© 2017 IJSRST | Volume 3 | Issue 3 | Print ISSN : 2395-6011 | Online ISSN : 2395-602X
Themed Section: Science and Technology

Modeling and Optimization of EDM Process Parameters : A Review

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ABSTRACT

Electric discharge machining (EDM) process is one of the most extensively used non-conventional machining processes. The EDM process removes metal without having any direct contact with the work piece. There are different performance parameters which influence on the response parameters such as Metal removal rate and Surface Roughness. Optimization is a techniques used in the manufacturing field to arrive the best manufacturing conditions, which is an essential need for the industries towards manufacturing of quality products. In machining process, it is very difficult to determine optimal cutting parameters for improving machining performance and modeling techniques is necessary to relate the precise relationship between the input and output parameters. This paper provides a review on the various research activities carried out in modeling and optimization of EDM process parameters by various techniques.

Keywords : Electric Discharge Machining, Modeling, Optimization.

I. INTRODUCTION

Electrical Discharge Machining (EDM) is an important manufacturing process for machining hard metals and alloys. This process is widely used for aerospace and automotive. The process is capable of getting required dimensional accuracy and surface quality by controlling the process parameters.

During the EDM operation, tool does not make direct contact with the work piece eliminating mechanical stresses and vibration problems. EDM has thus, become an indispensable machining option in the manufacturing of difficult to machine complex shapes. The process has however, some limitations such as high specific energy consumption and lower productivity which limit its applications. Researchers are worldwide focusing on process modeling and optimization.

Modeling technique includes mathematical modeling and optimization techniques includes such as artificial neural network and genetic algorithm etc. The modeling technique is used to relate the relationship of input parameters on output parameters. Modeling and optimization techniques used in EDM to improve the productivity.

In this paper, research carried out by many researchers on various modeling and optimization techniques used for EDM process parameters is presented.

II. LITERATURE MODELING AND OPTIMISATION TECHNIQES

It is essential to produce any product with good quality at low cost. To achieve this objective, the influence of various process parameters has been studied to get the best performance processes by many researchers and they are reported briefly in the sub sections.

III. MATHEMATICAL MODELS

The Mathematical models, the most useful and non-destructive modeling techniques are emerged with the growth of the computer memory. The utilization such techniques in EDM is briefly mentioned in the following. To start with, the development of Mathematical models to obtain the better surface finish [1, 2]. based on the parameters. The Mathematical models are widely developed to

Established the relationship between the performance measures of the process variable and its controllable parameters [3]; Calculate the minimum gap distance for the spark generation between the work piece and the electrode [4]; predict the responses based on constraints of optimization techniques [5]; Proposed a model for texturing based on the effect of dielectric fluid and in particular the influence of change in the resistance in the dielectric [6].

Developed a model on variable mass and cylindrical plasma. In which using the three differential equation combined with plasma equations of state. [7]. correlate the interrelationship and find the best working conditions of various parameters during the machining [8];

Developed the anode erosion model. In which the power was the boundary condition at anode interface and assumed to produce a Gaussian-distributed heat flux [9]. Investigated on surface profile machined under varying machining parameters. The information obtained is then modeled in the form of Fourier series [10]. studied and determined the crack zone beyond the crater due to the thermal stresses exceeding the limits [11];

IV. FUZZY LOGIC

The Fuzzy Logic model was developed, compared and analyzed by the multi process response using the optimization parameters [12]. The Gray – Fuzzy logic model was developed by the the multiple process response and analysed that the electrode wear ratio decreases and MRR increases [13]. Studied about the reliable pulse rate in the adoptive control system [14]. Developed a fuzzy mathematical model for predicting the characteristics of surface roughness (Ra value) and hardness (HRB) [15].

V. ARTIFICIAL NEURAL NETWORKS (ANN)

An artificial neural network is an information-processing system that has certain performance characteristics in common with biological neural networks. Artificial neural networks have been developed as generalizations of mathematical models of human cognition or neural biology.

ANN models are being used in modeling of machining parameters either independently or combining with other algorithms. A neuro-fuzzy model for MRR in EDM are observed and the ANTIS model is more accurate compared with other types of models [16].

The ANN models are used to estimate, back propagation and Feed forward with Back propagation technique to predict MRR, [17] With machining depth, tool radius, orbital radius, radial step, offset depth, pulse on-time, pulse off-time and discharge current as the input parameters, back propagation neural network was developed, experiments have been performed to check the validity of the ANN model [18].

An adaptive neuro-fuzzy inference system (ANFIS) model has been developed for the prediction of the white layer thickness (WLT) and the average surface roughness is achieved as a function of the process parameters [19]. The cutting speed and surface roughness of Tungsten carbide cobalt composite are predicted by using soft computing models, [20]. Surface roughness and crater shapes [21, 22]

The computational speed and accuracy are improved on one side and MRR is estimated on other side during the EDM of AISI D2 Steel by Neuro – Fuzzy Model [23]. ANN model. Six neural network models and neuro-fuzzy model for MRR have been established and analyzed. Results show that adaptive-network fuzzy interference system (ANFIS) is more accurate [24]

The BPN is reasonably more accurate than RBFN whereas RBFN is faster in comparison to BPN while modeling the surface roughness [25]. Combined the ANN and genetic algorithm to find an integrated solution to the problem of modeling and optimization of manufacturing processes. The error in the MRR and surface roughness were minimum. The modeling system established better knowledge about interaction between tool (graphite) and work piece (nickel alloy) [26]

The radial basis functions of Neural Networks in MRR [27]. An artificial feed forward neural network based on the Levenberg–Marquardt back propagation technique has been used to predict MRR. The model provides faster, more accurate results and performs well under the stochastic environment of actual machining conditions in electro-discharge machining [28]

Modeling and optimization of tool wear rate (TWR) in powder mixed EDM of metal matrix composite (MMC). Process parameters are peak current, pulse-on-time, pulse-off-time, Powder concentration were considered. Work piece material was made up of steel and electrode was copper material. It was observed that mixing graphite powder in dielectric fluid significantly reduces the tool wear rate. The current has been identified as most significant factor controlling TWR. ANN model is reliable and adequate to predict the TWR [29].The machining parameters, such as TWR and MRR are determined by the Intelligent Process Model with FEM and ANN [30].

Optimize the surface roughness and material removal rate of electro discharge machining of SiC using Artificial neural network (ANN) algorithm . Multi-objective optimization method by non-dominating sorting by genetic algorithm was used . The Effects of three important parameters are, discharge current, pulse on time (Ton), pulse off time (Toff) [31].

Multi-objective optimization on the INCONEL 718 was studied. Various process parameters are pulse-on time, flushing pressure, current, gap voltage, shape factor, tool electrode lift time and duty cycle. Output parameters where material removal rate (MRR), surface finish. Copper was used as the electrode material. The average percentage difference between experimental and artificial neural network (ANN) predicted value is 4 and 4.67 for MRR and SR respectively [32].

The ANN model with back propagation can predict the response parameters such as MRR, Ra and fractal dimensions very accurately while machining HSS of M2 grade working with electrolyte copper tool, [33]. Development and application of a hybrid artificial neural network and genetic algorithm methodology to modeling and optimization of electro-discharge machining [34]. surface roughness of AISI 4340 steel is predicted with factorial design. Then the relationship between the Mathematical regression analysis and ANN model where studied [35]. (ANFIS) to predict the surface finish. The results showed that tangent sigmoid multi-layered perceptron (TANMLP), radial basis function network (RBFN), Adaptive RBFN and ANFIS models have shown consistent results. [36].

VI. RESPONSE SURFACE METHODOLOGY (RSM)

In statistics, Response surface methodology (RSM) investigates the interaction between several illustrative variables and one or more response variables. RSM is used in the experiments to obtain an optimal response. A second-degree polynomial model was used in RSM. Response surface methodology (RSM) is a collection of mathematical and statistical technique useful for the modeling and Analysis of problems in which a response of interest is influenced by a several variables and the objective is to optimize the response and it is used in the development of an adequate functional relationship between responses of interest.

Response Surface Methodology (RSM) is a technique being used in analysing the surface finish obtained in EDM. It is established that the, Peak current influence the maximum MRR and smooth SR in a Powder Mixed Electrical Discharge Machining [37]; Investigated the effect of pulse on time, pulse off time, voltage and discharge current. They found that pulse on time, pulse off time and current have significant effect on the surface roughness [38].

Response surface methodology was used to model and optimize the process parameters.They found that all the responses are affected by the rate and extent of discharge energy but in a controversial manner [39]. Optimize the process parameters during machining of metal matrix composite by using response surface methodology and mathematical model have been developed to investigate the kerf, microstructure and surface roughness. They found that kerf plays a significant role [40].

Response Surface Methodology (RSM) is use to investigate the effect of input parameter. A fractional factorial Design of Experiment of two levels was employed to conduct the experiment. The responses were observed by mathematical modeling using RSM on experimental data. They found that Performance largely depends not only upon the combination of material of work piece and electrode but also the optimal combination of the independent control process parameter [41].

Modeling and analyzed using the response surface methodology to influence the machining parameters on the performance characteristics of the material removal rate, electrode wear and surface roughness. They found that discharge current and duty factor are most significant factor on metal removal rate. The pulse on time and current also have statistical significance on both the value of the electrode wear and surface roughness [42].

Developed a single order mathematical model for correlation the various machining parameters like peak current, pulse on time and pulse off time and performance characteristics surface roughness using Ti-6Al-4V with copper as electrode. Response surface methodology is utilized to develop the mathematical model as well as to optimize. They found that increasing the pulse on time causes fine surface until a certain value and afterwards deteriorates [43].

Optimize the process parameters using response surface methodology and mathematical model have been developed to investigate the surface roughness and the kerf width. They investigated that kerf plays a significant role [44]. Modeled with the response surface methodology. The input variables are pulse on time and wire tool offset. The optimum constant cutting speed was 3mm/min [45].Optimize the process parameters using response surface methodology for optimize the parameters and Box- Behnken method was used to analyze. Quadratic model was used for modeling the response parameters.[46]

Response surface methodology was used to investigate the effect of four controllable input variables on surface roughness. The discharge current, pulse on time and pulse off time have significant effect on the surface roughness [47].

VII. TAGUCHI TECHNIQUE

Taguchi technique is the new engineering design optimization methodology that improves the quality of existing products and processes and simultaneously reduces their costs very rapidly, with minimum engineering resources . The Taguchi Method achieves this by making the product or process performance "insensitive" to variations in factors such as materials, manufacturing equipment, workmanship and operating conditions. Taguchi's philosophy is founded on the following three very simple and fundamental concepts. Quality should be designed into the product and not inspected into it; Quality is best achieved by minimizing the deviations; The product should be so designed that it is immune to uncontrollable environmental variables. The cost of quality should be measured as a function of deviation from the standard and the losses should be measured system-wide.

Investigated on the effect of machining parameters on MRR by using Taguchi method. They found that different combinations of process parameters are required to achieve higher MRR. The current and pulse off time are most significant machining parameter for MRR. Taguchi method seems to be an efficient methodology to find the optimum cutting parameters [48]. Ra and MRR by Parametric Optimization [49]; multi-response optimization by weighted principle component method [50]; precision and accuracy are by Taguchi Dynamic Experiments with Fuzzy Logic Analysis by 81.5 %, [51];

Study carried-out for the minimum number of experiments on machining of Aluminum problem is solved using full factorial design and proved by experimental results to demonstrate that the machining model is suitable, [52]

Warrier Ashish et al. [53] determined the optimal setting of the process parameters of EDM machine while machining carbon–carbon composites. The input parameters are current, voltage and pulse on time. The responses parameters are metal removal rate and tool wear rate. Taguchi method was used to determine the optimal setting parameters of the EDM.

Optimize the parameters by considering the effect of input parameters for material removal and surface roughness by forming quadratic mathematical model and optimization was done through Taguchi method [54]. Taguchi method is used to analyze the effect of machining parameter on the machining characteristics, and to predict the optimal choice for each parameter [55]. the number of experiments and Optimization of machining parameters in relation to work piece by orthogonal array method [56];

Studied WEDM of titanium alloy for surface finish for the various parameters using Taguchi. They develop mathematical model by means of linear regression analysis to establish relationship between input parameters and output parameters. They made an attempt to optimize the surface roughness [57].

Investigate the effect of machining parameters such as pulse off time, voltage, current and pulse on time on MRR in 304 stainless steel. They found that the current and pulse off time are most significant parameter. They also mention that based on minimum number of trails conducted to arrive at the optimum cutting parameters. Taguchi method was used to find the optimum cutting parameters [58].

VIII. ANOVA

Analysis of Variance (ANOVA) is used to estimate the performance of any system based on the input parameters. The influence of parameters was investigated and established that the surface roughness is affected by multifold regression analysis for MRR, [59]. DOE technique is used for investigating with full factorial design with four center points to provide protection against curvature in model building. Though, different significant main and interaction effects between input parameters were identified using ANOVA [60].

The optimal solutions to find the MRR and SR are developed and established that the Gaussian Process Regression (GPR) models have the advantage over the regression models [61]. Investigated based on rotatable central composite design (CCD) to evaluate and analyze the edge disintegration created around holes. Major significant parameters were identified using the ANOVA and then the minimum amount of thermal damage were obtained by developing suitable second order response equation [62].

Analysis of variance (ANOVA) technique is used to analyse, the amount of variation from the desired performance and find out the various important process variables affecting the process response [63]. The variation of output responses with process parameters are mathematically modeled using Non-linear regression analysis method and then checked for correlation with the experimental results, [64]. Analysis of Variance (ANOVA) has been performed to evaluate the fit and adequacy of the developed mathematical models and observed that current has major effect on MRR followed by pulse on time and voltage. As current increases, tool wear rate increases. An increase in current and pulse duration increases the radial over cut [65]

IX. THERMAL MODEL

Studied and employed a heat transfer model to study the effects of input parameters and material properties on MRR [66]. Studied and analyzed a thermal model is capable of simulating discharge super position and representing the EDM processed surfaces. The main conclusions obtained from this study that superposition of multiple discharges must be considered, since the amount of material removed per discharge increases as the operation progresses [67]. Illustrated thermal modeling using data dependent system (DDS) which is a stochastic approach during the time [68]. Developed and analyzed with a thermal model to detect thermal load for on-line monitoring control to prevent wire rupture [69].

X. OTHER METHODS

The other modeling and optimization techniques used for analyzing electric discharge machining process parameters are Central Composite Design (CCD), Multi-response optimization, grey entropy, Linear Regression Technique, Grey-Taguchi Method, simulated annealing, Feasible-Direction Algorithm, SA algorithm, Pareto, Artificial Bee Colony (ABC), Tabu-Search Algorithm, Principle component method and Trust region method.

XI. CONCLUSION

The review is done based on previous research work on electrical discharge machining process on modeling & optimization techniques used. The researchers used latest optimization techniques such as mathematical model, thermal model, Taguchi, ANN, RSM and ANOVA. The optimization techniques give good positive results in optimizing EDM process parameters for maximize the Material Removal Rate (MRR), reduced the Tool Wear Rate (TWR) and improve the Surface Roughness (SR). This helps in identifying optimization parameters for EDM process.

XII. REFERENCES

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