Available online at www.elixirpublishers.com (Elixir International Journal)

Mechanical Engineering

Elixir Mech. Engg. 99 (2016) 43233-43236

ISSN: 2229-712X

Optimization of PAC process parameters using Genetic Algorithm

R. Sandeep[1], S. Bala Anki Reddy[2] and V. Govind Naik[3]

[1,2]Siddartha Institute of Science and Technology, Puttur, A.P and India -517583.

[3]Associate Professor, Siddarth Institute of Engineering & Technology, Puttur, India - 517583.

ARTICLE INFO

Article history:
Received: 15 August 2016;
Received in revised form:
15 October 2016;
Accepted: 18 October 2016;

Keywords
Plasma Arc cutting (PAC),
Surface roughness (Ra),
Material removal rate (MRR),
Genetic algorithm (GA).

ABSTRACT

This paper outline is an experimental study to optimize process parameters of plasma arc cutting for stainless steel 420. Three process parameters were chosen these are cutting speed, cutting current and torch height. The experiments are conducted based on taguchi's L_9 OA. The objective of optimization is to attain minimum Ra and maximum MRR individually. Regression models for Ra and MRR are developed based on Regression analysis in Minitab 17 Software. The optimal settings is obtained for Ra and MRR by using Genetic algorithm optimization technique in MATLAB R2013a software.

I. Introduction

Modern industry depends on the manipulation of many heavy metals and alloys. Now a days, various thermal cutting techniques are used for shaping materials in different fields such as railway wagon manufacturing, automobile sector, boiler manufactures and food processing machinery. There are many thermal machining processes are one among them is plasma arc cutting (PAC) process. Generally there are four forms of physical matter, solid state, liquid state, gaseous sate if temperature is raised above 3000 ^{o}C the atoms gets ionized this state of gas is called plasma state.

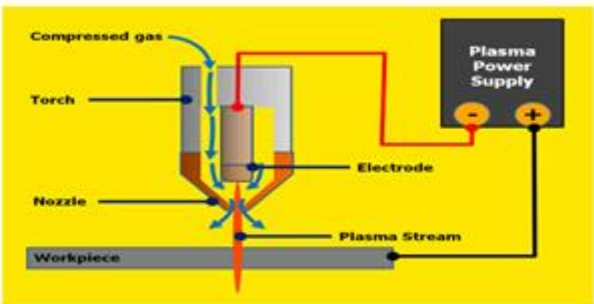

Figure 1. Schematic Diagram of PAC Process

With the help of this high temperature gas, we can melt and separate the material. The source of energy in plasma arc cutting (PAC) is in the form of heat, which is concentrated on a work piece and reacts with it. Thus the work material melts out and even vaporize and finally cut into pieces. [10]. The materials like aluminium, titanium alloys, magnesium and its alloys, stainless steel, copper alloys which have large heat capacity, high thermal conductivity and good oxidation resistance cannot be cut by conventional techniques like oxyfuel cutting. So, plasma arc cutting (PAC) is more advantages than conventional techniques.

Previously, some of researchers have been tried to optimize process parameters in PAC. Milan Kumar Das et. Al. investigates the effects of process parameters such as Torch height, arc current and gas pressure for Plasma arc cutting of EN31 steel and also optimized process variables with considerations of multiple process responses such as surface roughness and material removal rate by using grey relational analysis [1]. Milan Kumar Das et. Al. Have optimized process variables such as torch height, arc current and gas pressure with consideration of process responses such as MRR and surface roughness in plasma arc cutting by using weighted principal component analysis (WPCA) [2]. K.P. Maity and Dilip kumar bagal have investigated the effect of plasma arc cutting parameters such as current, torch height, feed rate and voltage on the process responses such as MRR, Dross, chamfer and mean surface roughness of AISI 316 stainless steel and also optimized the process variables for multi objective responses by using principal component analysis and grey relational analysis [3]. Subbarao chamarthi et. Al. have been investigated plasma arc cutting process parameters such as arc voltage, plasma gas pressure and cutting speed and also optimized process variables for obtain best surface finish for Hardox-400 plate [4]. K. Salonitis and S. Vatousianos have examined plasma arc cutting process parameters experimentally for identifying process variables that influence the most on cut quality. The process variables were examined, namely gas pressure, Torch height, cutting current,cutting speed and also, optimized the process variables for achieving minimum surface roughness and minimum HAZ [5]. Kulvinder Rana et. Al. have optimized process variables in plasma arc cutting for minimizing HAZ for Mild steel thin plates. The process variables which are optimized namely, current, stand-off distance, cutting speed, and air pressure [6]. R. Bhuvnesh et. Al. have investigated the process variables namely cutting speed, air pressure, cutting current, arc gap and also optimized process variables for multiple responses such a surface roughness and material removal rate by using Taguchi techniques for AISI 1017 Steel [7].

The main objective of this present study is optimization of process parameters such as cutting current, cutting speed and Torch height to obtain minimum surface roughness (R_a) and maximum material removal rate (MRR) in plasma arc cutting

Tele: +91 - 9642522379
E-mail address: sandeep.r2404@gmail.com

while machining of SS 420. For optimizing R_a and MRR individually genetic algorithm (GA) is applied. For optimization mathematical models must be developed.

To develop mathematical models regression analysis is applied to the experimental data of Ra and MRR.

II.Experimental procedure

a. Experimental setup

All the experimental runs were performed on the CNC Plasma arc cutting system. The plasma arc cutting machine (MESSER Kjellberg) is available with M.B. Engineering Industries Pvt. Limited, India. Experiments were conducted on SS420 material (170mm L X 170mm B X 10mm H). The machining conditions at which the experiments were conducted as follows: the gases used in this experiment are Argon and Hydrogen as plasma gas and Nitrogen as shielding gas. The plasma arc cutting system which is used for this research had a nozzle with an outlet diameter of 2.0 mm and it is made up of Brass, the primary and secondary gas pressure at 9.1 bar and arc voltage setting of 120 volts was used.

Figure 2. Plasma arc cutting Equipment

The parameters considered for this experiment are cutting current (x_1), cutting speed (x_2) and torch height (x_3). The process responses are Surface roughness (Ra) and material removal rate (MRR). MRR is calculated as weight loss of work piece material to the machining time. Surface roughness measurement is done by using a Talysurf (Mitutoyo). In the machining process parameter design, 3 levels with equal space of process parameters are selected as shown in Table 1.

Table 1. Process parameters and their levels

Process parameters	Units	Notation	Levels		
			1	2	3
Cutting Current	Amp	X_1	100	130	160
Cutting Speed	mm/min	X_2	1000	1300	1600
Torch height	mm	X_3	4	5	6

Figure 3. Talysurf (Mitutoyo) equipment

b. Selection of work piece material

In this experiment, Rectangular block of 170 mm X 170 mm X 10 mm thickness of martensitic stainless steel was used as work piece material. SS 420 is a high carbon steel with a minimum chromium content of 12%. Martensitic stainless steels have high hardness, good corrosion resistance and good oxidation resistance. The key applications of SS420 include threaded pipe for oil well, surgical equipment, shear blades, pump shafts and plastic moulds. The chemical composition and mechanical properties of SS 420 are shown in Table 2 and Table 3 respectively.

Table 2. Chemical composition (wt. %) of SS 420

C	Mn	Si	Cr	P	S	Fe
0.15 (min)	1.00	1.00	12.0 – 14.0	0.04	0.03	Balance

Table 3. Mechanical properties of SS 420

Density (kg/m^3)	Poisson's ratio	Elastic modulus (GPa)	Tensile strength (MPa)
7800	0.27 - 0.30	200	800

c. Design of experiment (DOE)

Design of experiment (DOE) technique is employed to acquire maximum amount of conclusive information from the minimum amount of experimental run, energy, money, time or any other limited resource. By applying this method, it is possible to reduce the required time as well as number of experiments significantly for experimental investigations. In Taguchi technique, an orthogonal array (OA) is used to reduce the number of experimental runs for identifying the optimal machining process parameters. An orthogonal array (OA) requires the minimal number of experimental runs to determine the main effects as well as interaction effects of process parameters simultaneously. The choice of an appropriate orthogonal array depends upon the total degree of freedom (DOF) required for studying mean and interaction effects. In this study, there are three process parameters and three levels each so, the DOF for this experimental is 6 [3 X (3 – 1)]. For this experiment, L_9 OA has been selected for because as per Taguchi technique, the total degree of freedom of selected OA must be greater than to the total DOFs required for the experiment. The selected OA and experimental results for surface roughness (Ra) and material removal rate (MRR) are included in Table 4.

Table 4. Design of experiment and experimental results.

Exp. Run	Cutting Current (Amp)	Cutting speed (mm/min)	Torch height (mm)	Ra (μm)	MRR (gm/sec)
1	100	1000	4	0.907	1.635
2	100	1300	5	0.844	1.588
3	100	1600	6	0.886	3.269
4	130	1000	5	1.105	2.171
5	130	1300	6	1.002	2.325
6	130	1600	4	0.923	3.53
7	160	1000	6	1.231	2.476
8	160	1300	4	1.092	2.71
9	160	1600	5	1.214	3.982

III.Results and Discussions

d. Development of Regression models:

The plasma arc cutting experiments were conducted by using the parametric approach of Taguchi's technique. Regression analysis is applied to the experimental data for developing regression models for R_a and MRR using Minitab 17 Software. During regression analysis it was assumed that the process parameters and process responses are linearly related to each other. General first order models were developed to predict the values of R_a and MRR over the experimental region (Equ. 1 & Equ. 2). For this experiment regression coefficient (R^2) for R_a was found to be 90.12 %. Adj. R^2 for number of predictor in the model is 84.19 % values shows that the data are fitted well. And also R^2 value for MRR was found to be 83.33 % and Adj. R^2 for number of predictor in the model is 74.12 % values shows that the data are fitted well.

$$R_a = 0.367 + 0.005 * x_1 - 0.000112 * x_2 + 0.0328 * x_3 \quad (1)$$

$$MRR = -2.71 + 0.01487 * x_1 + 0.002499 * x_2 + 0.033 * x_3 \quad (2)$$

e. Single-objective optimization

Genetic algorithm

GA are computerized search and optimization algorithm based on the mechanics of natural genetics and natural selection.

Genetic algorithms (GA) are good at taking larger, potentially huge, search spaces and navigating them looking for optimal combinations of solutions. GA's work with a coding of variables. The advantage of working with a coding of variable space is that coding discretizes the search space even though the function may be continuous. The main difference between GA and other traditional an optimization method is that GA uses a population of points at one time in contrast to the single point approach by traditional optimization methods. This means that GA processes a number of designs at the same time. Generally to solve a problem it is worked out towards some solution which is the best among others. The space for all possible feasible solutions is called search space. For solving optimization problem using genetic algorithm the following procedure was adopted:

- Fitness function is required, fitness function in fact, are the objective function. In this study, regression analysis has been employed to develop the mathematical model which establish the relation between process parameters and responses. The developed mathematical model was converted into a MATLAB (R2013a) function. This function will be used as fitness function in GA tool box of MATLAB R2013a.
- Select the number of variables.
- Enter lower bound (LB) and upper bound (UB) values as per machining process parameters levels.
- Select the population type and enter the population size value.
- Select fitness scaling function type.
- Select function selection procedure type.
- Select the mutation function type and cross over type.

i. Minimization of R_a using GA tool

The objective function for minimizing Surface roughness (R_a) from regression analysis is stated as:

Minimize $R_a = 0.367 + 0.005 * x_1 - 0.000112 * x_2 + 0.0328 * x_3$

The process parameters of objective function are limited by its LB and UB as given as

$100 \leq x_1 \leq 160$

$1000 \leq x_2 \leq 1600$

$4 \leq x_3 \leq 6$

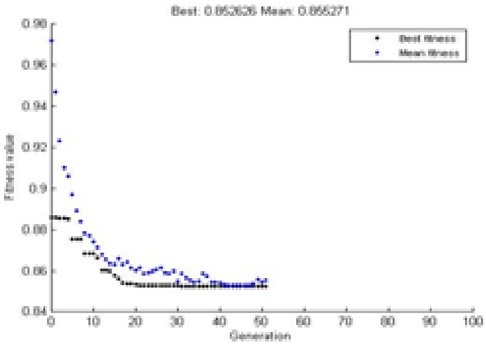

Figure 4. Fitness Value plot for R_a

The optimization are carried out by using GA parameters as: number of population is 20, cross over fraction 0.8, migration fraction 0.2 and migration interval of 20. Based on the objective function the optimum value of R_a = 0.852626 are obtained at 51 iterations and the optimal setting for minimum R_a of 0.852626 is at Cutting Current 100.001 Amp, Cutting Speed 1299.822 mm/min and Torch height of 4 mm.

iii. Maximization of MRR using GA tool

The objective function for maximizing Material removal rate (MRR) from regression analysis is stated as:

Maximize

$MRR = +2.71 - 0.01487 * x_1 - 0.002499 * x_2 - 0.033 * x_3$

The process parameters of objective function are limited by its LB and UB as given as

$100 \leq x_1 \leq 160$

$1000 \leq x_2 \leq 1600$

$4 \leq x_3 \leq 6$

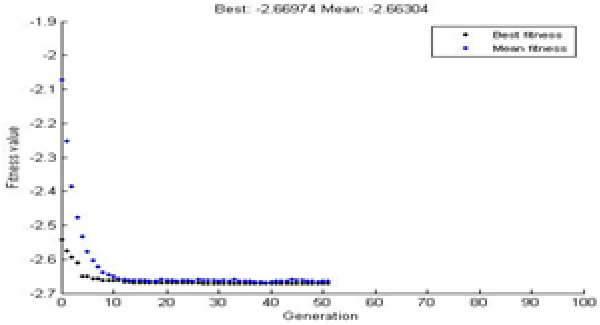

Figure 5. Fitness Value plot for MRR

The optimization are carried out by using GA parameters as: number of population is 20, cross over fraction 0.8, migration fraction 0.2 and migration interval of 20. Based on the objective function the optimum value of MRR = -2.66974 are obtained at 51 iterations and the optimal setting for maximum MRR of -2.66974 is Cutting Current 129.999 Amp, Cutting Speed 1300 mm/min and Torch height of 5.999 mm.

Conclusion

In this research, plasma arc cutting experiments were conducted based on parametric approach of the Taguchi method. Regression analysis was performed to find out the relationship between process parameters and responses using Minitab 17 software. General first order model was developed to predict the surface roughness and MRR over the experimental region. The optimal setting for R_a and MRR were obtained individually by using genetic algorithm (GA), the optimal process parameter setting form minimum surface roughness is found to be at Cutting Current 100.001 Amp, Cutting Speed 1299.822 mm/min and Torch height of 4 mm and optimal setting for maximum MRR is found to be at Cutting Current 129.999 Amp, Cutting Speed 1300 mm/min and Torch height of 5.999 mm. These optimal set of solutions could help as a ready to ease to achieve high production rate & best quality demanded by the consumer.

References

[1] Milan Kumar Das, Kaushik Kumar, Tapan Kr. Barman and Prasanta Sahoo "Optimization of MRR and Surface Roughness in PAC of EN 31 Steel Using Weighted Principal Component Analysis", 2nd International Conference on Innovations in Automation and Mechatronics Engineering, ICIAME 2014, Procedia Technology 14 (2014) 211 – 218.

[2] Milan Kumar Das, Kaushik Kumar, Tapan Kr. Barmana and Prasanta Sahoo "Optimization of process parameters in plasma arc cutting of EN31 steel based on MRR and Surface Roughness Using Grey relational analysis", International conference on advances in manufacturing and materials engineering, Procedia Technology 5 (2014) 1550 – 1559.

[3] K. P. Maity & Dilip Kumar Bagal, "Effect of process parameters on cut quality of stainless steel of plasma arc cutting using hybrid approach", Int J Adv. Manuf. Technology.

[4] Subbarao Chamarthia, N.Sinivasa Reddy, Manoj Kumar Elipey, D.V. Ramana Reddy "Investigation Analysis of Plasma arc cutting Parameters on the Unevenness surface of Hardox-400 material", International Conference On DESIGN AND MANUFACTURING, IConDM 2013, Procedia Engineering 64 (2013) 854 – 861.

[5] K. Salonitis, S. Vatousianos, “Experimental Investigation of the Plasma Arc Cutting Process”, 45th CIRP Conference on Manufacturing Systems 2012, Procedia CIRP 3 (2012) 287 – 292.

[6] Kulvinder Rana, Dr. Parabhakar Kaushik, Susmit Chaudhary “Optimization of plasma arc cutting by applying Taguchi Method”, International journal of enhanced Research in science Technology & Engineering.

[7] R. Bhuvenesh, M.H. Norizaman, M.S. Abdul Manan “Surface Roughness and MRR Effect on Manual Plasma Arc Cutting Machining” World Academy of Science, Engineering and Technology Vol: 6 2012-02-21.

[8] Abdulkadir, Gullu. , Umut, Atici ., “Investigation of effects of plasma arc parameters on the structure variation of AISI 304 and St 52 steel” Materials and Design ,volume 27.

[9] Rahul Dhabale, Vijay Kumar S. Jattib, T.P.Singh “Multi-Objective Optimization of Turning Process during Machining of AlMg1SiCu Using Non-Dominated Sorted Genetic Algorithm”, 3rd International Conference on Materials Processing and Characterisation (ICMPC 2014), Procedia Materials Science 6 (2014) 961 – 966.

[10] Dushyant P. Patel, Prof. S. P. Shah, Optimization Of Process Parameters For Turning Operation On CNC Lathe For Inconel 600 Using Genetic Algorithm, International Journal for Advance Technological Research and Analysis Volume-1; Issue-I.