Optimization Of Process Parameters in Electro Discharge Machining in Obtaining Maximum MRR And Minimum EWR Using Taguchi Method

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ABSTRACT

In today's manufacturing environment many large industries use nontraditional machining process such as EDM to adapt the ever-changing competitive market requirement. Due to high capital and manufacturing cost, there is an economic need to operate these machines as efficiently as possible in order to obtain the required pay back. The success of the any manufacturing process depends greatly upon the appropriate selection of control parameter. In the present study, multi response optimization of EDM parameter has been attempted to achieved the feasibility in small size hole manufacturing. The experiment will be performed on Monel k-500 using rotary brass hollow tubular electrode of 1mm diameter with through hole center flushing technique. In this experimental work, the control parameters namely, pulse current, gap voltage, pulse duration, pulse off time and dielectric pressure have been considered to determine their optimum level based on the Taguchi methodology. ANOVA was carried out to examine the effect of each control parameter on output response. The confirmation experiment has been conducted to validate the experimental result which demonstrates that the response parameter of the EDM-drill process can be improved effectively through this approach.

Keywords: *EDM, MRR, EWR, ANOVA and Optimization*

INTRODUCTION

Electrical discharge machining (EDM), sometimes also referred to as spark machining, spark eroding, burning, die sinking, wire burning or wire erosion, is a manufacturing process whereby a desired shape is obtained using electrical discharges (sparks). Material is removed from the workpiece by a series of rapidly recurring current discharges between two electrodes, separated by a dielectric liquid and subject to an electric voltage. One of the electrodes is called the tool-electrode, or simply the "tool" or "electrode", while the other is called the workpiece-electrode, or "workpiece". The process depends upon the tool and workpiece not making actual contact. EDM is now become the most important accepted technologies widely used in automotive, aerospace, tool and die making industries since precise, complex, and irregular 3-D shapes can be machined using a simple shaped tool electrode. Very fine holes, delicate sections and weak materials can be machined without any distortion because there is no direct contact between the tool electrode and the workpiece.

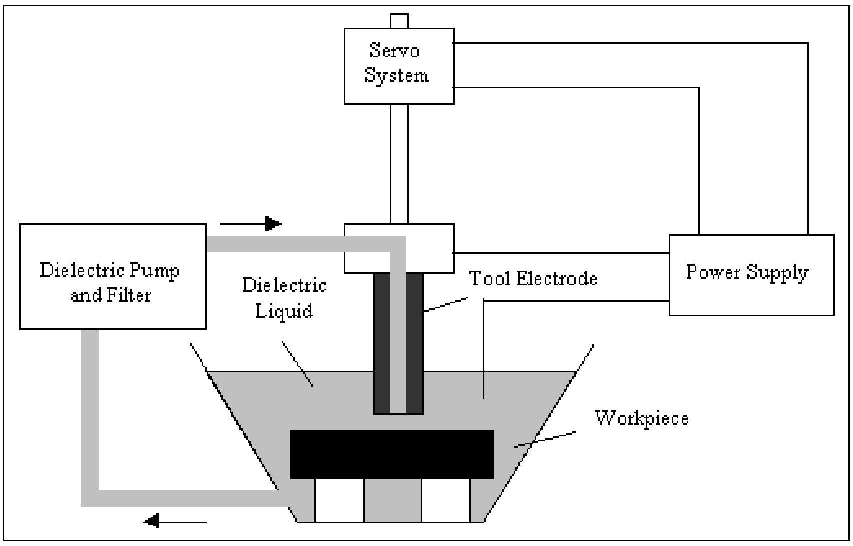

Fig. 1 Setup of EDM Process

Material removal mainly occurs due to instant vaporization of the material as well as due to melting. The plasma channel is no longer sustained. As the plasma channel collapse, it generates pressure or shock waves, which evacuates the molten material forming a crater of removing material around the site of the spark.

In this chapter, different types of EDM and their characteristics, working principle, advantages and limitation have been introduced. Then ideal properties of electrodes and dielectric fluid have been discussed. Finally, they form the background knowledge of the EDM and associated application areas.

Literature Review

Torres, A. et. al The increasing use of INCONEL alloys and the importance which the EDM industry has nowadays have motivated numerous studies focused on determining the influence of machining parameters such as current intensity, pulse time, duty cycle, and polarity, among others, on some response variables Tight control of the settings of these parameters is very important to ensure the success of the process. Influence of EDM of an INCONEL alloy 600 has been carried out with copper electrodes. Design factors such as current intensity, pulse time, and duty cycle were selected in order to analyze the most important technological parameters, which are MRR, EW, and SR. Moreover, the effect of electrode polarity has also been studied and compared [1].

Yilmaz, O et. al Electrical discharge hole drilling is a variation of electrical discharge machining (EDM) process, which has been widely used for making starting holes for wire-EDM applications, opening ventilating holes on dies and diesel ejectors and turbine blade cooling holes, etc. EDM hole drilling is a different variation of die sinking and wire EDM processes. An extensive research work aimed to develop an automated, intelligent, and interactive system in order to facilitate the EDM hole drilling applications which are to be performed on aerospace alloys, namely IN718 and Ti64. Comprehensive experimental tests were designed and conducted for this purpose, satisfying with necessary precisions in hole making and accurate measurements [2].

Ali Okka et. al Investigation of electrical discharge machining fast hole drilling of aerospace alloys, namely Inconel 718 and Ti– 6Al–4V. A series of experiments was carried out using electrical discharge machining process in order to explore the influence of electrode type and material, i.e., single and multi-channel tubular electrodes made of brass and copper materials. The comparisons were made from the results of material removal rate, electrode wear, micro hardness, and scanning electron microscope images taken from the machined/drilled hole surfaces. Single-channel electrode type seems to be more effective to obtain higher MRR than multi-channel electrodes for both alloys. Brass electrode material is more efficient in terms of obtaining better MRR results while EDM fast hole drilling [3].

Kuppan, P. et. al The parameters such as peak current, pulse on-time, duty factor and electrode speed were chosen to study the machining characteristics. An electrolytic copper tube of 3 mm diameter was selected as a tool electrode. The experiments were planned using central composite design (CCD) procedure. The output responses measured were material removal rate (MRR) and depth averaged surface roughness (DASR). Mathematical models were derived for the above responses using response surface methodology (RSM). The results revealed that MRR is more influenced by peak current, duty factor and electrode rotation, whereas DASR is strongly influenced by peak current and pulse on time. Finally, the parameters were optimized for maximum MRR with the desired surface roughness value using Desirability function approach. The results obtained would be a good technical database for the aerospace/automotive manufacturers [4].

Basak, I. et. al The use of the electrochemical discharge phenomenon to machine materials is a very recent technique in the field of non-conventional machining. When the machined material is electrically conducting, the process is usually termed 'electrochemical arc machining' (ECAM), whereas for non-conducting work materials it is termed 'electrochemical discharge machining' (ECDM). Although in both cases electrical discharge takes place through the electrolyte and plays a critical role, the mechanism of spark generation has not been investigated adequately. [5].

Bharti, P.S. et. al Parametric optimization of electric discharge machining (EDM) process is a multi-objective optimization task. In general, no single combination of input parameters can provide the best cutting speed and the best surface finish simultaneously [6].

Talla, G. et. al Electro discharge machining (EDM), one of the most popular non-conventional machining processes, is an electro-thermal process in which work piece is usually submerged in a liquid dielectric medium and shaped through the action of a succession of high frequency discrete electrical discharges (sparks) produced by a DC pulse generator. Low material removal rate (MRR) and high surface roughness values hinder large-scale application of electro discharge machining (EDM) in the fields like automobile, aerospace and medical industry. In recent years, however, EDM has gained more significance in these industries as the usage of difficult-to machine materials including metal matrix composites (MMCs) increased. Machining the MMC by suspending conductive powder particle in the dielectric has shown improvement in productivity as well as surface quality [7].

Kolli, M. et. al Taguchi method was employed to optimize the surfactant and graphite powder concentration in dielectric fluid for the machining of Ti-6Al-4V using Electrical Discharge Machining (EDM). The influence of surfactant and graphite powder mixed EDM of Ti-6Al-4V and also optimizing the process parameters such as discharge current, surfactant and powder concentrations [8].

Wong, Y.S. et. al In recent years, machining of difficult-to-cut materials is an important issue in the field of manufacturing. Since these difficult to-cut materials possess excellent mechanical properties, which can be useful in many important applications, machining of them can open opportunities of utilizing them comprehensively. Micro electro-discharge machining (micro-EDM) has become a widely accepted non-traditional material removal process for machining difficult-to-cut but conductive materials effectively and economically. Among the difficult-to cut materials, cemented carbide (WC-Co) and austenitic stainless steel (SUS 304) are two important materials used extensively in manufacturing because of their superior wear and corrosion resistance. Therefore, machining of WC-Co and SUS 304 has become one of the major concerns of the manufacturer for the last few decades. The machinability was evaluated by means of MRR, EWR, machining stability, surface quality, and accuracy of the machined micro holes [9].

K, S., P, C., and Rao et. al The electrochemical discharge machining (ECDM) process has the potential to machine electrically non-conductive high-strength, high-temperature resistant (HSHTR) ceramics, such as aluminum oxide (Al_2O_3). To overcome this problem and to increase the volume of material removed during drilling operations on Al_2O_3, two different types of tool configurations, i.e., a spring-fed cylindrical hollow brass tool as a stationary electrode and a spring-fed cylindrical abrasive tool as a rotary electrode, were considered [10].

METHODOLOGY

Experimental Workpiece

Modern manufacturing encourages the utilization of substitute cutting-edge substances (such as composites, super alloys, and ceramics) to develop and produce goods.

Table 1 Chemical composition of material Work piece

Element	Fe	C	Si	Mn	Cr
Concentration (weight %)	96.73	0.45	0.30	0.75-1.0	1.1

EDM-Drill machine

The investigation was carried out utilizing a specialized EDM Drill machine known as EDD 44, manufactured by Sparkonix (India) Pvt. Ltd. The control and regulation of the feed rate for the brass electrode, which is consumable, were accomplished through the implementation of an automatic servomotor control system integrated into the EDM drill machine. The Machine table consists of two axes for translation, and their range of motion is 200x150 mm. The size of the electrode can be adjusted between 0.3 and 3 mm, with increments of 0.1 mm, depending on the hole's dimensions. This machine has the capability to function as a Micro-EDM, with a maximum machining current of 25A. The drilling of Monel k-500 was carried out using a rotary hollow tubular electrode made of brass, which had a diameter of 1 mm. Shown in fig 2.

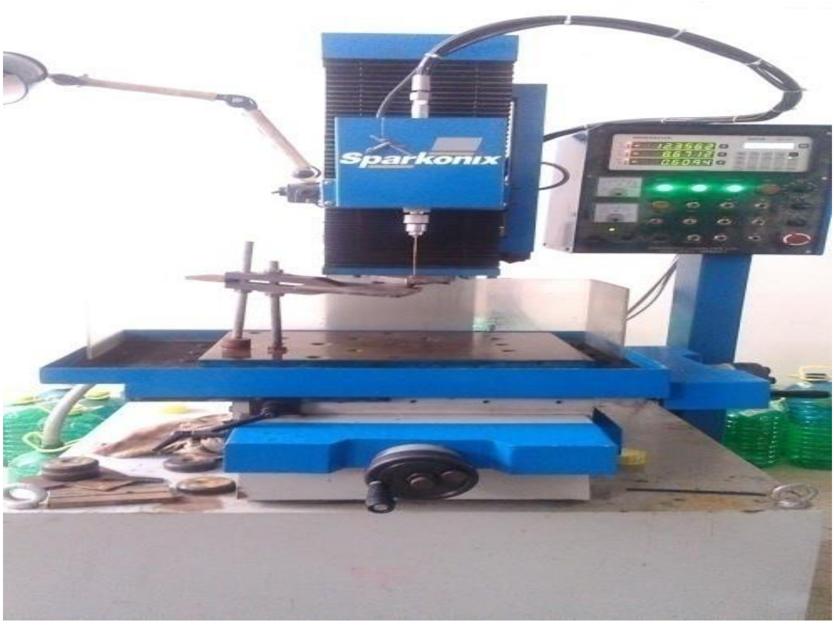

Fig. 2 EDM-Drill machine

Design of Experiment

The selection of a suitable OA depends on the number of control parameters and their respective levels. The control parameters and their levels utilized in the EDM-Drill process can be found in Table 2

Table 2 Control Parameters and their Levels

Control Parameters	Level 1	Level 2	Level 3
Gap Voltage (V)	50	60	-
Pulse Current (A)	8	10	12
Pulse Duration (µs)	6	8	10
Pulse Off Time (µs)	2	4	6
Dielectric Pressure (kg/cm^2)	80	90	100

RESULTS AND DISCUSSION

Experimental results corresponding to individual and multi response optimization for Monel K-500 in this chapter. The plots between the control parameters and response parameters have been obtained using Minitab 16 software. As shown in figure 2 and table 1.

Variation of MRR with Control Parameters

Table 3 SNR Table of MRR

Control Parameter	Level-1	Level-2	Level-3
V	-24.37	-21.63*	-
I	-25.55	-22.37	-21.09*
T_{ON}	-23.96	-21.93*	-23.11
T_{OFF}	-21.05*	-22.19	-22.17
P_D	-20.04*	-22.17	-26.79

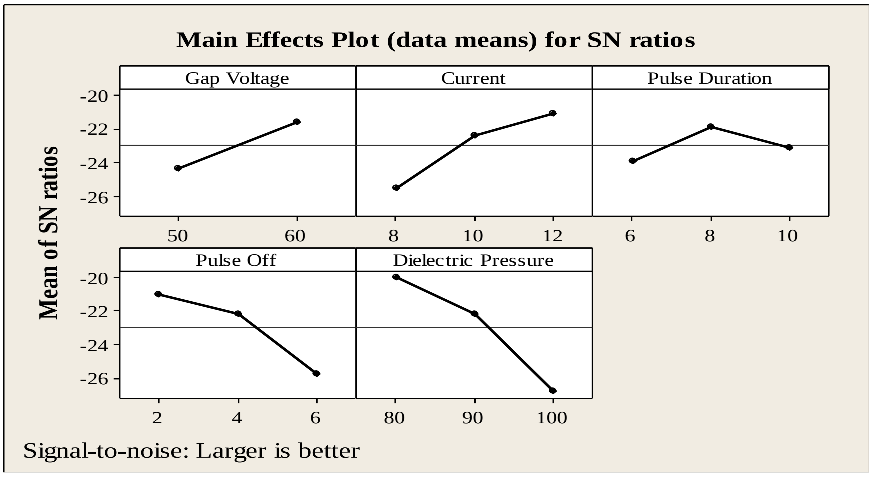

Fig. 3 SNR plot for MRR

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Table 4 ANOVA Result of MRR

To determine the SNR associated with the metal removal rate (MRR), the outcomes of specific experiments were averaged. For instance, experiments 1 to 9 were utilized to compute the SNR corresponding to the initial level of gap voltage, while experiments 10 to 18 were employed for the second level the findings are presented in Table 3. The graphical representation of the average effects plot exhibits the SN ratios, indicating that a higher value is preferable for achieving a greater MRR, as showcased in Figure 3. It demonstrates that when transitioning from 50V to 60V for both the first and second levels, the SN ratio enhances by 11.24%. Similarly, when the current is raised from 8A to 10A and from 10A to 12A for levels 1, 2, and 3, an increase of 12.44% and 5.72% is observed, respectively

Variation of EWR with Control Parameters

Table 5 SNR Table of EWR

Control Parameter	**Level-1**	**Level-2**	**Level-3**
V	29.08*	24.77	-
I	27.88*	27.80	25.10
T_{ON}	26.89	26.66	27.23*
T_{OFF}	26.20	25.07	29.52*
P_D	24.39	24.93	31.46*

For the EWR, the Signal-to-Noise Ratio (SNR) for gap voltage level-1 and level-2 was determined by averaging the results of experiments 1-9 and 10-18, respectively. Likewise, the SNR for the remaining control parameters was computed and presented in Table 5.

Control Parameters	**Degree of Freedom**	**Sum of Square**	**Variance**	**Percentage of Contribution**
V	1	0.002655	0.002655	0.05
I	2	0.004401	0.002201	93.50
T_{ON}	2	0.003155	0.001577	3.004
T_{OFF}	2	0.002225	0.001112	1.054
P_D	2	0.007243	0.003622	2.38
Total	9			100

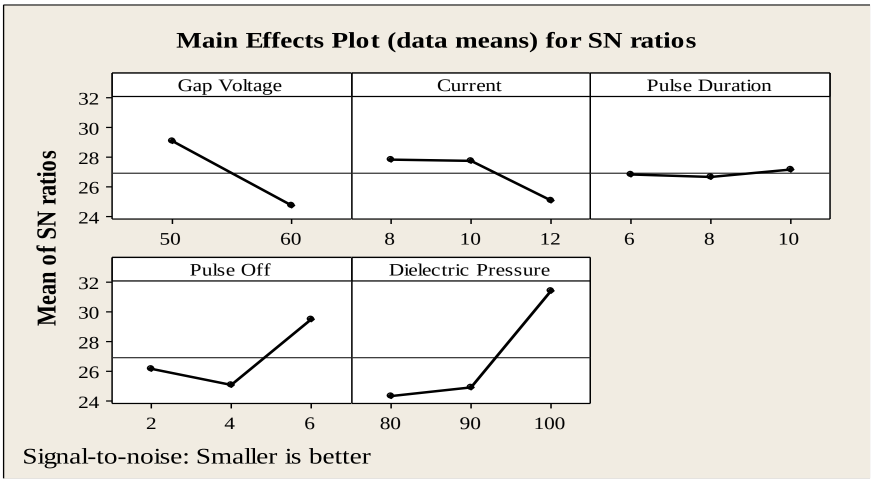

Fig. 4 SNR plot for EWR

The significance of Signal-to-Noise Ratio (SNR) for Electric Wire Rope (EWR) can be observed in Figure 4. A lower SNR value indicates a better performance. As the voltage gap increases from 50V to 60V, transitioning from level-1 to level-2, the SNR decreases by 14.82%. Similarly shown on fig 4

Table 6 ANOVA Result of EWR

Control Parameters	Degree of Freedom	Sum of Square	Variance	Percentage of Contribution
V	1	0.0026185	0.0026185	1.31
I	2	0.0004343	0.0002171	92.87
T_{ON}	2	0.0000367	0.0000183	3.20
T_{OFF}	2	0.0008063	0.0004032	0.768
P_D	2	0.0039427	0.0019714	1.84
Total	9			100

CONCLUSION

An application of the Taguchi method to optimize the response parameters i.e. MRR, EWR in EDM-Drill process of Monel K-500 using rotary brass hollow tubular electrode has been in this thesis work. The experimental results confirm that this approach is simple, effective and efficient for simultaneous optimization of multi-response characteristics. From the result of confirmation, it was concluded that for Monel K-500 with different cases.
MRR, EWR, are reduced by some amount respectively. Pulse current is the most significant parameter affecting the multi response, while dielectric pressure has little effect on multi-response. It was evident from the above study that optimization of complicated multiple performance characteristics can be simplified through this approach based on the basic underlying philosophy of Taguchi methodology.

FUTURE SCOPE

The present work in this thesis is not the end. In future, this thesis work can be modified by using robust work materials, different dielectric fluid, and different geometry of electrode material (triangular, rectangular, or multi-hole electrode) and hybrid optimization technique so as to build a Computer Aided Process Planning (CAPP) for expert system of EDM-Drill with the goal of automation.

The computational method can be used to fully understand the dynamics of the dielectric fluid in the inter-electrode gap and its effect on response characteristics. There is only limited work on optimization of EDM parameters using Multi-objective Evolutionary Algorithm. This algorithm can be used further to re-examine the problem for better economical solution.

Apart from the experimental work, there is a wide scope in designing and mathematical modeling of EDM parameters by using Finite Element Analysis (FEA), Regression analysis, Artificial Neural Network (ANN), Fuzzy modeling, Genetic algorithm, Response Surface Methodology (RSM) and Principal Component Analysis (PCA).

REFERENCES

[1]Torres, A., Luis, C. J. and Puertas, I. (2015), “Analysis of the influence of EDM parameters on surface finish, material removal rate, and electrode wear of an INCONEL 600 alloy”, *International journal of advanced manufacturing technology*, 80, 123-140.

[2]Yilmaz, O., Tolga Bozdana, A., and Ali Okka, M. (2014), “An intelligent and automated system for electrical discharge drilling of aerospace alloys: Inconel 718 and Ti-6Al-4V”, *International journal of advanced manufacturing technology*, 74, 1323-1336.

[3]Yilmaz, O., and Ali Okka, M. (2010), “Effect of single and multi-channel electrodes application on EDM fast hole drilling performance”, *International journal of advanced manufacturing technology*, 51, 185-194.

[4]Kuppan, P., Rajadurai, A., and Narayanan, S. (2008), “Influence of EDM process parameters in deep hole drilling of Inconel 718”, ”, *International journal of advanced manufacturing technology*, 38, 74-84.

[5]Basak, I., and Ghosh, A. (1996), “Mechanism of spark generation during electrochemical discharge machining: a theoretical model and experimental verification”, *Journal of Materials Processing Technology*, 62, 46-53.

[6]Bharti, P.S., Maheshwari, S., and Sharma, C. (2012),” Multi-objective optimization of electric-discharge machining process using controlled elitist NSGA-II”, *Journal of Mechanical Science and Technology*, 26(6), 1875-1883.

[7]Talla, G., Sahoo, D.K., Gangopadhyay, S., and Biswas, C.K. (2015),” Modeling and multi-objective optimization of powder mixed electric discharge machining process of aluminum/alumina metal matrix composite”, *Engineering Science and Technology, an International Journal*, 18, 369-373.

[8]Kolli, M., and Kumar, A. (2015), “Effect of dielectric fluid with surfactant and graphite powder on Electrical Discharge Machining of titanium alloy using Taguchi method”, *Engineering Science and Technology, an International Journal*, 18, 524-535.

[9]Jahan, M.P., Wong, Y.S., and Rahman, M. (2010),” A comparative experimental investigation of deep-hole micro-EDM drilling capability for cemented carbide (WC-Co) against austenitic stainless steel (SUS 304)”, *International journal of advanced manufacturing technology*, 46, 1145-1160.

[10]K, S., P, C., and Rao, V. (2008), “The drilling of Al2O3 using a pulsed DC supply with a rotary abrasive electrode by the electrochemical discharge process”, *International journal of advanced manufacturing technology*, 39, 633-641.

[11]Zhang, Y., Liu, Y., Shen, Y., Ji, R., Li, Z., and Zheng, C. (2014), “Investigation on the influence of the dielectrics on the material removal characteristics of EDM”, *Journal of Materials Processing Technology*, 214, 1052-1061.

[12]Muthuramalingam, T., and Mohan, B. (2014),” Performance analysis of iso current pulse generator on machining characteristics in EDM process”, *Archives of civil and mechanical engineering*, 14, 383-390.

[13]Qingfeng, Y., Baorui, W., Yongbin, Z., Fang, J., and Guangmin, L. (2014),” Research of lower tool electrode wear in simultaneous EDM and ECM”, *Journal of Materials Processing Technology*, 214, 1759-1768.
[14]Urso, G.D., and Merla, C. (2014),” Workpiece and electrode influence on micro-EDM drilling performance”, *Precision Engineering*, 38, 903-914.
[15]Koshy, P., Boroumand, M., and Ziada, Y. (2010), “Breakout detection in fast hole electrical discharge machining”, *International Journal of Machine Tools & Manufacture*, 50, 922-925.