PAPER ID - 06

PRODUCTIVITY IMPROVEMENT OF PLASMA CUTTING MACHINE: A REWIEW

Akash Dalvi
Dept.of Mechanical Engineering, Indira College of Engineering and ManagementPune, India
dalviakash709@gmail.com
Shrinivas Upganlawar
Dept.of mechanical engineering, Indira College Of Engineering and Management, Pune, India
upganlawarshrinivas@gmail.com
Shubham Kondhalkar
Dept.of mechanical engineering, Indira College Of Engineering and Management, Pune, India shubhamkondhalkar28@gmail.com
Suraj Pawar
Dept.of mechanical engineering
Indira College Of Engineering and Management, Pune, India pawarsk88@gmail.com
Prof. N. Ulmek
Asst. Professor, Dept.of Mechanical Engineering Indira College of Engineering and ManagementPune, India
nitin3546@rediffmail.com

Abstract—

In today's increasingly competitive world, it is important to constantly improve, be it a manufacturing or service industry. Quality with quantity is a main characteristic which helps a company stay in the competition. The ultimate goal of company is to pursue profit. One approach for achieving this goal is via productivity improvement. High productivity refers to doing work in shortest possible time without sacrificing quality and with minimum use of resources. Competition and the drive for profits are forcing companies to implement various productivity improvements efforts. JCB India Ltd. Located in Talegaon manufactures earth moving equipment's like excavators, wheel loaders, compactors, backhoes. This product requires various shapes of sheet metal plates. These plates are cut by using plasma and laser cutting machines. The problem faced by company resulted in low productivity. The root cause for the problem was studied and analyzed which finally demanded for the designing and manufacturing of material handling device which will lift maximum numbers of finished parts at same time. This project work presents study and experimental analysis of causes that are responsible for low productivity of machine and methods to tackle the problem faced by industry.

Keywords—Plasma, Messer, Productivity

I. INTRODUCTION

In plasma machine, plasma is used for cutting the metal. Basically there are three states of matter i.e. solid, liquid and gas. The basic difference between them is of energy. Energy of solid is minimum. If we add energy to solid it is converted into liquid. If we add more energy to liquid it is converted into gas, when we add extra energy to gas, it becomes plasma. Plasma is highly ionized and electrically conductive. It is much useful to increase temperature as well as to perform cutting. In plasma cutting technology argon, nitrogen and compressed air are used to generate a plasma jet and then nonferrous metal, stainless steel and black metal are cut by the high temperature of the highly-compressed plasma arc and the mechanical erosion of the fast plasma jet.

The 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 emitting 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 productivity of plasma cutting machine depends upon various parameters such as arc voltage, kerf, cutting speed, surface roughness material, gas pressure, torch-to-work distance, etc. These factors are accompanied by several external factors such as material loading and unloading time, process sheet planning and material handling.

This paper gives a review on various methods of improving productivity of plasma cutting machine by better utilization of various parameters.

II. LITERATURE REVIEW

W.J.Xu and **J.C fang** were conducted experiment on ceramic during plasma arc cutting. They measured cutting qualities by varying process parameter the flow rate of injected water and the magnetizing current using nozzles of different diameters. From the experiment they found that both water constriction and magnetic constriction of plasma arc forms a three dimensional constriction with improved shape and uniformity of the arc column and hydro magnetic constriction is capable of improving arc stability. [1]

E.Gariboldi and **B. Previtali** were conducted experiment to improve the quality of cuts performed on titanium sheets using High Tolerance Plasma Arc Cutting (HTPAC) process. They were investigated under different process conditions like using several feed rates in the dross-free feed rate range and with the adoption of oxygen or nitrogen as cutting and shielding gases. They found that when oxygen was used as cutting gas higher feed rate and geometry attributes (unevenness and kerf width) of better quality were achieved due to the oxidation reaction. The quality features of the cutting edge of HTPAC of commercially pure titanium were integrated with considerations on micro structural features related to the formation of a wide layer severely affected by plasma induced thermal cycle and by interaction with the cutting gas. They showed that temperature measurements during the passage of the torch defined the thermal cycles of the cutting process in several locations of the sheet. These are characterized by high heating rates (above 2000 K/s within the Heat Affected Zone) and low cooling rates (150–580 K/s within the HAZ). They were applied to simulate the thermal effects of the material interaction with the torch in the case of slow cuts with oxygen by analytical model. A comparison between predicted thermal cycles, experimental measurements and microstructural observations confirmed the reliability of the estimation in terms of extension of microstructural modifications. [2]

AbdulkadirGullu et.al were carried an experiment on AISI 304 stainless steel and St 52 carbon steel have been cut by plasma arc and the variations of structural specifications occurred after cutting has been investigated. From the experiment they found that, it has been seen that burning of particulars and distribution amount were increased when the cutting was performed using the speeds which are upper or lower limits of the ideal cutting speeds proposed by the manufacturer of the machine tool. They had determined that the hardness from the outer surface to the core decreased, while the hardness near to the outer surface which affected by the high temperature occurred during cutting increased. Thus they revealed that the area of 0.399–0.499 mm of stainless steel materials and 0.434–0.542 mm of carbon steel materials were more affected by heat according to cutting speed. [3]

B.M. Colosimo et.al published that the HTPAC is a very promising thermal coating technology which combines high productivity with good cutting quality. However, this process is deeply influenced by several variables. The operating conditions have to be carefully optimized through parameter adjustment in order to obtain top quality results. In this paper, two sequential experimental designs were performed and analyzed in order to investigate the effect of the main process parameters on the output unevenness, in a real cutting application. The analysis confirmed that the HTPAC response is difficult to predict and has a complex behavior. It was found out that the arc voltage is the main parameter and it influences all the aspects related with the cut quality. Rather than the effect on the arc power, its proportionality with the standoff distance seems to be the true responsible for its importance. In fact, the bottom of the kerf, which has been identified as the critical zone, suffers from an excessive distance from the arc hottest part. On the other hand, by reducing the arc voltage, i.e. the standoff distance, the thermal stress on the torch components, especially the electrode and the nozzle, increases, thus accelerate their wear. This tradeoff can be taken into account by adding some suitable constraints to the parameters domain. 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. However, care has to be taken in order to not exceed the limit of square edges and step into the zone of negative bevel cut. [4]

Adriana Munteanu et.al presents some experimental results concerning the surface roughness variation at plasma arc cutting, in case of processing a stainless steel work piece. The plasma arc machining (PAM) is complex processes that are used in the machine manufacturing field due to their possibilities. In this study, AISI 304 stainless steel has been cut by plasma arc and the variation of Ra surface roughness parameter occurred after cutting has been investigated. A plasma cutting device is used to convert electrical power into thermal energy through a high temperature plasma jet which melts and ejects the molten metal out of the kerf. The plasma cutting process may be used to cut any conductive material, including carbon steel, stainless steel, aluminum, cooper, brass, cast metals and exotic alloys. [5]

MiroslavRadovanovic et.al had done a modelling of the plasma arc cutting process using Artificial Neural Networking (ANN). Aimed to develop the ANN mode to predict the ten point height of irregularities taking input parameters such as cutting speed, cutting current and plate thickness. After prediction of data the accuracy of ANN has been validated. Using this model one can select the machining conditions. [6]

K. Salons et.al finds that the scope of the present paper was the experimental study of the plasma arc cutting in order to identify the process parameters that influence the most the quality characteristics of the cut. Four process parameters were examined, namely the cutting speed, the cutting current, the plasma gas pressure and the distance of the plasma torch from the work piece surface (cutting height). The quality characteristics that were assessed included the surface roughness, the heat affected zone and the conicity of the cut geometry. Using design of experiments and analysis of variance, it was found that the surface roughness and the concerti are mainly affected by the cutting height, whereas the heat affected zone is mainly influenced by the cutting current. [7]

BogdanNedic et.al knows that Plasma cutting is an unconventional technology that represents the best relation between cost and quality value for money for most of the standard ports and small series production types. In addition, the processing speed is far greater than the technology of machining, and quality is comparable to the laser cutting technology. Plasma cutting process may be used to cut any conductive material, including carbon steel, stainless steel, aluminum, copper, brass, cast metals and exotic alloys.
Obtained experimental results are consistent with theoretical considerations, as well as previous experimental results. The best quality is obtained increasing the speed by 20% of tablet speed value, which indicates that in this area has a place for further research and improvements. [8]

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

The current has maximum effect on the process after that torch travelling speed and stand-off distance and air pressure have minimum effect on the process. The overall optimum values of each parameter give the calculation is, the optimum current is 65 A optimum air pressure is 65 psi, optimum torch travelling speed is 3.0 m/min, optimum stand-off distance is 3.0 mm of having and Heat Affected Zone. As from the observation we found that it is cheaper than laser cutting for thick plates and from oxy-acetylene for thin plates. Pac has better cut quality. Heat affected zone is less or minimum. So we can prefer it in spite of other cutting processes. It can also be used to cut ceramic which results in high accuracy and less cost. Someone can make another study using plasma arc cutting and can implement it for quantitative analysis. [9]

SubbaraoChamarthiet.al was performing that Cutting speed increases 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. First of all, three process parameters like Voltage, Plasma gas and cutting speed than DOE are taken on the based DOE experiments are carried out. Then ANOVA analyses are done and after optimization experiments are carried out. It was found out that the arc voltage is main parameter and it influences all the aspects related with the cut quality rather than the effect on the arc power, beyond the arc voltage the cutting speed showed a noticeable effect.

Results obtained in the experimental stage allowed one to observe that unevenness can be reduced by reducing the cutting speed. Eventually, it was shown that very good quality can be achieved for all the sides by varying the cutting speed, plasma flow rate and arc voltage only. As recorded optimized minimum unevenness for 12 mm Hardox plate is 421 microns at optimum value of the 70L/Hrplasma flow rate, 125 V voltage and 2100 mm/min cutting speed. [10]

TKavka et.al published this paper which devoted to the experimental study of the effect of gas type and flow rate on properties of transferring arc and cutting phenomena. Three gases, mostly used for arc cutting of mild steel were considered, namely air, nitrogen and oxygen. Moreover, a plasma gas originated from a liquid with significantly different thermo physical properties was also investigated. The study involved the following steps: a theoretical examination of properties of acid gases, experimental study of the generated arcs, analysis of cutting performance and the energy balance of the cutting process. The predominance of nitrogen in air explains the similarity in plasma properties and cutting performance for both gases. They exhibited the same voltages, the smallest arc diameters and the narrowest kerfs among the studied cases. Despite the significant difference in gas and arc properties, oxygen and steam cutting exhibited similar features. For both gases kerfs had a bell-shaped geometry and were much wider than for nitrogen or air cutting. Similar cutting performance is a result of different phenomena. In steam cutting, a wider kerf was caused by higher energy density in the plasma and better ability of radial heat transfer from the arc center towards the material in the kerf. In oxygen cutting, oxidation of the material played a significant role and the energy input originated from oxidation increased with the plasma gas flow rate. It was shown that under study conditions 20% of supply oxygen reacted with the cut material with a release of 3.4 KJ per gram of oxygen. In steam cutting, despite the rather high oxygen content, oxidation did not take place. Bounded-free oxygen was necessary to provide the reaction of oxidation. However, most of the oxygen flowed into the cold outer region, where it was bounded either with hydrogen or with carbon. An increase in the plasma gas flow rate can facilitate improvement of cut quality for all gases because it increases both energy and momentum density. [11]

Yahahismanselic et.al cut the sheet material S235JR using the CNC plasma cutting machine at different cutting speeds, 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 cut. From the results of the experiments he had concluded that the quality of plasma CNC machine depend on the cutting current, cutting speed, arc voltage and material thickness.

To get the best surface roughness the cutting current and the cutting voltage kept low and cutting speed must be high for the thin sheet and while using CNC plasma machine prevent hardness increase, and have a minimum HAZ. While the thickness of the cutting sheet increase the cutting current must be increase and cutting voltage is to be decrease. However this leads to decrease in corresponding cutting speed. [12]

Milan Kumar et.al were conducted experiment on EN31 steel using process parameters like gas pressure, arc current and torch height to influence effect on material removal rate and roughness characteristics. They developed empirical graph of response surface methodology and finally they worked on chip morphology. They analyzed their experimental reading through ANOVA and grey relational analysis. They found that highly effective parameter is gas pressure, whereas arc current and torch height are less effective factors for the response. [13]

N.Senthilkumar et.al were carried out experiments on 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 response. 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 is done. [14]

B.Venugopal et.al presents the effects of the process parameters such as cutting current, cutting speed, and torch height on Ra and MRR. Grey Taguchi technique is employed for optimal process parameters for obtaining minimum Ra and maximum MRR simultaneously. The optimal setting for obtaining minimum Ra and maximum MRR are 100 Amp cutting current, 1300 mm/min cutting speed and 4 mm torch height.[15]

S. S. Pawar et.al studies stainless steel 316l is cut with CNC controlled plasma arc cutting process, and kerf width and taper these two quality characteristics were monitored. Through S/N ratio analysis it is found that increase in arc voltage results in increase kerf width and decrease in taper produced. Increase in cutting speed results in decreased kerf width and increase in taper. Increase in gas pressure causes increase in kerf width and decrease in taper produced. ANOVA is done in order to identify influence of process parameters on quality characteristics. It is found that arc voltage and cutting speed are significant for kerf width. Whereas all three input parameters arc voltage, cutting speed and gas pressure are found significant for taper. Contribution of arc voltage is found more for kerf width followed by cutting speed and gas pressure. Cutting speed is contributing more for taper followed by arc voltage and cutting speed. GRA is used to optimize both the responses kerf width and taper. GRG is 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. Taguchi method is employed to optimize GRG it is found that GRG is 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. [16]

HardikDholakiya et.al presents work done on plasma arc cutting of various materials like S235 mild steel, EN 10025, St37 mild steel and Hardox-400 and other steels like 21Cr ferritic stainless steel, EN 31 Steel, AISI 316 stainless steel, AISI 304 stainless steel and St 52 carbon steel. Based upon the experiments, the effect of selected input parameters on the responses parameters such as bevel angle, unevenness of surface, kerf width, surface roughness, temperature distribution, and heat affected zone and hardness were studied. Most influential process parameters for the above mentioned experiments are standoff distance, cutting speed, cutting current and gas pressure. [17]

Deepak kumarNaik et.al was experimentally investigated PAC process on 304L stainless steel. The influence of process parameters onto the X direction affects dimensional accuracy. Also, the deviation was established using ANOM and ANOVA. The work concludes that the optimal condition for the leaner dimensions on the X axis were; current: 80 A, voltage: 140 V, SOD: 4 mm and cutting speed: 2500 mm/min.
The optimum parameters values for the deviation were; current: 70 A, voltage: 150 V, SOD: 4 mm and cutting speed: 3000 mm/min. ANOVA portraits that the X axis leaner dimension is contributed the most by the SOD (67.74 %) and the deviation is affected the most by the current (42.45 %). [18]

A parthiban et.al experimented response surface methodology based optimization techniques 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. The work concludes that the anova tables of the top kerf width and bottom kerf width show that the developed models are significant The Response surface graph was used to graphically select the plasma arc cutting parameters, as the favored top kerf width and bottom kerf width values. The optimal parameters combination was determined as plasma arc current at 40 Amp, cutting speed at 4999.9 mm/min and stand of distance 2mm. This work demonstrates the method of using Response surface methodology for optimizing the Plasma arc cutting process; the multiple responses are top and bottom kerf width characteristics. [19]

J. Kechagias et.al suggested right bevel angle has been selected as the quality indicator for PAC process multi parameter optimization using robust design. A right bevel angle near zero means less post processing of the part. The experimental design showed that the arc ampere is the most important parameter that affects the right bevel angle by 58.7%. The torch standoff distance affects the right bevel angle by 15.7% and the cutting speed 19%. All the other process parameters used in the orthogonal experiment had a negligible effect on the right bevel angle within its experimental limits. The experimental limits were designed in order for all the combinations suggested in the orthogonal matrix to be able to be conducted. This means that if a combination could not be conducted the orthogonally would be lost and the conclusions would be unbalanced. Multi-parameter optimization of the process according to other quality indicators such as kerf width, cut surface hardness, top edge rounding, dimensional accuracy, accumulation of metal underneath the part and surface quality parameters will be studied and analyzed in future work. [20]

III. CONCLUSION

After reviewing all these papers, we have concluded that,
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. An increase in the plasma gas flow rate can facilitate improvement offcut quality for all gases because it increases both energy and momentum density.
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.
Surface roughness and conicity are mainly affected by the cutting height, whereas the heat affected zone (HAZ) is mainly influenced by the cutting current.
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.
For the thin plate of work piece material cuttingcurrent and cutting voltage should be decrease and cutting speed should be increase for better surface roughness.

IV. REFERENCES

[1] Experimental Investigation of the Plasma Arc Cutting Process, W.J xu, J.C fang, Y.S Lu, journal of material processing C. technology 152-156 (2002).
[2] High tolerance plasma arc cutting of commercially pure titanium E, E. Gariboldi, B. Previtali, Journal of Materials D. Processing Technology.77–89(2005).
[3] Investigation of the effects of plasma arc parameters on the structure variation of AISI 304 and St 52 steels, Abdulkadir B. Gullu, UmutAtici, Materials and Design 27 1157–1162 (2006).

[4] Experimental study of the features of the kerf generated by a 200A high tolerance plasma arc cutting system, R. Bini, B.M. Colosimo, A.E. Kutlu, M. Monno, journal of materials processing technology(2008)
[5] Experimental results concerning the variation of surface roughness parameter at plasma arc cutting of stainless steel work piece, Sanda-Maria Ilii , Margareta Coteaţa, Adriana Munteanu , International Journal of Modern Manufacturing Technologies ISSN 2067–3604, Vol. II, No. 1 / 2010
[6] Modeling the plasma arc cutting process using ANN, MiroslavRodovanovic, Milos Madik, Nonconventional technologies review, vol. 4, pp. 43–48, 2011.
[7] Experimental Investigation of the Plasma Arc Cutting Process, K. Salonitis, S. Vatousianos, Procedia CIRP 3 (2012) 287 – 292
[8] Quality of plasma cutting, BogdanNedic, Marko Jankovic, MiroslavRadovanovic, GordanaGlobockiLakic., 13th International Conference on Tribology, 17 May 2013.
[9] Optimization of plasma arc cutting by applying Taguchi Method KulvinderRana, Dr. ParbhakarKaushik, SumitChaudhary, International Journal of Enhanced Research in Science Technology & Engineering, ISSN: 2319-7463 Vol. 2 Issue 7, July-2013
[10] Investigation Analysis of Plasma arc cutting Parameters on the Unevenness surface of Hardox-400 material, SubbaraoChamarthi, N.Sinivasa Reddy, Manoj Kumar Elipey, D.V. Ramana Reddy, Procedia Engineering 64 (2013) 854 – 861.
[11] Experimental study of the effect of gas Nature on plasma arc cutting of mild steel, T Kavka, A Maslani, M Hrabovsky, P Krenek, T Stehrer and H Pauser, Journal of applied physics, 46 (2013)
[12] Investigating the effect of cutting parameters on material cut in CNC plasma, YahyaHismanSelic, materials and manufacturing processes, vol. 28, pp. 1053 – 1060, 2013.

[13] Optimization of process parameter in plasma arc cutting of EN31 steel based on MRR and multiple roughness characteristic using grey relational analysis, Milan Kumar, Kaushikkumar, Tapan barman, Prasantasahoo, international conference on advance in manufacturing and material engineering.1550-1559 (2014).
[14] Analysis of Process Parameters in Plasma Arc Cutting, N.Senthilkumar, T.Tamilkannan , B.Thirumoorthi , G.Vigneshkumar, J.Vijayaragavan, International Journal of Innovative Research in Science, Engineering and Technology, Vol. 5, Special Issue 8, May 2016
[15] Experimental Investigation and Optimization of Process Parameters in Plasma Arc Cutting Process, B.Venugopal, Dr. R. Ramachandra, B.Sreenivasulu, International Journal of Engineering Science and Computing, August 2016
[16] Experimental Analysis of Plasma Arc Cutting Process for SS 316l Plates, S. S. Pawar, K. H. Inamdar, IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE), 18th March 2017.
[17] Parametric study on plasma arc cutting of AL-6063, HardikDholakiya, Vikasgondalia, International Journal of Advance Engineering and Research Development (IJAERD) Volume 4, Issue 5, May-2017
[18] Optimization of Dimensional accuracy in plasma arc cutting process employing parametric modeling approach, Deepak kumarNaik, K.P. Maity, IOP Conf. Series: Materials Science and Engineering ,NCPCM 2017.
[19] Experimental Investigation of plasma arc cutting for stainless steel sheet, A parthiban, J.P.prasath, P.vivek, R. pugazhenthi , International Journal of Mechanical and Production Engineering Research and Development (IJMPERD) ISSN (P): 2249-6890; ISSN (E): 2321-8001 Vol. 8, Issue 1, Feb 2018,
[20] On the multi – parameter optimization of CNC plasma-arc cutting process quality indicators using Taguchi Design of Experiments, J. Kechagias, P. Stavropoulos , S.Maropoulos and K. Salonitis, Recent Advances in Electrical Engineering, ISBN: 978-1-61804-260-6