stand-off distance 2 mm. & The experimental values match reasonably well with the predicted values of R-squared for GRG, indicating better fit. & All the cutting parameters (air pressure, cutting speed, arc current and stand-off distance) were found to have a potential effect on the responses (kerf width and surface roughness), and the generated second-order polynomial response surface model for the GRG was found to be significant and adequate. The Taguchi OA had reduced the number of experimental trials, and RSM was used to model the GRG in terms of all factors, square terms and their interactions; hence, the merits of both the methods were combined. The results were evident in the effectively predicted optimal setting of parameters. & A lower value of arc current (60 A) was found to produce better responses as the increase in thermal content of the arc at higher amperage was observed to spoil the surface finish and increase the kerf width. Similarly, a lower level of stand-off distance (2 mm) was observed to produce a better cut surface as higher values lead to arc deflection pampering the cut surface. The research findings along with the generated response surface model offer the required guidelines for cutting 304 L stainless steel using the plasma arc cutting process. The results will offer a good cutting database for the textile, Pharmaceutical and chemical processing industries. However, importance can also be given for the qualitative variables affecting the PAC process, and studying the correlation between those quantitative and the qualitative variables can be another contribution to the subject.

g) Stainless steel SS321

H. Ramakrishnan, R. Balasundaram, N. Ganesh And N. Karthikeyan[34] In this work, the mechanism of ANOVA and genetic algorithm are used to analyze the cut quality characteristics of SS 321 using plasma arc cutting. The material SS321 has wide application in engineering components and maintains good hardness and strength even at an elevated temperature. Due to high hardness, it is difficult to process in conventional methods. Hence, thermal energy-based plasma arc cutting is proposed to measure the cut quality characteristics. To minimize the number of experiments, L9 orthogonal array is proposed. The input parameters are cutting speed, current, SOD and gas pressure and the output parameters are surface roughness, HAZ and average kerf width. The statistical models for all the output responses are significant. From the interaction plot, it is revealed that the average contribution of current is 93.75%, cutting speed is 0.59%, standoff distance is 3.5% and gas pressure is 2.13%. From this work, it is revealed that the minimum surface roughness and HAZ can be achieved for lower values of current, SOD, cutting speed and high gas pressure. For minimum kerf width, the cutting speed, current, gas pressure can be increased and SOD can be lowered. To find the best operating parameters, the regression models generated from the ANOVA are given as input to the genetic algorithm. The best values obtained from genetic algorithm are surface roughness—0.28, 732 lm, kerf width—7.3943 mm and HAZ—2.9242 mm. This optimization work supports the plasma arc cutting in industries to find the best operating parameters for quality product. In future, instead of single objective function, a Pareto front may be developed to analyze combined objective function.

h) Stainless Steel SS410 Material Plates (100mm x 100mm x 2.5mm)

Dr. Piyush Jain, Himesh Gohil and Mr. Hardik Naik [35]In this work, 1. In plasma arc cutting process gas pressure is the parameter has a significant effect whereas the other parameters viz. cutting current and standoff distance are less effective. 2. Surface roughness and conicity are mainly affected by the cutting height, whereas the heat affected zone (HAZ) is mainly influenced by the cutting current. 3. While the oxygen is used as the cutting gas the oxidation reaction will occur and result in higher feed rates and unevenness and kerf width of better quality were achieved. 4. For the thin plate of work piece material cutting current and cutting voltage should be decreases and cutting speed should be increases for better surface roughness.

i) Stainless steel thick plates (420x350x6mm)

N.Senthilkumar,T.Tamilkannan,B.Thirumoorthi,G.Vigneshkumarand J.Vijayaragavan[36] In this project experiments are carried out for cutting speed, cutting current, cutting height with responses as the machining time, kerf taper, surface roughness and hardness. There are nine experimental readings are taken. Taguchi orthogonal array is selected for the optimum parameter levels. Taguchi level9 orthogonal array is selected. We compared the input parameters and the responses by using the Design of Expert Software. Each input parameters are affects the each responses. Minimization the process responses are carried by the s/n ratio. Our goal of the experiment of s/n ratio is smaller is better. Finally analysis of best combination of process parameter.

j) AISI 206 STEEL Plates (5-40mm)

Surender Kumar [37] the experiments were designed and conducted by employing Taguchi and ANOVAs method. The selection of appropriate model and the development of response were carried out by using statistical. The analysis of variance (ANOVA) was performed to statistically analyze the results. To decide about the adequacy of the model, F Test and ANOVAs method were performed.

The important results from optimal set of process variables in CNC flame cutting machine are written as: 1. ANOVA result shows that pressure of gases and speed of nozzle are significant parameters for minimizing Kerf and maximizing Penetration. 2. Kerf (11.11%) and penetration (2.0%) error in mean analysis were obtained, by confirmation Experiments. 3. Confirmation experiments present that Kerf (7.81 %) and penetration (7.12 %) error in s/n ratio were achieved. 4. In kerf case optimum sets of parameter for mean analysis was A3B3C2 and for s/n ratio was A1B3C3 respectively. 5. In penetration case optimum sets of parameter for S/N ratio was A1B1C3 and for s/n ratio was A1B3C2 respectively.

k) Stainless steel 316L (2 mm thickness) Plates

A PARTHIBAN, J. P. PRASATH, P. VIVEK & R. PUGAZHENTHI[38] In this work to optimization of plasma arc cutting parameter on kerf for AISI 316L stainless steel sheet (2mm thickness). In these Work optimization techniques was used to solve the problem by using design expert software. In these optimization techniques is to set the goal. To predict the output value top kerf width 0.8523 mm and Bottom kerf width 0.7648 mm has been reached. Response surface methodology based optimization methods were applied in this work to improve the multi response characteristics such as top kerf width and bottom kerf width of AISI 316L stainless steel sheet during Plasma arc cutting process (PAC). The conclusions of this work are summarized as follows: >The ANOVA tables of the top kerf width and bottom kerf width shows the developed models are significant. >The Response surface diagram used to selecting the plasma arc cutting parameters and as long as the preferred top kerf width and bottom kerf width values. >The optimum parameters combination was determined as plasma arc current at 40 Amp, stand of distance 2mm and cutting speed at 4999.9 mm/min.>This work establishes the procedure of using Response surface methodology for optimizing the Plasma arc cutting process parameters for multiple responses are top and bottom kerf width characteristics.

l) AISI 316 Stainless Steel

K. P. Maity & Dilip Kumar Bagal[39]this paper furnishes the findings of an experimental investigation into the effect of feed rate, current, voltage and torch height on the characteristic of cut when machining AISI 316 stainless steel by plasma. The specific problems of PAC have been analyzed. Response surface method coupled with grey relational analysis and principal component analysis has been carried out to optimize plasma arc cutting processes with multi-objective criteria. The best possible optimum conditions of this process are the following: 970 mm/min of feed rate, 47.5 A of current, 140 V of voltage and 1.5 mm of torch height. Torch height as well as interface of torch height with feed rate is the most influencing parameters in plasma arc cutting machining. The shortened quadratic models developed using the combinatorial plea of RSM and grey relational analysis (GRA) with principal component analysis (PCA) were reasonably accurate and can be used for prediction within the limits of the factors investigated.

m) Stainless steel X10CrNiMn-16-10-2 (EN 10025)

Dr Anđela Lazarević[40]the experimental research provided data necessary for further analysis and considerations of the plasma cutting process. This data were used for plasma cutting process modelling, using different methods, while not all data should be used for every modelling method. Data graphical representation provided the visual insight in the dependencies that exist among data. Metering of the output process parameters for different combination of the input parameters provided the information needed to understand the plasma cutting process mechanisms. However, the software application used for the process control constrained some variations of the input parameters in accordance with the machine manufacturer's recommendations. The flexibility in input parameters selection was limited, and it would be useful for the further considerations to predict wider ranges of input parameters changes, for the purposes of the data analysis and monitoring of parameters interdependences. This paper provided visualization of the input parameters impact to the process output parameters and, therefore, data preparation for the plasma cutting process modelling using different statistical and/ or artificial intelligence methods.

Figure no. 11 shows the kerf width, surface roughness and bevel angle dependences of the cutting speeds, for the material thickness s =12 mm and cutting current I=130 A. Since this was the case of cutting thick work piece material, the cutting current used during this experiment was high in order to provide successful cutting. As in the previous analysis of the experimental results, the increase in cutting speed implies the increase in surface roughness and bevel angle. However, these trends are less pronounced in the case of thicker materials and bigger cutting currents. Figure 11 also shows that higher cutting speeds imply smaller kerf widths.

n) SS304 Alloy (6mm thickness)

Pothur Hema and Ramprasad Ganesan [41] Based on the careful experimental research of CNC PAM on SS 304 alloy using two different nozzles, the following conclusions are highlighted: • The experimental results clearly show that an arc voltage of 136 volts, cutting speed of 2000 mm/min, standoff distance of 2 mm, and plasma offset of 2.25 mm will give the optimum results for PAM of SS 304 alloy by implementing multi-response optimization technique using grey relational analysis. • Based on GRA, the response tables were established for both the nozzles, from which it is concluded that cutting speed and standoff distance have the most influence, while plasma offset and arc voltage have the least influence on the kerf ratio, surface roughness, and MRR in PAM of SS 304 alloy. • Finally, the best suited nozzle for machining the SS 304 alloy material which yields better surface roughness and MRR characteristics were determined with the aid of performance graphs. • 200 A Nozzle produces more accurate kerfs due to its larger nozzle diameter and maintains lesser kerf ratio than nozzle 1. • 130 A Nozzle has a smaller nozzle diameter and can produce higher MRR while maintaining lower surface roughness. Hence, 130

A nozzle is selected as the best suited nozzle for machining SS 304 alloy material. • The surface morphology was studied carefully on both the materials to understand how the high-temperature plasma gas influences the machined surface and its characteristics during machining.

o) Stainless Steel (316 L) materials

Prateek Kumar Gautam, and Vivek Gupta[42]This thesis has presented an application of the Taguchi method to the optimization of the machining parameters of 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 Surface Roughness (Ra) can be significantly improved in the Plasma Arc Cutting process using the optimum level of parameters. Plasma Arc Cutting Machine is widely utilized in BHEL, Bhopal to cut materials such as Stainless Steel and Nickel-Base Alloys. This is the basis work where Plasma Arc Cutting was utilized to perform the material removal process at finishing stage. The Plasma Arc Cutting (PAC) machining of Stainless Steel (316L) has been performed with the application of combination with design of experiment (DOE).The PAC parameters studied were how to have setting for the parameter such as Gas Pressure, Current flow, Cutting Speed and Arc gap of machine. 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 0r L32 orthogonal array with 3 level designs. Mathematical equation for MRR of first order is of R-sq of 71.2% and for Surface Roughness (Ra) is of R-sq 77.5% which is acceptable.

p) Stainless steel SS 420Rectangular block of 170 mm X 170mm X 10 mm thickness

Renangi. Sandeep, Dara. Sudhakara and Bathina. Sreenivasulu[43]The scope of present paper was the experimental investigation and optimization of process parameters in plasma arc cutting of stainless steel 420 using grey relational analysis. The process parameters examined in this investigation are cutting current, cutting speed and torch height. The following conclusions are made.

· From the effects of process parameters on responses, it is clear that Ra increases while increasing cutting current, Ra decreases while increasing cutting speed and torch height. · With increase of cutting speed, cutting current and torch height, MRR also increases. · Accordingly grey analysis, the optimal setting for obtaining minimum surface roughness and maximum material removal rate are A1 B3 C2 i.e. 100 Amp cutting current, 1600 mm/min cutting speed and 5 mm torch height. · ANOVA resulted that the cutting speed has been more effected parameter on Surface roughness and MRR.

q) Stainless Steel SS410 Material

P. Mariya Felix, K. Ramesh, and S. Roseline[44] This Investigation investigates the application of the Taguchi method to the optimization of the machining parameters of CNC Plasma Arc Cutting Machine. Material Removal Rate can be expressively improved in the CNC Plasma Arc Cutting process using the optimum level of parameters. From experimental analysis done on SS410, it was concluded that: 1. In CNC plasma arc machining the Pierce delay is the parameter has a significant effect whereas the other parameters viz. Arc voltage and cutting speed are less effective.2. The steam as the plasma gas will generate more energy than other gases for the identical current value and the plasma jet generated is much narrowed when primary gas, Oxygen and secondary gas, air is used as plasma gases. 3. For geometrical Error rate the Arc voltage &cutting speed play a very important role. Higher the value of cutting speed create more geometrical error.

Optimal Control Factor

1. Perpendicular Error- A3 (arc volt 160) B1 (cutting speed -3500mm) C2 (pierce delay0.50) 2. Surface Roughness- A2 (arc volt 155) B1 (cutting speed -3500mm) C3 (pierce delay0.75) 3. Parallelism Error- A1 (arc volt 152) B3

(Cutting Speed -4000mm) C2 (pierce delay0.50) 4. Flatness Error- A2Arc Volt 155) B3 (Cutting Speed -4000mm) C1 (pierce delay0.25).

Percentage of Contribution of Process Parameter

1. Perpendicular Error-Pierce Delay-31% 2. Surface Roughness-Cutting speed-31% 3. Parallelism Error-Arc Voltage-42% 4. Flatness Error-Pierce Delay-53%.

r) Stainless Steel SS410 (6mm thick) plate

Mr. Maulik K. Bhalodiya1 Mr. Vijay F. Pipalia2 Mr. Akash B. Pandey[45] It is concluded that, The regression analysis model conclude that the second order non-linear mathematical model is best suited to give the relation between process parameters and various response parameters. By the comparison of experimental data and model predicted data it is observed that the experimental data is highly fitted with regression model line and for all response parameters the value of R square and adjusted R square are above 95% which is tolerable. From the results of analysis of variance (ANOVA) the current and cutting speed contributes 40 and 48 percent in material removal rate. For the top kerf width the speed, SOD*speed and pressure * SOD contributes respectively 25%, 30% and 15% followed by all other parameters. The contribution of speed in bottom kerf width is 49% followed by current and SOD having 25%. There are equal contribution of SOD, current and cutting speed for bevel angle. And for straightness the most influencing parameters is speed which contribute the 51% in straightness. From the experimental data and model generated data it is observed that the residual and adjusted residual for the MRR is relatively 98.1 % and 95.8%, for TKW it is 97.4% and 94.3%, for BKW it is 98.8% and 97.5%, for bevel angle it is 99.3% and 98.5% and for straightness it is 97.6% and 94.8%. This percentage shows that all the data is very close to the residual line. Here for all the response parameters have approximately more than 95 % Residual Square and adjusted residual square value which is under the acceptable level. So that the mathematical model used for give the relationship between input parameters and output parameters is good up to acceptable level.

Non Ferrous Material

3) Aluminium Alloys & Nickel based

a) AA6061-T6

KKadirgama [46] established mathematical model for prediction of heat affected zone (HAZ) and optimization of parameters for air plasma cutting process on AISI 6061 aluminium alloy material. Experimental and predictive values from Response Surface Method (RSM) are found of same trend. Partial swarm optimization (PSO) was employed to optimize cutting parameters. Deviation of HAZ obtained by optimized HAZ model was 2.72%. Optimum cutting parameters for minimum HAZ were: output current, 100 A; stand-off gap, 1 mm and pressure, 620.52 kPa.

b) AA5754

Miroslav Radovanovic et al [47] had done a modeling of the plasma arc cutting process using Artificial Neural Networking (ANN). The aim of this work was to develop the ANN mode to predict the ten point height of irregularities (Rz) taking input parameters such as plate thickness, cutting speed and cutting current. After prediction of data the accuracy of ANN has been authenticated. Using this model one can select the machining conditions which correspond to the cutting region with minimal surface roughness.

c) Aluminum5083 (EN ISO 9013)

Abdul Hamid [48] The combination of treatment parameters for cutting CNC plasma cutting on aluminum 5083 (EN ISO 9013) metal uses the Taguchi and GRA method on the variable surface roughness response and conicity obtained by cutting current settings of 90 A, cutting speed of 1800 mm / s, gas pressure of 3 bars, and cutting distance by 3mm. after conducting a confirmation experiment it was found that the surface roughness was 13.13µm and the conicity angle was 11,220. The contribution that influences the variable surface roughness response and conicity, the contribution of the cutting current factor is 79.42% followed by the cutting speed of 11.03%. Comparison of the optimal conditions and the optimum increase in the target response value increased by 28.12% and the amount of conicity was 23.72%. While finishing time is 2.16 seconds, and finishing costs can be minimized to 25.11 rupiah per 100 mm2.

d) Aluminium Alloy 6082 plates (140x50x5mm)

Sagar B. Patel, Tejas K. Vyas[49] From the some exploratory experiment it was found that 5 mm thickness aluminium alloy 6082 can cut in the range of current between 30 A and 40 A. Material was not throughout cut at high speed and low current. For good quality cut all parameters has appropriate value. (1) For MRR the current, stand-off distance and speed are more significant parameter follow by pressure. Current contribute highest 85.03% on MRR. MRR is increase at pressure slight increase and then decrease and for stand-off distance the effect is reverse as compared to pressure. (2)Current, stand-off distance, pressure and speed are contribute 52.06%, 07.27%, 04.57% and 19.21% respectively on top kef width. For top kerf width with increase in current top kef width is decrease and then increase with increase current. With increase in standoff distance top kerf width is increase. (3) For bottom kerf width current, stand-off distance and speed are most significant parameter followed by pressure. With increase in speed and pressure bottom kerf width falls off. While for current bottom kerf width is increases and then decreases. In case of standoff distance, bottom kerf width increase with increase stand-off distance. Current contribution highest 54.84% on Bottom kerf width. (4) For bevel angle the current and speed is most significant parameter then pressure and stand-off distance. The percentage contribution of current, stand-off distance, pressure and speed on Bevel angle are 44.36%, 07.66%, 05.92% and 27.28% respectively. With increase in current and stand-off distance bevel angle reduces. While for pressure, it increases and then decreases with increase in pressure.

e) Monel 400™ super alloy (Nickel-based) sheet 3mm

D. Rajamani, K. Ananthakumar, E. Balasubramanian & J. Paulo Davim[50]In this study, the impact of significant PAC parameters on surface roughness, kerf width, and micro hardness of Monel 400 superalloy is investigated through design of experiments and desirability optimization approach. The following are the key observations: ● From ANOVA analysis, stand-off distance, and arc current are found to be more influencing parameters on surface roughness, whereas kerf width and sub-surface hardness are influenced by cutting speed and gas pressure. The proposed regression models for Ra, KW and micro hardness are found to be adequate having obtained 95% of confidence level to estimate the responses accurately within the limits of process variables considered. ● Morphological study reveals that low stand-off distance with higher gas pressure leads to profound striation patterns and dross attachments causes reduction in the cut quality. It is improved with low arc current and high gas pressure. ● Optimization studies using RSM desirability approach predicted optimal process variables for enhancing surface roughness, kerf quality and micro hardness are as follows: cutting speed of 2427.08 mm/min, gas pressure of 3.83 bar, stand-off distance of 2.14 mm, and arc current of 45 A. ● the validation experiment results are found to be in conformance with predicted optimal parameter settings. A minimal error of 2.64% for surface roughness, 4.45% for kerf width, and 4.36% for micro hardness is obtained. Hence, the established model can be effectively utilized to evaluate the quality characteristics of PAC process.

III. Conclusion

The present work just gives an overview of previously done investigates and also for new research work, it gives a way for optimisation of plasma arc cutting using various optimization techniques. The conclusions are discussed below,

1) Plasma arc cutting (PAC) is one of the frequently used unconventional machining process that is capable of producing the complex shapes.
2) It is seen that work has been done on plasma arc cutting of various ferrous and nonferrous materials like Hardox-400, S235, AISI 1017, AISI 1018, EN31, EN8, EN-45A, IS 2062 E250 BR, ST37, ASSAB 760, S235JR,St-52, IS 2062 (E250), SS 316L, AISI 304, SS321, SS410, AISI 206, EN 10025,SS 420, AA6061-T6AA5754, EN ISO 9013 and Aluminium Alloy 6082etc.,
3) There are certain process parameters such as gas pressure, cutting speed, arc voltage , arc gap, arc current, and gas flow rate that affect the quality distinctiveness of plasma cut like bevel angle, kerf generated, heat affected zone (HAZ) and surface finish.
4) The most influential process parameters from the above mentioned experiments are cutting speed, gas pressure, arc current, arc gap, gas flow rate and arc voltage.
5) Experiment will be carried out for response variables are material removal rate, surface roughness and kerf with process parameters as cutting speed, gas pressure, arc current and arc gap.
6) Plasma arc cutting (PAC) and its assisted processes as well as optimization techniques, which made some new research scopes in the Plasma arc cutting (PAC). Developments in modeling techniques have made new research and scopes in the plasma arc cutting and improves the performance of plasma arc cutting process.

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