ANNALS OF FACULTY ENGINEERING HUNEDOARA
– INTERNATIONAL JOURNAL OF ENGINEERING
Tome X (Year 2012) – FASCICULE 3 (ISSN 1584 – 2673)

[1.] Md. Anayet U. PATWARI, [2.] N. A. CHOWDHURY, [3.] M. D. ARIF, [4.] Md. S. I. CHOWDHURY

SURFACE ROUGHNESS OPTIMIZATION IN EDM FOR CIRCULAR COPPER ELECTRODE BY RSM-GA APPROACH

[1-4.] DEPARTMENT OF MECHANICAL AND CHEMICAL ENGINEERING, ISLAMIC UNIVERSITY OF TECHNOLOGY (IUT), BOARD BAZAR, GAZIPUR, DHAKA, BANGLADESH

ABSTRACT: *Surface Roughness is important to the quality and performance of the finished products. Therefore, the minimization of roughness in manufacturing sectors, such as: automotive and aerospace, is of utmost importance. It is also economical and desirable if the finished parts do not need further grinding or polishing operations to meet the required finish tolerances. For achieving the required optimum level of surface quality, the proper selection of machining parameters in EDM is very essential. In this study, a 1 inch diameter round copper electrode was used to achieve minimum surface roughness, in the EDM of mild steel specimens, by controlling three important machining parameters: T_{on} (On Time), T_{off} (Off Time), and V (Gap Voltage). Machining was performed on a CNC JS EDM machine. A statistical prediction model for average surface roughness, previously developed by the authors using Design Expert Software, was coupled with genetic algorithms to predict the minimum possible R_a. The minimum roughness predicted by GA shows good agreement with the physical measurement. The predicted surface roughness was also validated using a novel Digital Image Processing (DIP) technique developed by the authors and determined to have an accuracy of 90.62%.*
KEYWORDS: *EDM, Surface Roughness Model, Genetic Algorithm, Optimization, Digital Image Processing*

INTRODUCTION

In modern industries the demand is towards the development of parts with good dimensional accuracy and surface finish. So, surface roughness, which is an inherent by product of EDM process needs to be minimized [1]. Several researchers have used statistical approaches to model and optimize response variables in machining processes. Alauddin et al. [2] used Response Surface Methodology (RSM) and ANOVA to optimize the surface finish in end-milling of Inconel 718. Design Expert Software (DOE) has been used to conduct 13 experiments in order to build a statistical model for resultant surface roughness. Contours of constant surface roughness were then constructed to develop optimum cutting parameters. Suresh et al. [3] developed statistical models for milling operations and then optimized them by employing Genetic Algorithms (GA). They were able to achieve valuable insight into the interaction of various machining parameters on machining response. Dalai et al. [4] performed a case study on the multi-response optimization in EDM of stainless steel using both Desirability Function (DF) and Taguchi method. Their reviewed models were developed using Central Composite Design (CCD) in RSM and two contradictory responses were considered: Material removal rate (related to productivity) and Surface roughness (related to product quality). They reviewed how the two optimization techniques were used to successfully maximize the first while minimizing the second responses. Anayet U Patwari et al. [5] used coupled RSM-GA to model and optimize surface roughness produced in high speed end milling of medium carbon steel S45C. The accuracy of their method was 94.29%, which was experimentally carried out using a 3 factors and 5 levels rotatable CCD model in DOE [6].

The authors, previously, utilized a similar 3 factors: T_{on} (On Time), T_{off} (Off Time), and V (Gap Voltage); and 5 levels (-1.414, -1, 0, 1, 1.414) rotatable CCD model in RSM, to develop the mathematical model for average surface roughness R_a. The DOE suggested a quadratic model based on lack of fit assessment and comprehensive analysis by ANOVA [7]. In the current study, the authors used the developed statistical model for surface roughness as the fitness criteria for GA optimization. This process suggested a minimum R_a and corresponding machining conditions that were verified using a digital image processing technique developed by Anayet U Patwari et al. [8].

MATHEMATICAL MODEL

The quadratic model equation used in the GA algorithm as fitness function is:

$$\text{Ln (surface roughness)} = + 0.031 - 0.052*A + 0.039*B + 0.100*C + 0.19*A^2 - 0.17*B^2$$

Where, the transformation equations for the variables are:

$$A = \frac{\ln T_{on} - \ln 300}{\ln 700 - \ln 300};$$

$$B = \frac{\ln T_{off} - \ln 10}{\ln 16 - \ln 10};$$

$$C = \frac{\ln V - \ln 70}{\ln 90 - \ln 70}$$

The following table I shows the three levels of independence and coding identification.

Table I . List Of Independent Variables And Coding Identification

Sl. No.	Levels Coding	Lowest	Low	Center	High	Highest
		(-)√2	(-)1	0	(+)1	(+)√2
1	A, On T, T_{on}	80	120	300	700	1000
2	B, Off T, T_{off}	5	6	10	16	20
3	C, Gap Voltage, V (volts)	50	55	70	90	100

GENETIC ALGORITHM

Genetic algorithms are a family of computational models inspired by evolution. These algorithms encode a potential solution to a specific problem on a simple chromosome–like data structure and apply recombination operators to these structures so as to preserve critical information. Genetic algorithms are often viewed as function optimizers, although the range of problems to which genetic algorithms have been applied is quite broad. The objective of the optimization is to achieve minimum average surface roughness by adjusting the cutting conditions with the help of numerical optimization technique. Genetic algorithms are search algorithms for optimization, based on the mechanics of natural selection and genetics. The optimization problem in this study will be solved by coupling the RSM surface roughness model with the GA algorithm. In the solutions of the optimization techniques GA will begin with a set of chromosomes (bit strings) which will be randomly generated or selected. The entire set of these chromosomes will comprise a population. The chromosomes will evolve several iterations or generations and will make new generations called offsprings using crossover and mutation techniques. The chromosomes will be evaluated using fitness criteria and the best one will be kept and the others will be discarded. The optimization will be formulated in the standard mathematical format:

Table II. GA parameters

Subject	Values
Population sizes	50
Scaling Function	Rank
Function	Stochastic Uniform
Crossover function	Scattered
Crossover fraction	0.8
Mutation: Function	Gaussian
Scale	1.0
Shrink	1.0
Stopping criteria: generation	300

Find: A (On Time), B (Off Time), C (Gap voltage)

Minimum: R_a (A, B, C)

Subject to constrains: $R_{a\,(model)} \leq R_{a\,(min)}$ (μm)

Within ranges: $(A_{(min)} \geq A \leq A_{(max)})$

$(B_{(min)} \geq B \leq B_{(max)})$

$(C_{(min)} \geq C \leq C_{(max)})$

In this work, MATLAB's Toolbox GA was used to develop the GA program. The GA, written in MATLAB programming language, selected chromosomes based on objective value and level of constraint violation. The genetic parameters are shown in Table II, below:

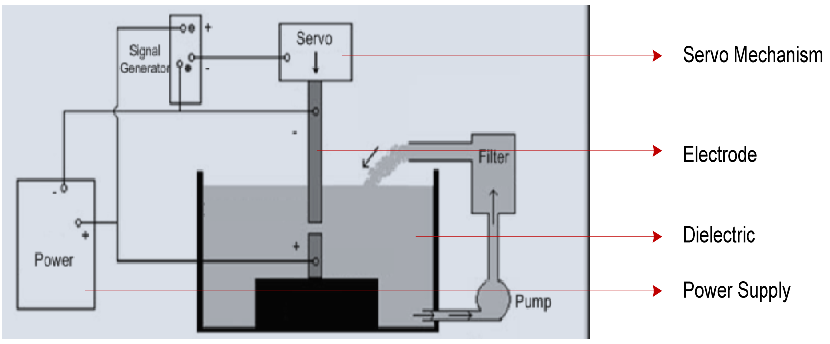

Fig. 1: Schematics of EDM machine

EXPERIMENTAL SETUP

For this experiment a JS EB 600L CNC EDM (Model No: EB600L/60A) was used. Figure 1 is a labeled schematic diagram of an EDM. Mild steel was selected as the work-piece with length 110 mm, width 50 mm and height 5 mm. It was first surface ground and prepared for EDM machining. The process sequence for preparation of the steel specimens is illustrated by figure 2.

(a) (b) (c)

Fig. 2: Work-piece preparation sequence: (a) Initial work-piece, (b) Surface grinding machine, and (c) Polished work-piece

Pure circular copper electrode with diameter 1 inch and length 8 inch was used to drill holes of diameter 1 inch and depth of 1 mm. Figure 4 represents the dimension of the electrode.

Table III. Best cutting condition found in GA

Parameters	Coded Values
Optimized Cutting Conditions	
On T, T_{on}	-0.9424
Off T, T_{off}	-1.4136
Gap Voltage, V (volts)	-0.6285
Response	Results
Roughness (predicted by GA) $Ra_{(model)}$	0.5537 μm
Roughness (Experimental) $Ra_{(exp)}$	0.611 μm

Kerosene with dielectric constant k = 1.8 at 70° F was chosen as it is readily available and commonly used in EDM.

RESULTS

The GA predicted the optimum roughness as 0.5537 µm for the EDM of Mild steel in the selected cutting condition range. The optimum conditions leading to minimum surface roughness are shown in Table III. The GA-predicted optimum conditions were further validated with physical measurements. The performance of fitness value with every generation and the best individual performances are shown in Fig. 3 in coded form. The experimental results of surface roughness with the optimum cutting parameters (as predicted by GA) show good agreement.

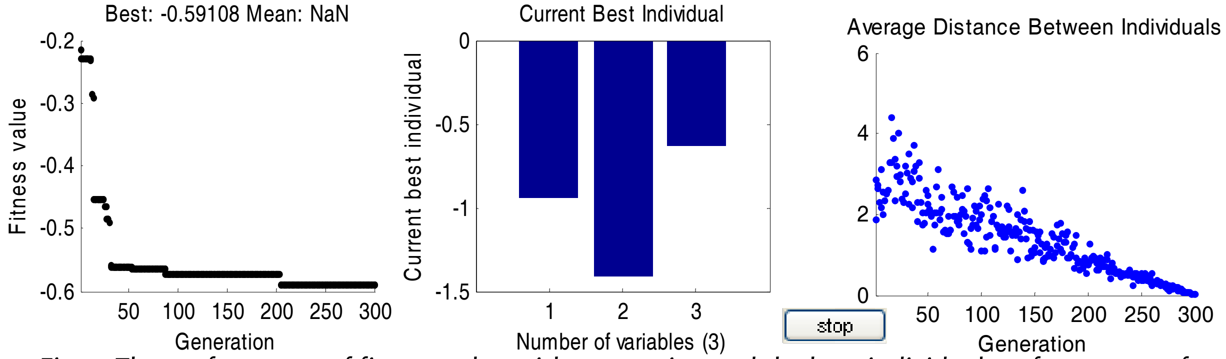

Fig. 3: The performance of fitness value with generation and the best individual performances of variables in coded form

VALIDATION

The suggested machining conditions were used to EDM a specimen. Digital image processing technique, previously developed by Anayet U Patwari et al. [8], was then used to measure the resultant surface roughness and subsequently validate the prediction. Figure 4 illustrates the DIP processes sequence for surface roughness measurement.

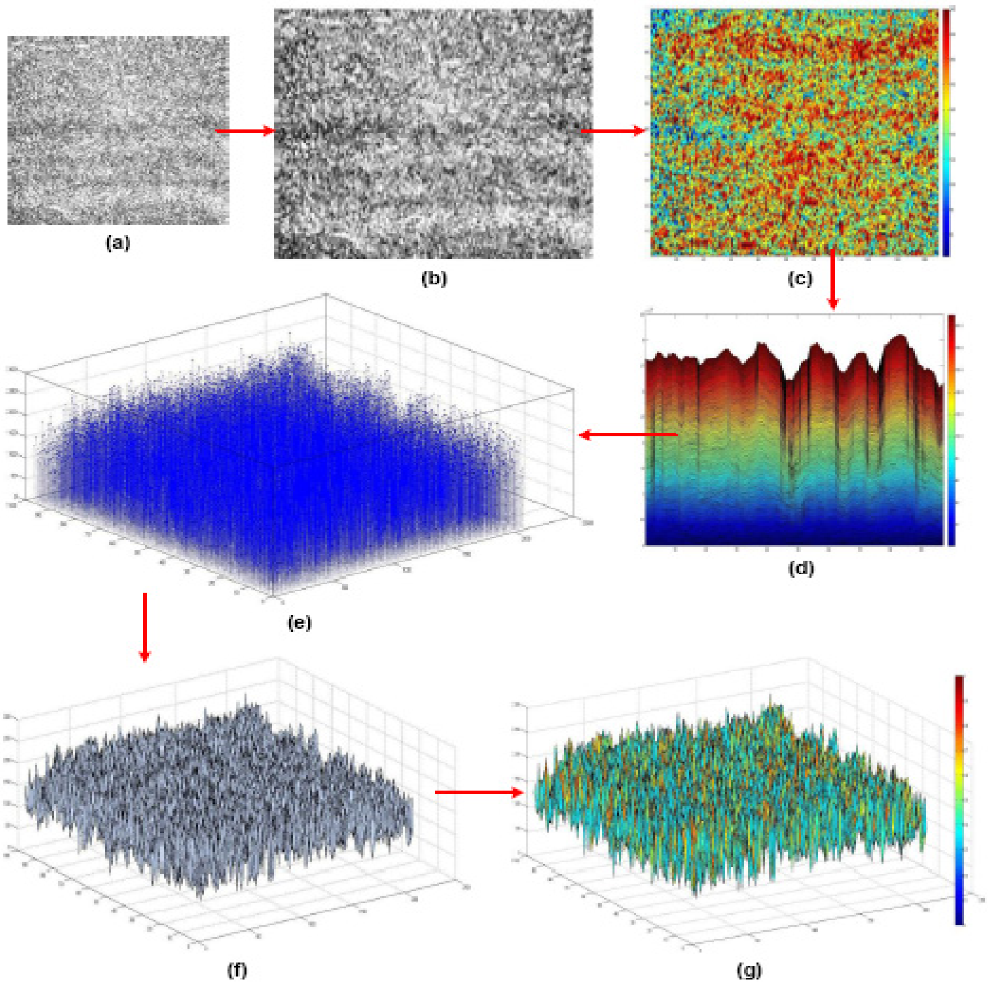

Fig. 4: DIP validation of optimization results (a) microphotograph, (b) resized grayscale, (c) 2-D colored contour plot, (d) 2-D profile plot, (e) 3-D plot of datum points, (f) 3-D contour plot, and (g) 3-D coloured contour plot

The surface profilometer and DIP results were 0.5961 μm and 0.6111 μm, respectively. These correspond to errors of 7.11 % (with respect to profilometer) and 9.39% (with respect to DIP analysis).

CONCLUSIONS

This paper discusses the optimization of surface roughness in EDM of mild steel using coupled RSM-GA approach. The general conclusions can be summarized as follows:

- The two-stage effort, obtaining a surface roughness model by surface response methodology and optimization of this model by Genetic Algorithms, has resulted in a fairly useful method of obtaining process parameters in order to attain the required surface quality in EDM process.
- The CCD model developed by RSM using Design Expert package is able to provide accurately the predicted values of surface roughness close to actual values found in the experiments for EDM machining. The equations are checked for their adequacy with a confidence level of 95%.

REFERENCES

[1.] Todd, R. H., Allen, D. K., Alting, L., Fundamental Principles of Manufacturing Processes, 1st ed., Industrial Press INC., New York, 1994.

[2.] Alauddin, M., El Baradie, M. A., Hashmi, S. J., "Optimization of surface finish in end milling Inconel 718," J. Materials Processing Technology, 56, pp. 54–65 (1996).

[3.] Suresh, P. V. S., Venkateswara, P. R., Deshmukh, S. G., "A genetic algorithmic approach for optimization of surface roughness prediction model," International Journal of Machine Tools & Manufacture, 42, pp. 675–680 (2002).

[4.] Dalai, H., Dewangan, S., Datta, S., Patel, SK., Mahapatra, SS., "A case study on quality and productivity optimization in electric discharge machining (EDM)," Proceedings of 14th International Conference in Advanced Materials and Processing Technologies AMPT 2011, 13-16 July, Turkey (2011).

[5.] Anayet U Patwari, Amin, A. K. M. N., Arif, M. D., "Optimization of surface roughness in end milling of medium carbon steel by coupled statistical approach with genetic algorithm," e-proceedings of The First International Conference on Interdisciplinary Research and Development (INRIT 2011), paper reference: 167/2011(2011).

[6.] Design-Expert Software (Version 6.0.8), User's Guide, Technical Manual, Stat-Ease Inc., Minneapolis, MN, 2000.

[7.] Anayet U Patwari, Chowdhury, N. A., Arif, M. D., Chowdhury, S. I., Hasan, M., "Prediction of surface roughness during electric discharge machining by response surface methodology," proceedings of International Conference on Mechanical and Renewable energy (ICMERE 2011), CUET, 22-24 December 2011.

[8.] Anayet U Patwari, Arif, M. D., Chowdhury, N. A., Chowdhury, S. I., "3-D Contour generation and determination of surface roughness of shaped and horizontally milled plates using digital image processing," International Journal of Engineering, Annals of Faculty of Engineering, Hunedoara, Issue: 3, Issn: 1584-2673 (2011).