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Optimization of Multiple Performance Characteristics in EDM: A Critical Literature Review

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Abstract: ***Electrical discharge machining (EDM) plays a very important role in manufacturing industries for shaping hard metals and alloys. Optimization is one of the techniques used in manufacturing sectors to arrive for the best manufacturing conditions, which is an essential need for industries towards manufacturing of quality products at lower cost. [14] EDM performance is evaluated on the basis of multiple performance characteristics. The objective of this paper work is to study optimization of multiple performance characteristics in EDM. A sufficient amount of research work has been described by the researchers on the evaluation of EDM performance on the basis of multiple performance characteristics for various materials. Design of experiment (DOE) is very useful in the analyzing the optimum condition of parameters, main effect, and the significance of individual parameter to machining characteristics for various materials. In a vision of above, this paper work presents a critical literature review on optimization of multiple performance characteristics in EDM.***

Keywords: EDM Parameters, EDM Characteristics, DOE Method

I. INTRODUCTION

Electrical Discharge Machining (EDM) is one of the most widely applied nontraditional processes in die production. Its most important advantage is that its effectiveness is independent of the mechanical properties of the machined materials. Thus, materials with high hardness, brittleness and strength, that are difficult –to-cut, can be machined. In EDM, the mechanism for removing materials primarily turns electrical energy into thermal energy through a series of successive sparks between the electrode and the work piece in a dielectric fluid. The thermal energy is consumed in generating high temperature plasma, eroding the work piece material. The method has become essential to precision die production, since the work pieces doesn't contact physically the electrodes and so no mechanical stress is exerted on the work piece. Accordingly the accuracy of the shape after machining is fairly high [04].

1.1 Objective

Objective of this paper is-

- To study the most influential machining parameters in EDM for machining hardened material and able to deliver better results in terms of multiple performance characteristics.
- To study the optimization of multiple performance characteristics in EDM.
- To study the evaluation of EDM performance on the basis of multiple performance characteristics for various materials.

II. CRITICAL LITERATURE REVIEW

Yan Cherng Lin, Biing Hwa, Yong Song Chang [2000] were presented an experimental investigation of the machining characteristics of titanium alloy using combination process of EDM with USM. The EDM and USM machining were investigated to improve the machining efficiency and accuracy. During the experiments, parameters such as dielectric type, abrasive size, concentration of abrasive in the dielectric fluid, discharge peak current and pulse duration were changed to explore their effect on the material removal rate, electrode wear rate, relative wear ratio, surface roughness and thickness of the recast layer. From the experimental results, they concluded that this combination EDM/USM process could increase the MRR and decrease the thickness of the recast layer. In addition the discharge wave form analysis showed that the combination EDM/USM process could dramatically reduce abnormal discharge, thus improving the discharge efficiency [01]. Lee and X.P.Li [2001] studied the effect of the machining parameter in EDM of tungsten carbide on the machining characteristics. The EDM process with tungsten carbide better machining performances were obtained generally with the electrode as the cathode and the work piece as anode. Tool with negative polarity gave the higher material removal rate, lower tool wear and better surface finish. High open circuit voltage was necessary for tungsten carbide due to its high melting point and high hardness value and cupper tungsten as the tool electrode material with tool electrode material with negative polarity. This study confirms that there exists an optimum condition for precision machining of tungsten carbide although the condition may vary with the composing of material, the accuracy of the machine and other external factor [02]. B. Mohan and Satyanarayana [2002] evaluated the effect of EDM Current, electrode polarity, pulse duration and rotation of electrode on metal removal rate, TWR, and SR, and the EDM of Al-Sic with 20-25 vol. % SiC, Polarity of the electrode and volume present of SiC, the MRR increased with increased in discharge current and specific current it decreased with increasing in pulse duration.

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Increasing the speed of the rotation electrode resulted in a positive effect with MRR, TWR and better SR than stationary. The electric motor could be used to rotate the electrode (tool) AV belt was used to transmit the power from the motor to the electrode. Optimization parameters for EDM drilling were also developed to summarize the effect of machining characteristic such as MRR, TWR and SR [03]. H. C. Tsai, B. H. Yan, F. Y. Huang [2003] proposed a new method of blending the copper powders contained resin with chromium powders to form tool electrodes. Such electrodes were made at low pressure and temperature in hot mounting machine. The results showed that using such electrodes facilitated the formation of a modified surface layer on the work piece after EDM, with remarkable corrosion resistant properties. The optimal mixing ratio, appropriate pressure, and proper machining parameters such as polarity, peak current and pulse duration were used to investigate the effect of the material removal rate, electrode wear rate, surface roughness and thickness of the recast layer on the usability of these electrodes. According to experimental results, a mixing ratio of copper and chromium and a sinter pressure of 20Mpa obtained an excellent MRR. Moreover, this work also revealed that the composite electrode obtained a higher MRR than copper metal electrodes, the recast layer was thinner and fewer cracks were present on the machine surface. Furthermore, the Cr elements in the composite electrode migrated to the work piece, resulting in good corrosion resistance of the machined surface after EDM [04].

Puertas, I., Luis, C.J. and Alvarez, L. [2004] carried out on the influence of the factors of intensity, pulse on time and duty factor over machining characteristics such as surface roughness, electrode wear and material removal rate. Mathematical model was obtained using the technique of design of experiments to select the optimal machining conditions for finishing stages. This was done by using a small number of experiments [05].

H. K. Kansal, Sehjipal Singh, and P. Kumar [2005] studied that the results of an experimental study conducted with the objective to understand the mechanism of material removal in powder mixed electric discharge machine (PMEDM). A new experimental set up was developed for this composite process. The obtained result allowed them to gain insight into the underlying erosion pattern on the surface of workpiece materials. Relationships were developed between various input process parameters such as concentration of the added nickel powder, peak current, pulse on time and output characteristics like material removal rate and surface roughness [06].

The effects of the machining parameters (MRR, TWR and SR) in EDM on the machining characteristics of high-speed steel were investigated by Y. Lin, C. Cheng, and L. Hwang [2006]. Experimental design was used to reduce the total number of experiments. Parts of the experiment were conducted with the L18 orthogonal array based on the Taguchi method. Moreover, the signal-to-noise ratios associated with the observed values in the experiments were determined by ANOVA and F -test. The relationship of MRR and SR with pulse duration graph in different peak current. During the experiment MRR increases with peak current MRR initially increased to a peak at around 100 μs, and then fell [07].

Dhar and Purohit [2007] evaluated the effect of current (c), pulse-on time (p) and air gap voltage (v) on MRR, TWR, O C of EDM with Al–4Cu–6Si alloy–10 wt. % SiCP composites. This experiment was used the PS LEADER ZNC EDM machine and a cylindrical brass electrode of 30 mm diameter. And three factors, three levels full factorial design was used and analyzed the results. A second order, non-linear mathematical model was developed for establishing the relationship among machining parameters. The significant of the models were checked using technique ANOVA and finding the MRR, TWR and OC increase significant in a non-linear fashion with increase in current [08]. A A. Khan [2008] presented study an analysis was done to evaluate the electrode wear along the cross section of an electrode compared to the same along its length during EDM of aluminum and mild steel using copper and brass electrodes. In overall comparison of copper and brass electrodes, they found that electrode wear increases with an increase in both current and voltage, but wear along the cross section of the electrode was more compared to the same along the length. It was also found that the wear ratio increases with an increase in current. The highest wear ratio was found during machining of steel using a brass electrode. The highest MRR was observed during machining of aluminum using brass electrodes [09].

Yan Cherng Lin, Yuan Feng Chen, Der An Wang, Ho Shiun Lee [2009]reported that effects of magnetic force on EDM machining characteristics were explored. Moreover, taguchi method was used to conduct a series of experiments, and statically evaluated the experimental data by ANOVA. The main machining parameters such as machining polarity, peak current, pulse duration, high voltage auxiliary current, no load voltage and servo reference voltage were chosen to determine the EDM machining characteristics such as material removal rate and surface roughness. The experimental results showed that the magnetic force assisted EDM was higher MRR, a lower relative electrode wear ratio, and a smaller SR compared with standard EDM [10].

Rajesh Choudhary, H. Kumar, and R K Garg [2010] conducted on the machining of EN-31 die steel with different electrodes materials such as copper, brass and graphite with EDM process. This study presented analysis and evaluation of heat affected zones of the workpiece surfaces machined using different tool electrodes by EDM. The effect of various important EDM parameters such as pulse duration, peak current, and discharge gap voltage were investigated to yield the response in terms of material removal rate and surface roughness. Experimental results indicated that copper as a tool electrode showed a good response towards MRR, whereas brass gave superior surface finish as compared to other tool electrodes. From the microstructural analysis study it was observed that heat affected zone was much deeper in the specimen machined by graphite electrode as comparted to other tool electrodes [11].

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N Natarajan, and R M Arunchalam [2011] presented optimization of multiple performance characteristics such as MRR, TWR and over cut in micro EDM using Taguchi method and grey relational analysis. Machining process parameters were selected pulse on time, discharge current, and gap voltage. Based on ANOVA pulse on time was found that the most significant factor, which affects micro EDM process. Optimized process parameters simultaneously leading to a higher MRR, lower TWR, and lower OC were then verified through a confirmation experiment. Validation experiment shown an improved MRR, TWR and OC when Taguchi method and grey relational analysis were used [12]. Pushpendra S. Bharati, S. Maheshwari and C. Sharma [2012] controlled elitist non dominated sorting genetic algorithm was used to optimize the process. Experiments were carried out on die sinking EDM by taking Inconel 718 as work material and copper as tool electrode. Artificial neural network with back propagation algorithm was used to model EDM process. ANN was trained with experimental data set. The effect of various important EDM parameters such as shape factor, pulse on time, discharge current, duty cycle, gap voltage, flushing pressure and tool electrode lift were investigated to yield the response in terms of material removal rate and surface roughness [13]. T Muthuramalingam and B Mohan [2013] reported that Taguchi grey relational approach based multi response optimization was used to maximize MRR, and to minimize surface roughness in EDM. EDM process parameters such as gap voltage, peak current and duty factor were used as input parameters. It was found that peak current was most influent nature in EDM process. Optimal combination of input parameters to acquire better responses was found with multi response optimization using Taguchi-grey relational analysis [14]. Sureshkumar S., Uthayakuma M., Thirumalai Kumaran S. Parameswaran P., and Mohandas E [2014] investigated EDM parameters of Al alloy (Al6351) matrix reinforced with 5wt. % silicon carbide (SiC) and 10 wt. % boron carbide (B4C) particles fabricated through stir casting route. Multi response optimization was carried out through grey relational analysis (GRA) with an objective to minimize the machining characteristics namely electrode wear ratio (EWR) and surface roughness (SR) and power consumption (PC). The optimal combination of input parameters were identified, which showed the significant enhancement in process characteristics. Contributions of each machining parameters to the responses were calculated using analysis of variance (ANOVA). The result showed that the pulse current contributes more (83.94%) to affecting the output responses [15].

Table 1: The Explicit Investigation Achieved In the Different Regions As Discussed By This Review Paper.

Sr. No.	Name of Researchers	Year	Contribution	Work piece material	Electrode Material	Parameters	
						Machining	Performance
01	Yan Cherng Lin, Biing Hwa, Yong Song Chang	2000	Presented an experimental investigation of the machining characteristics of titanium alloy using combination process of EDM with USM. The EDM and USM machining were investigated to improve the machining efficiency and accuracy.	titanium alloy	copper	dielectric type, abrasive size, concentration of abrasive in the dielectric fluid, discharge peak current and pulse duration	material removal rate, electrode wear rate, relative wear ratio, surface roughness and thickness of the recast layer
02	Lee and X.P.Li	2001	Studied the effect of the machining parameter in EDM of tungsten carbide on the machining characteristics. The EDM process with tungsten carbide better machining performances was obtained generally with the electrode as the cathode and the workpiece as anode.	tungsten carbide	copper tungsten	machining parameter	Material removal rate, tool wear and surface finish.

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03	B.Mohan and Satyanarayana	2002	evaluated the of effect of the EDM Current, electrode polarity, pulse duration and rotation of electrode on metal removal rate, TWR, and SR, and the EDM of Al-Sic with 20-25 vol. % **SiC**, Polarity of the electrode and volume present of SiC, the MRR increased with increased in discharge current and specific current it decreased with increasing in pulse duration.	Al-Sic with 20-25 vol. % SiC	-	EDM Current, electrode polarity, pulse duration and rotation of electrode	metal removal rate, TWR, and SR
04	H. C. Tsai, B. H. Yan, F. Y. Huang	2003	Proposed a new method of blending the copper powders contained resin with chromium powders to form tool electrodes. Such electrodes were made at low pressure and temperature in hot mounting machine. The results showed that using such electrodes facilitated the formation of a modified surface layer on the work piece after EDM, with remarkable corrosion resistant properties.	AISI 1045 Medium carbon steels	copper and chromium composite electrode	polarity, peak current and pulse duration	material removal rate, electrode wear rate, surface roughness and thickness of the recast layer
05	Puertas, I., Luis, C.J. and Alvarez, L.	2004	Carried out on the influence of the factors of intensity, pulse on time and duty factor over machining characteristics such as surface roughness, electrode wear and material removal rate.	WC-CO	copper	intensity, pulse on time and duty factor	Surface roughness, Electrode wear and material removal rate.
06	H. K. Kansal, Sehjipal Singh, and P. Kumar	2005	Studied that the results of an experimental study conducted with the objective to understand the mechanism of material removal in powder mixed electric discharge machine (PMEDM).	H-11 die steel	copper	concentration of the added nickel powder, peak current, pulse on time	Material removal rate and surface roughness.
07	Y. Lin, C. Cheng, and L. Hwang	2006	The effects of the machining parameters (MRR, TWR and SR) in EDM on the machining characteristics of high-speed steel were investigated by Yan-Cherng et.al.	high-speed steel	-	Peak current, pulse duration etc	MRR, TWR and SR

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08	Dhar and Purohit	2007	Evaluated the effect of current (c), pulse-on time (p) and air gap voltage (v) on MRR, TWR, OC of EDM with Al–4Cu–6Si alloy–10 wt. % SiCP composites. This experiment was used the PS LEADER ZNC EDM machine and a cylindrical brass electrode of 30 mm diameter.	Al–4Cu–6Si alloy–10 wt. % SiCP composites.	brass electrode	current (c), pulse-on time (p) and air gap voltage (v)	MRR, TWR, OC
09	A A. Khan	2008	Presented study an analysis was done to evaluate the electrode wear along the cross section of an electrode compared to the same along its length during EDM of aluminum and mild steel using copper and brass electrodes.	Aluminum and mild steel	Brass and copper	Current, voltage	electrode wear, material removal rate
10	Yan Cherng Lin, Yuan Feng Chen, Der An Wang, Ho Shiun Lee	2009	Reported that effects of Magnetic force on EDM machining Characteristics were explored. Moreover, Taguchi method was used to conduct a series of experiments, and statically evaluated the experimental data by ANOVA.	SKD 61 steel	copper	machining polarity, peak current, pulse duration, high voltage auxiliary current, no load voltage and servo reference voltage	material removal rate and surface roughness
11	Rajesh Choudhary, H. Kumar, and R K Garg	2010	Conducted on the machining of EN-31 die steel with different electrodes materials such as copper, brass and graphite with EDM process. This study presented analysis and evaluation of heat affected zones of the workpiece surfaces machined using different tool electrodes by EDM.	EN-31 die steel	copper, brass and graphite	as pulse duration, peak current, and discharge gap voltage	material removal rate and surface roughness
12	N Natarajan, and R M Arunchalam	2011	Presented optimization of multiple performance characteristics such as MRR, TWR and over cut in micro EDM using Taguchi method and grey relational analysis. Machining process parameters were selected pulse on time, discharge current, and gap voltage.	304 stainless steel	brass	Pulse on time, discharge current, and gap voltage.	MRR, TWR and over cut

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13	Pushpendra S. Bharati, S. Maheshwari and C. Sharma	2012	Controlled elitist non dominated sorting genetic algorithm was used to optimize the process. Experiments were carried out on die sinking EDM by taking Inconel 718 as work material and copper as tool electrode.	Inconel 718	copper	shape factor, pulse on time, discharge current, duty cycle, gap voltage, flushing pressure and tool electrode lift	Material removal rate and surface roughness.
14	Raghuraman S. Thiruppathi K. Paneerselvam T., Santosh S.	2013	investigated the optimal set of process parameters such as current, pulse on time and off time, in EDM process to identify the variations in three performance characteristics such as material removal rate, tool wear rate and surface roughness, value on the work material for machining mild steel IS 2026 used copper electrode.	mild steel IS 2026	copper	current, pulse on time and off time	material removal rate, tool wear rate and surface roughness
15	Sureshkumar S., Uthayakuma M., Thirumalai Kumaran S.,.Parameswaran P., and Mohandas E.	2014	Investigated EDM parameters of Al alloy (Al6351) matrix reinforced with 5wt. % silicon carbide (SiC) and 10 wt. % boron carbide (B4C) particles fabricated through stir casting route.	Al (6351)-5% SiC-10 % B4C Hybrid Composite	copper	Discharge current , Pulse on time, Duty cycle, Gap voltage	EWR, SR and PC

III. CONCLUSIONS

Basically this paper work is achieved the objective with the acceptable outcome by the various researchers. On the basis of this critical literature review it was observed that, EDM performance is evaluated on the multiple performance characteristics for various materials. The machining parameters in EDM play a key role to deliver better results in terms of multiple performance characteristics and machining hardened materials. Design of experiment (DOE) is very useful in the analyzing the optimum condition of parameters, main effect, and the significance of individual parameter to multiple performance characteristics for various materials.

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