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A Literature Survey on Optimization of EDM Process Parameters for Composite Material

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A B S T R A C T

This study represents the overall survey on Electric Discharge Machining. The investigation of new materials needs a development of optimal machining process regarding material and make an effective machining process. So Electric Discharge Machining is commonly used for those materials which are very difficult to machine with conventional machining process. In today's competitive environment, the industries around the world are trying to increase their profits without increasing the sales price of their products. This can only be done through minimizing the losses that are occurring during production. The minimizing in production time, step up profits an optimization of process. Parameters have a very major role for enhancement of productivity. Therefore, the work for the optimization of parameters can solve the problems.

Keywords:Electrical Discharge Machining, Composite, Process Parameter, Optimization

1. INTRODUCTION

Electro Discharge Machining is a non-conventional or non-traditional machining process which is used for machining hard materials which are difficult to machine by the conventional machining process. EDM can be used in machining difficult cavities and contours. There are various types of products which can be produced using EDM with high precision and good surface quality, such as dies and molds, parts for aerospace and automotive industry and surgical components.

A composite material comprises of two or more chemically and/or physically apparent phases. Composite materials, also termed as composition materials or known as composites, are naturally or engineered appearing materials produced from two or more composing materials with considerably different chemical or physical properties which persist distinct and separate within the finished structure. The constituent elements, mainly comprises of a reinforcing element, fillers, and a composite matrix binder which differ in composition or form on a macro-scale. The constituent elements preserve their own characters means they do not merge or dissolve completely into one another although they act in concert. Normally, the constituents exhibit an interface between one another and can be physically identified.

Composites which are of heterogeneous structures accommodate the necessities of specific function and design, infused with ambitious properties which limit the scope for classification. However, this blunder is made up for, by the reality new varieties of composites are being invented, each with their own specific characteristics and purpose like the particulate, flake, laminar and filled composites. Particles or fibers entrenched in matrix of another material are the most suitable example of modern-day composite materials, which are mostly structural. The present study deals with machining and machinability aspects of Metal Matrix Composites (MMCs) (Hybrid Composites) emphasizing parametric appraisal and multi-objective optimization in relation to machining performance features. The following sections accumulate basic knowledge on MMCs.

2. Literature Review

Chen and Mahdivian [1] showed that sparks are generated by electrical circuits of several types and of different wave form of current and voltage of its own and the material removal is a function of discharge energy. Yadav et al. [2] illustrated that the high temperature gradient generated at the inter electrode gap results in large localized stress which led to removal of material. Lawers et al. [3] identified that there are three types of material removal mechanism i.e. melting or evaporation, spalling and oxidation or decomposition. Singh and Ghosh [4] argued that the stress distribution and electrostatic forces acting on the cathode electrode are main reasons of metal removal for short pulses.

Hocheng et al. [5] analyzed the material removal of Al,SiC MMC by a single spark and investigated heat conduction model of finite step heat source that well explains the material removal in crater formation by single discharge and also recommended large current and short on time for effective machining of Al,SiC MMC. Singh et al. [6] reported that copper electrodes offer comparatively low electrode wear for the aluminium work piece and also copper is comparatively a better electrode material compared to other tool electrode material as it gives better surface finish, high MRR, low diametric overcut and less electrode wear. Kumar et al. [7] emphasized on the potential of EDM process for surface modification. Material removal rate, tool wear, surface roughness, circularity, overcut etc. are most important response parameters of Die sink EDM. Several researchers carried out various investigations for improving the process performance. Proper selection of machining parameters for achieving the best process performance is still a challenging job. To solve this type of multi-optimization problem.

Lin et al. [8] utilized grey relation analysis based on an orthogonal array and fuzzy based Taguchi method and used grey-fuzzy logic for the optimization of EDM process, as the performance parameters are fuzzy in nature, such as Lower-is-Better (LB) (tool wear and surface roughness), and Higher-is-Better (HB) (example MRR) contain certain degree of uncertainty. Grey relational coefficient analyzes the relational degree of the multiple responses (electrode wear ratio, material removal rate and surface roughness). Fuzzy logic is used to perform a fuzzy reasoning of the multiple performance characteristics. Zhang et al. [9] proposed an empirical model, built on both peak current and pulse duration, for the machining of ceramics. It was realized that the discharge current has a greater effect on the MRR; while the pulse-on time has more influence on the SR and white layer. Wang et al. [10] used Genetic Algorithm (GA) with Artificial Neural Network (ANN) in order to find out optimal process parameters for optimal yield of performances. ANN is used to model the process, where weights are updated by GA. In the optimization phase Gen-Hunter Software is used to solve multi-objective optimization problem. Two output parameters, MRR and surface roughness considered here to be optimized as a process performance. Optimization of the EDM parameters, from the rough cutting to the finish cutting stage, has been done by Su et al. [11].

Marafona and Wykes [12] used the Taguchi method to improve the TWR by introducing high carbon content to the electrode prior to the normal sparking process. Kiyak and Akır [13] observed that surface roughness of work piece and electrode were influenced by pulsed current and pulse time, higher values of these parameters increased surface roughness and lower current, lower pulse time and relatively higher pulse pause time produced a better surface finish.

Senthilkumar et al. [14] developed a mathematical model by using RSM for revealing optimal machining environment during electrochemical machining of LM25 Al/10%SiC composites produced through stir casting. The research focused on the effects of electrochemical process parameters such as applied voltage, electrolyte concentration, electrolyte flow rate and tool feed rate on the metal removal rate (MRR), and surface roughness (Ra).

Senthilkumar et al. [15] proposed a regression model based on non-dominated sorting genetic algorithm-II (NSGA-II) for improving the cutting performance of electrochemical machining of Al/15% SiC composites.

Kumar and Sivasubramanian [16] established a mathematical model by using artificial neural network with back propagation for modeling the experimental data of material removal rate in ECM of Al,SiCp MMCs. A comparison made between predicted values and experimental values revealed a close matching with an average prediction error of 6.48%.

Kumar et al. [17] used Taguchi's L27 orthogonal array and conducted experiments to study the effect of various parameters like applied voltage, electrolyte concentration, feed rate and percentage reinforcement on maximizing the material removal rate and developed a mathematical model using the regression method.

Goswami [18] studied the effect of electrolyte concentration, supply voltage, depth of cut, and electrolyte flow rate on the evaluation of material removal rate (MRR), surface finish, and cutting forces during electrochemical grinding of Al2O3/Al interpenetrating phase composite using Taguchi based design. Rao and Padmanabhan [19] employed Taguchi Methods, the Analysis of Variance (ANOVA), and regression analyses to find the optimal process parameter levels and to analyze the effect of these parameters on metal removal rate values in electrochemical machining of LM6 Al/5%SiC composites. Literature highlights that immense effort attempted by pioneer researchers to optimize various process parameters during machining operation of MMC composites. Motivated by this, present work aims to add value to the previous research and proposes application of TOPSIS integrated with Taguchi philosophy and grey embedded fuzzy approach coupled with Taguchi's philosophy for simultaneous optimization of quality and productivity in machining of MMCs. TOPSIS method has been utilized by different pioneer researchers for various sectors of quality improvement programme.

Opricovic and Tzeng [20] showed a comparative analysis of VIKOR and TOPSIS which are based on an aggregating function representing closeness to the ideal, which originated in the compromise programming method. It has been observed that TOPSIS has advantages of consideration of relative importance of distances from the ideal solutions and utilization vector normalization.

Athawale and Chakraborty [21] presented a logical procedure to evaluate the CNC machines in terms of system specification and cost by using TOPSIS method. It has been observed that the use of TOPSIS method is quite capable and computationally easy to select and evaluate proper machine tool from a given set of alternatives.

Lan [22] showed the multi objective optimization of responses surface roughness, tool wear and material removal rate in CNC machining industry using TOPSIS integrated with Taguchi philosophy. It has been found that TOPSIS method is a novel parametric optimization technique as it contributed satisfactory solution for multiple CNC turning objectives with profound incentives. Chakladar and Chakraborty [23] proposed TOPSIS-AHP combined method to select the most appropriate nontraditional manufacturing machining process for a specific work material and shape feature combination, while taking in account different attributes affecting the machining process selection decision. Grey-Fuzzy is another efficient technique to convert the multi-objectives into single objective widely applied in industrial applications. Grey relational analysis uses the quantitative analysis to describe the degree of relationship between an objective sequence (a collection of measurements or experimental results) and a reference sequence (target value) in the grey system. Further, the experimental data are also constrained to impreciseness and uncertainty. Hence, fuzzy inference system is employed to modify multiple responses into a single objective termed as multiperformance characteristic index (MPCI) considering the uncertainty and impreciseness. Horng and Chiang [24] developed a fast and effective algorithm to determine the optimum manufacturing conditions for tuning Hadfield steel with Al2O3/TiC mixed ceramic tool by integrating grey relational analysis with fuzzy logic. It has been shown that the required performance characteristics viz., flank wear and surface roughness have great improvement through this proposed algorithm. Chiang and Chang [25] illustrated an effective approach for the optimization of machining parameters to an injection-molded part with a thin shell feature (example of cell phone shell consist of PC/ABS material) based on the orthogonal array with the grey relational analysis and fuzzy logic analysis. It has been observed that through the grey-fuzzy logic analysis, the optimization of complicated multiple performance characteristics can be effectively converted into the optimization of a single grey-fuzzy reasoning grade. Selection of appropriate machining parameters for any particular material in EDM is very difficult. Many researchers have been adopted different multi-objective techniques for machining of Al, SiCp MMCs in EDM.

Singh et al. [26] proposed multi-response optimization of the process parameters viz., metal removal rate (MRR), tool wear rate (TWR), taper (T), radial overcut (ROC), and surface roughness (SR) on electric discharge machining (EDM) of Al– 10%SiCp as cast metal matrix composites using orthogonal array (OA) with grey relational analysis. Karthikeyan et al. [27] used nonlinear goal programming to optimize EDM characteristics such as material removal rate, tool wear rate and surface roughness in terms of the process parameters such as volume fraction of SiC, current and pulse time while machining of SiCp/LM25 Al composites. Velmurgan et al. [28] investigated the effect of parameters like Current(I), Pulse on time(T), Voltage(V) and Flushing pressure(P) on metal_removal rate (MRR), tool wear rate (TWR) as well as surface roughness (SR) in the electro discharge machining of hybrid Al6061 metal matrix composites reinforced with 10% SiC and 4%graphite particles. The method of least squares technique was used to calculate the regression coefficients and Analysis of Variance (ANOVA) technique was used to check the significance of the models developed.

Purohit and Sahu [29] reported the effect of pulse-on time (Ton), pulse current (Ip), and gap voltage (Vg) on metal removal rate (MRR), tool wear rate (TWR) and radial over cut (ROC) during ECM of Al-alloy- 20 wt. % SiCp composites utilizing a three-level-3 factor full factorial design of experiment. The EDM process parameters are found to be correlated conflicting in nature. A hybrid optimization technique PCA has been applied to convert the correlated responses into few numbers of uncorrelated and independent principal components and further TOSIS method has been utilized to convert the multi-objective problem into a single equivalent objective. Different researchers have been exploited these techniques for solving different decision-making problems in industrial applications. Tong et al. [30] proposed PCA combined with TOPSIS for solving various multi-response problems. It has been found that PCA is used to simplify multiresponse problems and determine the optimization direction by using a variation mode chart and the optimal factor/level combination is also determined based on the overall performance index for multiple responses obtained from TOPSIS. Chakravorty et al. [31] proposed PCA based proportion of quality loss reduction method for adequate optimization of correlated EDM performance characteristics MRR and TWR. Another robust optimization technique Multi-Objective Optimization by Ratio Analysis (MOORA) with Taguchi philosophy has been utilized for optimization of EDM characteristics while machining of Al,15% SiCp MMC. Brauers and Zavadskaset [32] represented the robustness of MOORA method over other multi-objective optimization techniques. It has been found that in terms of robustness MOORA is the most acceptable technique because of its simplicity, very less computational time, mathematical calculation and very good stability compared to other MODMs. Bains et al. [33] deals with an investigation of the hybrid ED machining process executed in a magnetic field for improving process performance. Previous magnetic field-assisted EDM techniques, however, are limited to use with a class of magnetic workpiece. In this particular study, the magnetic field was coupled with conventional EDM plasma zone to test hybrid process on Al-based Metal Matrix Composites. Ahmed et al. [37] [38] present a high speed, non-contact machining process named hybrid electrical discharge and arc machining (HEDAM). In this process, an additional DC power supply is used in conjunction with the normal EDM pulsed power supply to enhance material erosion, thereby reducing the machining time. The detailed design and development of this hybrid process have been discussed in the paper, including the reports of several drilling experiments that have been carried out to fabricate holes in Inconel 718 using the developed process. Different machining parameters like peak current, flushing pressure, and rotational speed of the electrode were evaluated to identify the main factors influencing the effectiveness of HEDAM.

3. PROBLEM IDENTIFICATION

Metal cutting is one of the most widely and important utilized manufacturing processes in engineering industries. The study of metal cutting focuses mainly on the input work materials, properties and features of tools, and machine parameter settings affecting output quality characteristics and process efficiency. A great improvement in process efficiency can be achieved by process parameter optimization that determines and identifies the regions of critical process control factors leading to responses or desired quality characteristics with acceptable variations promising a lower cost of manufacturing. The technology of metal cutting has advanced substantially over time with a common goal of achieving higher machining process efficiency. Selection of optimal machining condition(s) is the essential factor in achieving this goal. In any advanced metal cutting operation, the manufacturer wants to set the process-related controllable variable(s) at their optimal operating conditions with minimum variability in the output(s) and effect of uncontrollable variables on the levels. To design and implement an effective process control for metal cutting operation by parameter optimization, a manufacturer seeks to balance between cost and quality at each stage of operation. The multi objective optimization method is a systematic methodology of design and analysis of experiments for the intention of designing and improving product quality.

4. CONCLUSIONS

The multi objective optimization method has been become a powerful tool for improving productivity during research so that high quality products can be manufactured quickly and at low cost. However, the multi objective optimization method is designed and utilized to optimize a single quality characteristic or response. Furthermore, optimization of multiple objectives or responses is much more difficult than optimization of a single objective. Improving one particular quality characteristic would likely cause deliberate degradation of the other critical quality characteristics. It leads to increment of uncertainty at the time of decision-making process. Therefore, in this research various multi-objective techniques have been used with multi objective optimization method to optimize the processing parameters of various nonconventional machining methods used for machining of hybrid metal matrix

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