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# A Review Paper on Study and optimization of Process Parameter in Plasma arc Cutting

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***Abstract: The plasma arc cutting process was developed for difficult to machine materials in order to overcome the inefficiency and ineffectiveness of conventional machining method when it come to complex shape and work piece. Plasma cutting is a process that cut through electrically conductive material by means of jet of hot plasma. In this research work the study has been carried out on the PAC of Carbon steel by considering gas pressure (bar), current flow rate (A), cutting speed (mm/min) and arc gap (mm) as the process parameters and analysing the effect on the surface roughness (Ra), material removal rate. A comprehensive review was carried out on development in analysis and optimization of PAC for Carbon steel (A36). The Experimental study has been carried out by using Taguchi design methods and ANOVA analysis for Material removal rate (MRR), Surface roughness by performing cuts of different run sets of L9 orthogonal Array.***
**Keywords*: Plasma, Carbon Steel(A36) Material Removal Rate, Surface Roughness, Taguchi Design, ANNOVA.***

## I. INTRODUCTION TO PLASMA

### *A. Principle of Plasma Arc Cutting*

Plasma Arc Cutting (PAC) is a non-conventional process which can perform several electrically conducting materials, stainless steel, aluminium and its alloys, magnesium, titanium alloys, manganese steel and cast iron. Plasma cutting process is invented about 30 years ago for processing hard and difficult to machine materials.

This process uses a concentrated electrical arc which melts the material through a high-temperature plasma beam. All conductive materials can be cut. Plasma cutting units with cutting currents from 20 to 1000 amperes to cut plates with inert gas, 5 to 160 mm thicknesses. Plasma gases are compressed air, nitrogen, oxygen or argon/ hydrogen to cut mild and high alloy steels, aluminium, copper and other metals and alloys. The plasma arc process has always been seen as an alternative to the oxy-fuel process. In this part of the series the process fundamentals are described with emphasis being placed on the operating features and the advantages of the many process variants.

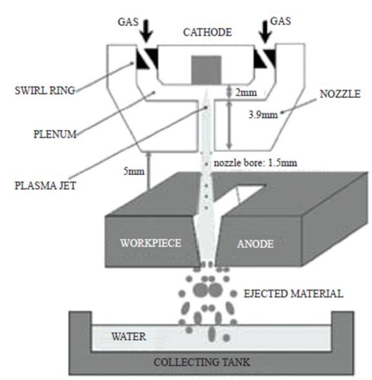


Figure 1: The principle of the plasma cutting [40]

The plasma is additionally tied up by a water-cooled nozzle. With this energy densities up to 2x106 W/cm$^2$ inside of the plasma beam can be achieved. Because of the high temperature the plasma expands and flows with supersonic velocity speed to the work piece (anode). Inside the plasma arc temperatures of 30 000$^o$C can arise, that realize in connection with the high kinetic energy of the plasma beam and depending on the material thickness very high cutting speeds on all electrically conductive materials.

For the cutting process first of all a pilot arc ignition by high voltage between nozzle and cathode takes place. This low- energy pilot arc prepares by ionization in parts the way between plasma torch and work piece. When the pilot arc touches the work piece (flying cutting, flying piercing), the main arc will start by an automatic increase in power The basic principle is that the arc formed between the electrode and the work piece 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.

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, aluminium, cast iron and non-ferrous alloys.

The power source required for the plasma arc process must have a drooping characteristic and a high voltage. Although the operating voltage to sustain the plasma is typically 100 to 160V, the open circuit voltage needed to initiate the arc can be up to 400V DC. On initiation, the pilot arc is formed within the body of the torch between the electrode and the nozzle. For cutting, the arc must be transferred to the work piece in the so-called 'transferred' arc mode. The electrode has a negative polarity and the work piece a positive polarity so that the majority of the arc energy (approximately two thirds) is used for cutting. [43]

In the conventional system using a tungsten electrode, the plasma is inert, formed using either argon, argon-H2 or nitrogen. However, as described in Process variants, oxidizing gases, such as air or oxygen can be used but the electrode must be copper with hafnium. The plasma gas flow is critical and must be set according to the current level and the nozzle bore diameter. If the gas flow is too low for the current level, or the current level too high for the nozzle bore diameter, the arc will break down forming two arcs in series, electrode to nozzle and nozzle to work piece. The effect of ‘double arcing’ is usually catastrophic with the nozzle melting. The quality of the plasma cut edge is similar to that achieved with the oxy fuel process.

However, as the plasma process cuts by melting, a characteristic feature is the greater degree of melting towards the top of the metal resulting in top edge rounding, poor edge squareness or a bevel on the cut edge. As these limitations are associated with the degree of constriction of the arc, several torch designs are available to improve arc constriction to produce more uniform heating at the top and bottom of the cut.

The process variants have principally been designed to improve cut quality and arc stability, reduce the noise and fume or to increase cutting speed. The inert or uncreative plasma forming gas (argon or nitrogen) can be replaced with air but this requires a special electrode of hafnium or zirconium mounted in a copper holder, by shearing. The air can also replace water for cooling the torch. The advantage of an air plasma torch is that it uses air instead of expensive gases. It should be noted that although the electrode and nozzle are the only consumables, hafnium tipped electrodes can be expensive compared with tungsten electrodes.

This relatively new process differs from conventional, dry plasma cutting in that water is injected around the arc. The net result is greatly improved cut quality on virtually all metals, including mild steel. Today, because of advances in equipment design and improvement in cut quality, previously unheard of applications, such as multiple torches cutting of mild steel, are becoming common place. [43]

## II. LITERATURE REVIEW

K. P. Maitry et al[1], Study out on 304L stainless steel the influences of process parameter on to the X directional accuracy using Taguchi L16, ANOM and ANOVA and concluded that optimal condition for leaner dimension of X axis Arc current 80A, Voltage 140V, Stand of distance 4mm and Cutting speed 250mm/min also optimum parameter values for deviation were Current 70A, Voltage 150V, Stand of distance 4mm and Cutting Speed 3000mm/min ANOVA portrait s X axis leaner dimension contribute most by Stand of distance (67.74%) and deviation is affected most by Current (42.45%).

Choon man lee et al[2], The study carried out the machining characteristic using Non transferred type Plasma arc cutting machine of AISI 1045 steel and Inconel 718 and conclude that the torch approached the vertical the preheating temperature also increased and angle of torch was $71^0$ proper preheating was obtained for AISI steel with Plasma arc cutting machine Cutting force decreased by up to $61^{\%}$ and $51^{\%}$ in comparison with Conventional machine and Laser assisted machine also Surface roughness improved up to $79^{\%}$ and $5^{\%}$ in comparison CM and LAM as the spindle rotation increase the cutting force reduce and surface roughness increase. For Inconel 718 with PAM the cutting force decreased $57^{\%}$ and surface roughness improved up to $82^{\%}$ Compare CM and Compare to LAM the cutting force increased up to $9^{\%}$ and surface roughness increased up to $4^{\%}$ and concluded that Plasma assisted machine can be more efficient Thermal assisted machining method.

Ashish bandyopadhyay et al[3], The experimental study carried out on AISI 304 Stainless steel by using ADOR plasma AP-100 machine and find out the best operating parameter by a full factorial design and ANOVA. They concluded that multiobjective optimization is well agreement with confirmatory test and percentage error are less than $10^{\%}$. ANOVA seen that speed and thickness of material pressure has a little effect on MRR and pressure only significant parameter on surface roughness and concluded that the maximum and minimum surface roughness is 23.85 $\mu m$ and 3.76 $\mu m$ and similarly MRR are 88.884 g/min and 21.982 g/min.

Navneet kanna et al [4], The study carried out on the Quard 400 material by Multi therm 4000, Messer cutting system India private limited to determine the effects and optimization of two process parameter as cutting speed and plasma gas pressure on Surface roughness and Material removal rate using response surface method coupled with ANOVA and concluded that the 4000mm/min Cutting speed, 90 Psi pressure with Material removal rate 2.35g/sec and Mean surface roughness of 1.40 $\mu m$. Material removal rate increase of cutting speed and Mean surface roughness decrease with increase of cutting speed.

Prashant Sahoo et al[5], The study carried out on EN31 steel by using Plasma arc cutting machine for the optimization and the effect of machining parameter on MRR and Surface roughness by using Taguchi orthogonal array with GRA and concluded that Pressure 6bar, Current 200A and Height 6mm is optimal process parameter combination (middle level of gas pressure, highest level of arc current and highest level of torch height) and by ANOVA the highly effective parameter is Gas pressure whereas arc current and torch height are less effective factors.

V. Rakesh Kumar et al[6], Study out the optimal Plasma arc machining parameter setting using FIS integrated with nonlinear analysis and JAYA optimization algorithm and concluded that cutting speed of 4000mm/min, Gas Pressure 95Psi and Torch Height 0.5mm is optimal process parametric combination to get most favourable output response in AISI D2 steel.

Antonio martin meizoso et al[7], The investigation carried out on Plasma arc cutting and LAM by rank correlation analysis, multidimensional data analysis and decision trees on high strength low alloy strip and plate and also conclude that major influence parameter in Plasma arc cutting is Current, Torch standoff, Cutting speed and Plasma gas flow on Surface quality.

C. S. Malvi et al [8], Study out the effect on MRR in AISI 1017 MS material on manual Plasma arc cutting by using different variable Pressure, Current, Voltages and used Taguchi with Doe and ANOVA for optimize it and conclude that the optimum Material removal rate can be obtained at Pressure 20bar, Current 35A and Speed 240mm/min. The Material removal rate value was obtained 95.577 $mm^3$/sec.

M. Rajmohan et al[9], Study carried out on Plasma arc cutting machine with 304L stainless steel in order to analysis the surface roughness to optimize process parameter Pressure, Cutting Speed, Current and Stand of Distance by using Taguchi based method, RSM and ANOVA and concluded that optimal setting is Pressure 5bar, Cutting Speed 2335mm/min, Cutting Current 60A and Stand of distance 2mm and also lower value Current 60A produces better response 2mm Stand of distance produces better cut and higher value lead to deflection.

Dilip Kumar bagal et al [10], The Experimental investigation carried out into the effect of Feed rate, Cutting Current, Voltage and Torch height on characteristic of cut when machining AISI 316 Stainless steel by MESSER company built CNC Plasma machine named as BURNEY 1250. The Response surface method coupled with Grey relational analysis principle component analysis has been carried out to optimize Plasma arc cutting process with Multi-objective criteria and concluded the best optimum condition 970mm/min of Feed rate, 47.5A of Current, 140V of Voltage and 1.5mm of Height and state that Torch height as well as interaction of torch height with feed rate is influence parameter in Plasma arc cutting machining.

Engin unal et al [11], Study carried out the predicting the Surface roughness of material AISI 4140 Steel by considering process variable Current, Cutting Speed and Thickness of material on AJAN HP 260A Plasma arc cutting machine and it has been concluded that Surface roughness was most affected by Cutting speed and Current is least. Defect free Surface were produced by increasing cutting speed and thickness of cut and decreasing the Current all the study carried out by Fuzzy models and ANOVA.

Tatsuo Ishijima et al[12], has Study carried out on Plasma arc cutting machine for investigation flux leakage and Kerf expect and they concluded that the double arc increase with decreasing Current or Increasing Flow rate (Q) and the leakage flux is perpendicular to the kerf expect at corner. The arc blow categorized by intensity and direction of leakage.

D. V. Rammana et al[13], was study carried out on 12mm Hardox plate with Plasma arc cutting machine in order to investigate Unevenness Surface by considering input variable is Cutting Speed, Voltage, Plasma flow rate and DOE and ANOVA used for optimised it. They are concluded that Voltage is main parameter and it influences on the Cut quality and the Unevenness can reduced by reducing Cutting Speed and Minimum Unevenness for 12mm Hardox plate is 421 micron at optimum value of 70 L/hr Plasma flow rate, 125V Voltage and 2100mm/min Cutting Speed.

Radovan grzonarik et al [14], carried out study on different Cutting process Plasma arc cutting, Abrasive water jet, Oxygen and Laser in order to obtain better surface finish with low cost manufacturing and concluded that Plasma arc cutting has Low cost manufacturing method then other.

Sachin bhartiya et al [15], Study carried out on Plasma arc Cutting machine used in BHEL Bhopal by using the Taguchi method. It should be study out the various process parameter of Gas Pressure, Current, Cutting Speed, and Arc Gap in order to increase Material removal rate and Surface finishing. They would be used 2 level method and L8 orthogonal array for optimize the experiment and concluded that the max MRR at Pressure 5bar, Current 150A, Cutting Speed 600mm/min and Arc gap 4mm and for surface roughness Pressure at 5bar, Current 150A, Cutting speed 400mm/min and Arc gap 2mm.

S. Vatausianos et al [16], Study carried out on CNC Plasma cutting system (Kaitenbach Kf 2512-HPR 260) with a duct flow torch and cut are performed on 15mm thick S235 Mild steel sheet by using different process parameter as Cutting Speed, Current, Cut height and Pressure in Order to optimize Surface Roughness and Heat affected Zone by using DOE and ANOVA. They would concluded that surface roughness and the conicity are mainly affected by the cutting height, whereas the heat affected zone is mainly influenced by cutting current.

K. S. Jayakumar et al [17], Study carried out on automated Plasma cutting machine in order to obtain selecting optimum process parameter and best suited method for optimization it has been used three methods for it 1) Multiple regression, Multiple polynomial regression and AI technique and concluded that ANFIS is more Accuracy method is better because they are not produces abrupt Rust even used new data set.

Navneet beri et al [18], the Study is carried out to multi parameter optimization by using DOE with GRA.

V. Nemchinsky et al [19], concluded that the chartristic time of arc transitions from the first pilot arc phase and stable Second pilot arc phase is quite difference in new and used electrode and arc stabilization at centre of emitter surface was also different for the case of fresh and used electrodes: Rapid and smooth for the new instant characterized by a long rotation of the arc attachment at insert periphery with subsequent very fast.

W S Severance et al [20], should be studied out the effect of Cutting speed on the Kerf, Surface and Cut quality squerness and Jet tilt on Speed the Bevel angle are increased and surface quality reduced and also tilt of jet increased but there is not only simultaneous between bevel angle and tilt of jet they are proven individual.

Claro Novoa et al [21], Study out the effect of seven input parameter versus 18 responses and in order to minimize the number of experiment they would conduct DOE and Optimize parameter and ANOVA used for find out significant factor affecting each response multiresponce optimization techniques used for optimization and they would concluded the effect of torch height, tool type and cut direction play vital role in surface quality characteristic.

W. J. Haung et al [22], Orthogonal array with grey relational analysis was used to optimize the multiple response characteristics of Plasma arc welding on 4mm thick SU5316 stainless steel plate. The undercut, root penetration and the welding groove width are measured to identify the optimal welding parameter combination for improvement of welding quality.

M. Monno et al[23], has performed an experiment in order to obtain the main process parameter on the output unevenness in a real cutting application by considering two sequential experimental design and analysed it by ANOVA analysis and concluded that the Arc voltage is main parameter and it influences all the aspect related with the cut quality rather than of Arc Power and on other side reducing the arc voltage the thermal stress on the torch component on specially electrode and nozzle increases and thus accelerate their wear. And also that very good quality can be achieved for all the side by varying the cutting speed and arc voltage only.

E. Negoescu et al[24], Study out the cutting performance on aluminium polyethylene composite material by using Italian plasma arc cutting machine telwin PL 3612 and used parameter main voltage 230V, Current 23A, Power 7 KVA, Pressure 0.41Mpa, Feed rate 50mm/min and Arc length 5mm and various output parameter Surface quality and Heat affected zone should be measured and concluded that the Kerf dimension 2mm thermally influence area of Polyethylene core is around 5mm and the burr in bottom side of work piece is around 1mm.

Umut atici et al [25], The study carried out on AISI 304 and St 52 Steel In order to obtain structure variation like HAZ and hardness by using different Cutting Speed, Voltage, Arc length and Cutting Current and concluded that area near outer surface hardness increase and decrease toward core of materials, Material removal rate is proportion to thickness and the area of HAZ is 0.399-0.499 mm of SS and 0.434-0.542 mm for Carbon steel.

B. Previtalli et al [26], Study carried out on the high tolerance Plasma arc cutting of a 5mm Commercially pure titanium sheet under the different process conditions like Feed rate, Current, Voltage, Stand of distance etc. and use oxygen and nitrogen as gas to investigate Unevenness, Kerf width, Angle of Cut and Surface Roughness.

Y.S. Lu et al [27], Studied out the Kerf width and to improve the Kerf quality. The hydro-magnetically confined Plasma arc was used to cut $Al_2O_3$ ceramic plates both theoretical and experimental result are used to proven the flexibility and validity of newly advance hydro-magnetic Plasma arc cutting and concluded that Arc stability can improve by the Voltage the higher voltage at arc-extinction then that single constriction and higher Quality cut can be produced by using lower arc Current.

L. J. Yang et al[28], has performed an experiment in order to obtain the optimum process parameter to archive maximum hardened depth of ASSAB 760 Steel specimens using a micro-Plasma arc and the Taguchi experiment design with 4-Factor 3-Level (L9) Orthogonal array. The factor considered Arc Current, Torch travelling 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 0.195 mm. However with the optimised processing parameters the overage depth obtained was 0.36 mm. the maximum hardness of the hardened zone observed was 753HV.

Valerian a Nemchinsky et al [29], Performed by using PT torch with $600^0$c Power supply manufactured by ESAB. The Current range (200-400A), Gas used Oxygen and Flow rate 0.94 $mm^3$/s, Stand of distance 0.95 cm, Cutting Speed 40mm/s, Nozzle diameter (2.3-3.3 mm) and Material thickness (12.7-50.8 mm) in order to estimate $U_{max}$ and $U_{min}$. The estimated and calculated value are compared.

K. Chan et al [30], Study out the effect on monolithic 2124 aluminium alloy and aluminium base by considering the input parameter as a Pressure, Voltage and Current which are Fixed and Speed are Varied and different measurement are take regarding to this as Kerf Width, Surface Roughness and Heat affected zone and concluded that no difference between cutting Speed of both material and the optimized cutting speed 55-60 mm/s.

## III. CONCLUDING REMARKS

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

*A.* The plasma arc cutting process there are various process parameters which affected on the cut quality of material being cut which is current, gas pressure, standoff distance and cutting speed.
*B.* The steam of Plasma gas will generate more energy than other gases for the same current and voltage value and produced narrowed plasma jet and pressure is required to maintained show result in kerf stick at the top surface and dross formation at the bottom.
*C.* The increase in Plasma gas flow rate can facilitate improvement in cutting quality and lower value of gas flow rate produced double arcing and that can reduced the life of consumables and equipments.
*D.* The amount of material removal rate from work piece is proportional to thickness of material being to cuts and cutting speed also depends on thickness of the materials.
*E.* The surface roughness and chamfer produced is mainly affected by cutting speed and cutting height and heat affected zone on workpiece is mainly affected by the cutting current.
*F.* Machining time for producing work piece will be better for maximum pressure, current, medium speed and arc height and hardness is good for maximum pressure and arc height, medium current and speeds.
*G.* The Effect of magnetic arc blow which affected in arc deflection which reduced using various process parameters like lower level of arc current, higher cutting gas flow rate and nozzle diameter.

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## REFERENCES

Research Paper
[1] K. P. Maitry et al, "Optimization of Dimensional accuracy in plasma arc cutting process employing process parameter modelling approach", Material Science and Engineering 138 (2018).
[2] Choon man lee et al, "A Study on the machining characteristics using Plasma assisted machining of AISI 1045 Steel and Inconel 718", International Journal of mechanical Science 142-143, Pg. 595-602, (2018).
[3] Ashish bandyopadhyay et al, "Experimental Study of Plasma are cutting of AISI 304 Stainless steel", Materials Today Pg. 4541-4550, (2018).
[4] Navneet kanna et al, "Study the effect of process parameter in Plasma arc cutting on Quard 400 material using analysis of variance", Materials Today Pg. xxx-xxx, (2018).
[5] Prashant Sahoo et al, "Optimization of process parameter in Plasma arc cutting of EN31 steel based on Material removal rate and Multiple Roughness characteristic using GRA", Procedia Materials Science Pg.1550-1559, (2017).
[6] V. Rakesh Kumar et al, "Machining performance optimization during Plasma arc cutting of AISI D2 steel: application of FIS, nonlinear regression and JAYA optimization algorithm", Mechanical Science and Engineering 240, (2017).
[7] Antonio martin meizoso et al, "Experimental investigation of the influences of laser beam and Plasma arc cutting parameters on edge quality of high strength low alloy strip and plates", Int J Advance Manufacturing Technology (2017).
[8] C. S. Malvi et al, "Parametric optimization of MRR in manual air Plasma arc cutting of AISI 1017 MS using DOE", Journal of Material and Metallurgical Engineering 2231-3818 Pg. 1-9, (2015).
[9] M. Rajmohan et al, "Application of Grey Taguchi based Response surface Methodology for optimizing the Plasma arc cutting parameter of 304L stainless steel", Int J Advance Manufacturing Technology (2015).

[10] Dilip Kumar bagal et al, "Effect of process parameter on Cut quality of stainless steel of Plasma arc cutting using Hybrid approach", Int J Advance Manufacturing Technology (2014).
[11] Engin unal et al, "A fuzzy model for predicting surface roughness in Plasma arc cutting of AIS 4140 Steel", Material and Manufacturing Process Pg. 95-102, (2014).
[12] Tatsuo Ishijima et al, "Experimental investigation of magnetic arc blow in Plasma arc cutting", Weld World (2014).
[13] D. V. Rammana et al, "Investigation analysis of Plasma arc cutting parameters on the Unevenness surface of Hardox-400 material", Procedia Engineering Pg. 854-861, (2013).
[14] Radovan grzonarik et al, "Comparison of Non-Traditional technology for material cutting from point of view of Surface Roughness", Int J Advance Manufacturing Technology (2013).
[15] Sachin bhartiya et al, "Analysis of Process Parameters of Plasma arc cutting of stainless steel using Taguchi method", Applied Mechanics and Material 110-116 Pg. 3551-3556, (2012).
[16] S. Vatausianos et al, "Experimental investigation of Plasma arc cutting process", Procedia CIRP Pg. 287-292, (2012).
[17] K. S. Jayakumar et al, "Comparision of modelling techniques for selecting optimized and automated Plasma Cutting process Parameter", Int J of Modelling and Simulation 1250011 Pg. (1-15).
[18] Navneet beri et al, "A study of Multiobjective parametric optimization of Silicon abrasive mixed Electrical Discharge machining of tool Steel", Material and Manufacturing Processes Pg.1041-1047, (2010).
[19] V. Nemchinsky et al, "High speed imaging investigation of transition phenomena in the Pilot arc phase in HF cathodes for Plasma arc cutting", Plasma Source Sci Technology 060205, (2010).
[20] W S Severance et al, "Plasma arc cutting: Speed and Cut quality", J. Phy. Appl Phys. 195204, (2009).
[21] Claro Novoa et al, "Optimising the automated Plasma cutting process by Design of experiment", Int J Rapid Manufacturing Pg. 19-40, (2009).
[22] W. J. Haung et al, "Optimization of Plasma arc welding parameter by using Taguchi method with Grey relational analysis", Material and Manufacturing Processes Pg. 51-58, (2008)
[23] M. Monno et al, "Experimental Study of the feature of the kerf generated by a 200A high tolerance Plasma arc cutting System", Journal of Material Processing Pg. 345-355, (2008)
[24] E. Negoescu et al, "Plasma cutting of composite material", Int J Master Pg. 1347-1350, (2008).
[25] Umut atici et al, "Investigation of the effect of Plasma arc Parameter on the structure variation of AISI 304 and St 52 Steel", Material and Design Pg. 1157-1162, (2005).
[26] B. Previtalli et al, "High tolerance Plasma arc cutting of commercially pure titanium", Journal of Material Processing Pg. 77-89, (2005).
[27] Y.S. Lu et al, "Study on ceramic cutting by Plasma arc", Journal of Material Processing Technology Pg. 152-156, (2002).
[28] L. J. Yang et al, "Plasma surface hardening of ASSAB 760 Steel specimens with Taguchi optimization the processing parameters", Journal of Material Processing Technology Pg. 521-526, (2001).
[29] Valerian a Nemchinsky et al, "Dross formation and heat transfer during Plasma arc cutting", J Phy D Appl Phy Pg. 2566-2572, (1997).
[30] K. Chan et al, "Fine Plasma Cutting of advanced Aerospace Material", Journal of Material Processing Technology Pg. 825-831, (1995).
[31] Hussain Altaf et al, Surface Roughness Analysis in Machining of GFRP Composites by Carbide Tool (K20). European Journal of Scientific Research Pg.84-98, (2010).
[32] Lajis Mohammd Amri et al, The Implementation of Taguchi Method on EDM Process of Tungsten Carbide. European Journal of Scientific Research Pg.609-617, (2009).
[33] Kandananond Karin et al, Characterization of FDB Sleeve Surface Roughness Using the Taguchi Approach. European Journal of Scientific Research Pg.330-337, (2009).
[34] Uttarwar S S et al, Effect of Voltage Variation on MRR for Stainless Steel EN Series 58A (AISI 302B) In Electrochemical Machining: A Practical Approach. Proceedings of the World Congress on Engineering (2009).
[35] Joseph C. Chen et al, Taguchi Based Six Sigma Approach to Optimize Plasma Arc Cutting Process: an Industrial Case Study. International Journal of Advanced Manufacturing Technology 41 Pg.760-769, (2009).
[36] Asiabanpour Bahram et al, Optimising the automated plasma cutting process by design of experiments. Int. J. Rapid Manufacturing, (2009).
[37] Mahapatra S S et al, An evolutionary approach to parameter optimisation of submerged arc welding in the hard facing process Int. J. Manufacturing Research (2007).
[38] Mahapatra S S et al, Optimization of wire electrical discharge machining (WEDM) process parameters using Taguchi method. International Journal of Advanced Manufacturing Technology (2006).
[39] Dr. K. H Inamdar et al, Factor affecting quality of Plasma arc cutting Process: A Review. ICRTESM (2006).
[40] Quasim Zishan et al, Developments in Plasma Arc Cutting (PAC) of Steel Alloys: A Review. JKUKM (2006).
[41] Vikash Gondalia et al, Parametric Study on Plasma Arc Cutting of Al – 6063. IJAER (2006).
Websites
[42] Plasma Cutting, http://en.wikipedia.org/wiki/Plasma_cutting.
[43] Benefits of Plasma Arc Cutting, http://www.airgas.com.
[44] Plasma (Physics), http://en.wikipedia.org/wiki/Plasma (physics)#History.
[45] Plasma Cutting, http://www.hypertherm.com/technology.htm.
[46] Lisega, https://www.lisega.de/en.
Book and Manual
[47] Engineering handbook, G. L. Huyet.
[48] Hyperformance Plasma HPR260XD Auto Gas.