Effect of EDM Parameters in Obtaining Maximum MRR and Minimum EWR by Using Taguchi Method

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1.0 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 achieve 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, ANOVA, EWR, Taguchi Method and MRR.

2.0 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.

2.1 Background of EDM

Though the first wire-cut EDM machines came online in the 1960s, the history of electrical discharge machining actually dates back to the 18th century. In 1770, an English scientist, theologian, chemist, philosopher and political theorist named Joseph Priestley made many discoveries; he is perhaps best known for discovering oxygen. However, he also discovered that electrical discharge could erode metal.

When it was originally observed by Joseph Priestly in 1770, EDM Machining was very imprecise and riddled with failures. Commercially developed in the mid-1970s, wire EDM began to be a viable technique that helped shape the metalworking industry we see today.

In the mid-1980s, the EDM techniques were transferred to a machine tool. This migration made EDM more widely available and appealing over traditional machining processes.

The EDM industry suffers from a non-standardization of terminology, which often creates confusion. Electrical Discharge Machining is a generic term for a method of machining that encompasses wire EDM, spark EDM and EDM hole drilling.

EDM as a process was introduced over fifty years ago; improvements in technology have led to increases in both cutting speeds and component precision. Developing from initially tool making industry sectors of press tool and mould tools, the EDM process is now mainly found within production engineering, aerospace, motorsport, medical and scientific industries. Many manufacturing applications for EDM already exist, they are merely waiting to be discovered and implemented. As this happens, the increased use of EDM in manufacturing will continue to grow and diversify though both a combination of awareness and process knowledge.

In manufacturing there will always be a need to find a better way to make something, EDM will help and support the drive to quality cost and delivery. Knowledge of EDM will provide the ability to design parts that are not possible or cost effective to produce by any other method. The prospect of machining complex shapes in hardened or exotic materials will continue to attract engineers and designers to produce more challenging parts and profiles.

2.2 Principle of EDM

Electrical Discharge Machining (EDM) is a controlled metal-removal process that is used to remove metal by means of electric spark erosion. In this process an electric spark is used as the cutting tool to cut (erode) the workpiece to produce the finished part to the desired shape. The metal-removal process is performed by applying a pulsating (ON/OFF) electrical charge of high-frequency current through the electrode to the workpiece. This removes (erodes) very tiny pieces of metal from the workpiece at a controlled rate. EDM spark erosion is the same as having an electrical short that burns a small hole in a piece of metal it contacts. With the EDM process both the workpiece material and the electrode material must be conductors of elctricity. The EDM process can be used in two different ways:

(1) A reshaped or formed electrode (tool), usually made from graphite or copper, is shaped to the form of the cavity it is to reproduce. The formed electrode is fed vertically down and the reverse shape of the electrode is eroded (burned) into the solid workpiece.

(2) A continuous-travelling vertical-wire electrode, the diameter of a small needle or less, is controlled by the computer to follow a programmed path to erode or cut a narrow slot through the workpiece to produce the required shape.

EDM is carried out in a liquid medium, the machine's automatic feed adjustment device to the workpiece and the tool electrode discharge gap between the right, when the tool is applied between the electrode and the workpiece strong pulse voltage (up to the gap in the media breakdown voltage) when the lowest breakdown strength of dielectric insulation, as shown. The discharge area is small, the discharge time is very short, so a high concentration of energy, so that the instantaneous temperature of the discharge area of up to 10000-12000 ℃, and tools for surface partial melting of the metal electrode surface, or even vaporized. Partial melting and vaporization of metal under the action of the explosive thrown into the working fluid, small particles of metal were cooling, and then quickly washed away by the working fluid work area, so that the surface to form a small pit. One discharge, the medium dielectric strength recovery waiting for the next discharge. This is repeated continuously so that the surface ablation, and copy the tool electrode on the work piece shape.

At such high pressure and temperature, some metal is melted and eroded. Such localized extreme rise in temperature leads to material removal.

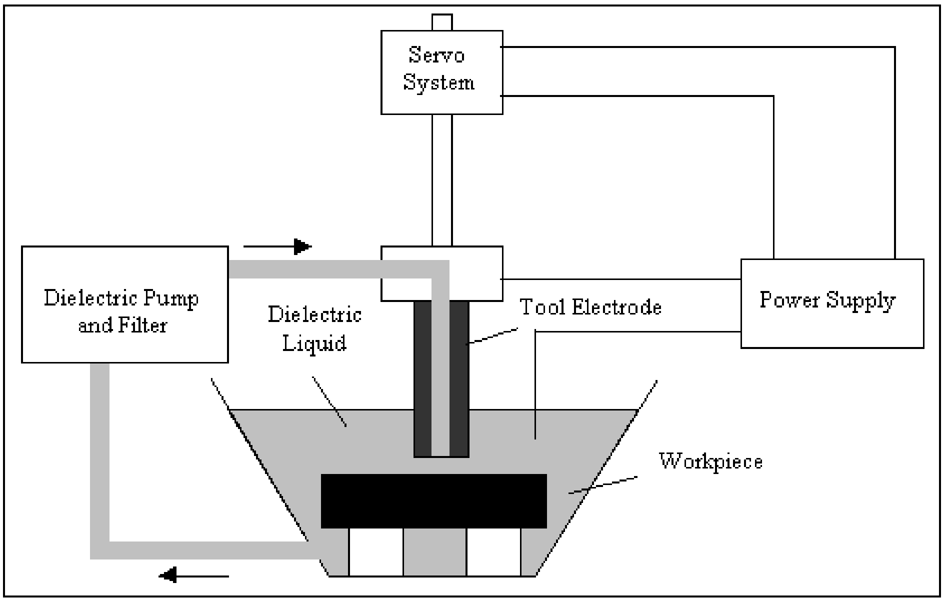

Fig.1 Setup of EDM Process

Material removal mainly occurs due to instant vaporization of the material as well as due to melting. The molten metal is not removed completely but only partially. As the potential difference is withdrawn as shown in fig.1.2, 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. The waveform used in the EDM process.

3.0 Literature Review: This chapter introduces the review of research work which is closely related to this thesis work. An overview of various techniques used for the optimization of manufacturing processes has been presented. Then an overview of EDM process optimization based on different dielectric fluid, different geometry of the electrode and workpiece material with their conclusion has been discussed. Finally, the problem has been formulated with the critical finding of literature survey.

Nickel-based alloys are attractive materials for industrial applications owing to their good mechanical properties and excellent resistance to corrosion and oxidation, even under extreme conditions. Some characteristics such as low Thermal conductivity, work hardening, and high melting temperature make it difficult to machine the alloy with traditional techniques, because of the high temperatures generated which shorten the life of the cutting tools. 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].**

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].**

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].**

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].**

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. The phenomenon of small electric discharges at the anode tip was first observed by Taylor during the electrolysis of molten NaCI at high current density he termed the phenomenon 'anode effect. Showed that similar phenomenon can occur at the cathode and during the electrolysis of an aqueous electrode, Electric discharge at the electrode has been observed to occur daring electrochemical machining and under some conditions, becomes the limiting factor for the process.

The process of ECD is a very complex phenomenon involving several processes taking place simultaneously. The simplified model based on an idealistic mechanism leading to switching, however, provides reasonably good estimates of the conditions leading to the onset of discharge. The mechanism also suggests several interesting characteristics, which are supported by the experimental observations; therefore, it will be appropriate to conclude that the idealized mechanism of ECD represses the actual physical phenomenon with reasonable accuracy **[5].**

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].**

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].**

2.1 Objective of the Proposed Research Work

In this study, multiple response parameters are optimized to get the accuracy of the product, enhance the productivity and process reliability. In order to improve the process performance, experiments were conducted on Monel k 500 for investigating the effect of control parameters on EDM-Drill process. A Taguchi method based on the basic underlying philosophy of Taguchi methodology was used to optimize the EDM-Drill process and confirmation experiment was conducted to verify the optimal condition.

The main objectives of the proposed research work are given below:

- To understand the effect of control parameters of EDM-Drill on output process.
- To determine the optimum level of control parameters for high MRR, less EWR, less OC and less TA simultaneously to operate the EDM-Drill more efficiently.
- To validate the experimental result based on the confirmation experiment.

3.0 Experimentation: The experimentation is as systematic and scientific and scientific approach to manipulate one or more output variables and control or measure the input variables. Every experimenter must plan and conduct experiments to obtain enough and relevant data. Modern industry promotes the use of alternative advanced materials (composites, super alloys, and ceramics) for establishing design and manufacturing. AISI 4147 that is precipitation hard enable, due to the additions of Aluminum is given as-

Table 3.1 Properties of Experimental Work piece

Properties	**Monel K-500**
Density	7.85g/cm^3
Melting point	1427 C
Coefficient of expansion	13.7µm/m^0C(20-100^0C)

Modulus of rigidity	66KN/mm^2
Modulus of elasticity	179KN/mm^2

AISI 4147 having good resistance to oxidation and corrosion at high temperature, extensively used in pump shafts, fasteners, marine propeller shafts, oil well tools, instruments & springs. The chemical composition of AISI 4147 is given as-

Table 3.2 Chemical Composition of Monel K-500

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

3.1 Taguchi Philosophy

Calibrations to existing cost of doing business in space indicate that to establish human presence on the Moon and Mars with the Space Exploration Initiative (SEI) will require resources, felt by many, to be more than the national budget can afford. In order for SEI to succeed, we must actually design and build space systems at lower cost this time, even with tremendous increases in quality and performance requirements, such as extremely high reliability. This implies that both government and industry must change the way they do business. Therefore, new philosophy and technology must be employed to design and produce reliable, high quality space systems at low cost. In recognizing the need to reduce cost and improve quality and productivity, Department of Defense and National Aeronautics and Space Administration (NASA) have initiated Total Quality Management (TQM). TQM is a revolutionary management strategy in quality assurance and cost reduction. TQM requires complete management commitment, employee involvement, and use of statistical tools. The quality engineering methods of Dr. Taguchi, employing design of experiments (DOE), is one of the most important statistical tools of TQM for designing high quality systems at reduced cost. Taguchi methods provide an efficient and systematic way to optimize designs for performance, quality, and cost.

Fig.2 EDM-Drill machine

4.0 Result 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.

4.1 Variation of MRR with Control Parameters

Table 4.1 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

(* indicates the optimum level of control parameter)

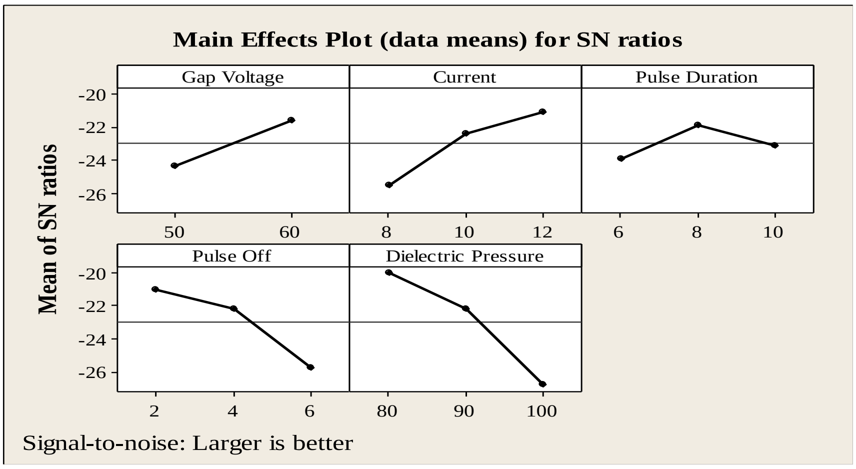

Fig. 4.1 SNR plot for MRR

5.0 Conclusion

An application of the Taguchi method to optimize the response parameters i.e. MRR, EWR in EDM-Drill process of AISI 4147 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 AISI 414with 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.

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.