International Journal on Recent Technologies in Mechanical and Electrical Engineering (IJRMEE) ISSN: 2349-7947
Volume: 3 Issue: 4 11 - 15

A Study on Effect of Powder on EDM (PMEDM)

Izhar Khan[1], Bilal Shaikh[2], Bilal Khan[3], Abdullah Khan[4], Irshad Shaikh[5]
[1]B.E.Student, Theem College of engineering Boisar(E) India.
[2]B.E.Student, Theem College of engineering Boisar(E) India
[3]B.E.Student, Theem College of engineering Boisar(E) India
[4]B.E.Student, Theem College of engineering Boisar(E) India
[5]Lecturer, Theem College of engineering Boisar(E) India

Abstract—EDM is a non- conventional machining process for removing material from workpiece using erosive effect.an arc is produced between electrode and tool, both must be electrically conductive. There is no direct contact between tool and workpiece. It is effective in machining hard materials, materials such as heat resistant alloys, super alloys and carbides which can't be easily machined with conventional method. It is widely used in mould, die making industry and in manufacturing of automotive, aerospace surgical components. Besides its advantages EDM have some drawbacks such as less material removal rate and poor surface finish. To overcome these drawbacks the metallic powder is mixed in the dielectric fluid, which increases its conductive strength and increases the spark gap distance between the tool and workpiece. This new evolved material removal process is called Powder mixed EDM (PM-EDM).For the purpose of experimentation D3 die steel as a workpiece with copper electrode as a tool and DEF-92 oil as dielectric has been used. PMEDM is very complex in nature and controlled by a large number of parameters, which are having impact on various responses. The present study is an attempt to investigate the potential of PMEDM for increasing material removal rate (MRR), decrease in tool wear rate (TWR) with improved surface roughness (SR) of Die steel. In previous research work Kerosene is used as dielectric fluid. Kerosene has adverse impact on the environment as well as health of the operator. So in this experimental method commercially available EDM oil will be used. The research outcome will identify the important parameters and their effect on material removal rate (MRR), tool wear rate (TWR) and surface roughness (SR) in the presence of suspended powder in a DEF-92 oil as dielectric of EDM. Experiments is designed using Taguchi method so that effect of all the parameters could be studied with minimum possible number of experiments .Results of the experimentation is analyze analytically as well as graphically using ANOVA and main effect-interaction plots, respectively. ANOVA has determined the percentage contribution of all factors upon each response individually.

Keywords- *PMEDM, DEF-92,D3 die steel Materil Removal Rate, Tool Wear Rate, Surface Roughnes, ANOVA.*
Index Terms—Powder mixed EDM, Material removal rate, Design of experiment, EDM oil.

*****

1.1 Introduction

Electrical Discharge Machining (EDM) is a thermoelectric process in which workpiece material is removed by high frequency controlled pulses generated in the dielectric medium between the tool and workpiece electrodes separated by a small gap. The disadvantages of the EDM are poor surface finish and less material removal rate. A plasma channel is formed due to the continuous bombardment of ions and electrons generating temperature in the range of 8000 °C–12000 °C in the discharge gap which causes vaporization and removal of the material. Powder mixed electro-discharge machining (PMEDM) is a promising technique which reduces the limitations and improves the machining performance of EDM. Mixing of fine metallic powder to the dielectric fluid decreases its insulating strength and consequently increases the inter-electrode space causing an easy removal of the debris. On application of a voltage of 80–315 V, an electric field in the range of 105– 107 V/m is applied, giving rise to positive and negative charges on the powdered particles. The powdered particles start moving in zig zag path on getting energized, thus forming clusters in the sparking area. The bridging effect takes place below the sparking area causing multiple discharges in a single pulse leading to quicker sparking and erosion from the workpiece surface. This easy short circuit improves the machining rate of the process. The plasma channel gets enlarged, producing consistent sparks forming shallow craters on the workpiece surface with superior surface quality. Material removal occurs from both the electrode surfaces and under suitable machining conditions, the removed material combined with the powder particles get settled on the surface of the workpiece, modifying and improving the properties resulting in breakdown of the dielectric fluid. As the sparking trend changes in the presence of metallic powders, lots of alteration in the surface properties occurs.

1.2 PMEDM Machining mechanism

On the basis of the results discussed for temperature distribution in the PMEDM workpiece, the machining mechanism for PMEDM is proposed. A schematic diagram of the proposed mechanism of material removal in PMEDM is explained in Fig. 1.1. When a voltage of 80–320 V is applied to both the electrodes, an electric field in the range 105–107 V/m is created. The spark gap is filled up with abrasive particles and the gap distance between tool and the workpiece increases from

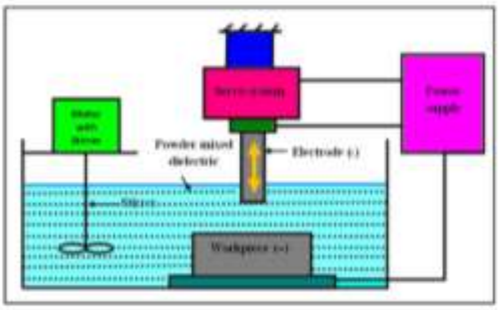

Fig.1.1 working principle of PMEDM

Schematic representation of machining mechanism of PMEDM. (a) It is expected that the conducting strength of the dielectric fluid increases as powder is suspended into it. The spark gap distance is increased by many times than normal

EDM. It is proposed that the increase in gap might have caused wider discharge passages. (b) In a wider and enlarged plasma channel, the suspended powder particles share and redistribute the impact force. As a result, shallow, uniform and flat craters are formed on the workpiece surface. 25–50 μm to many times as shown in Fig.2.2. The powder particles get energized and behave in a zigzag fashion. The grains come close to each other under the sparking area and gather in clusters. Under the influence of electric forces, the powder particles arrange themselves in the form of chains at different places under the sparking area. The chain formation helps in bridging the gap between both the electrodes. Due to the bridging effect, the gap voltage and insulating strength of the dielectric fluid decrease. The easy short circuit takes place, which causes early explosion in the gap. As a result, the 'series discharge' starts under the electrode area. Due to increase in frequency of discharging, the faster sparking within a discharge takes place which causes faster erosion from the work piece surface. At the same time, the added powder modifies the plasma channel. The plasma channel becomes enlarged and widened. The electric density decreases; hence sparking is uniformly distributed among the powder particles. As a result, even and more uniform distribution of the discharge.

1.3 PROCESS PARAMETERS OF EDM

Some of the important process parameters which influence the response variables are as follows:

- Discharge current (Ip):

It is the most important machining parameter in EDM because it relates to power consumption while machining. The current increases until it reaches a preset level which is expressed as discharge current. The maximum amount of amperage that can be used is governed by the surface area of the cut for a work piece tool combination. Higher currents will improve MRR, but at the cost of surface finish and tool wear. This is all more important consideration in EDM because the accuracy of machined cavity, which is a replica of tool electrode, will be affected due to excessive wears.

- Voltage Gap (V):

It is the open circuit voltage which is applied between the electrodes. The current flow starts; the open circuit voltage drops and stabilizes the electrode gap. It is a vital factor that influences the spark energy, which is responsible for the higher MRR, higher Tool wear rate and surface roughness. [5]

- Pulse-on time (Ton):

It is the time during which actual machining takes place and it is measured in μs. In each discharge cycle, there is a pulse on time and off time, and the voltage between the electrodes is applied during Ton duration. The longer the pulse duration higher will be the spark energy that creates wider and deeper created. It is because the material removal is directly proportional to the amount of energy applied during this on-time. Though with higher Ton, the MRR will be more, but rough surfaces are produced by the higher spark energy. [5]

- Duty cycle (Tau):

It is the ratio of pulse on-time and the pulse period. Duty cycle is defined in the equation below.

Tau =Ton/ (Ton + Toff)

At higher Tau, the spark energy is supplied for longer duration of the pulse period resulting in higher machining efficieccy.

- Polarity:

Polarity refers to the potential of the work piece with respect to tool i.e. in straight or positive polarity the work piece is positive, whereas in reverse polarity work piece is negative. Varying the polarity can have dramatic effect, normally electrode with positive polarity wear less, whereas with negative polarity cut faster. On the other hand, some of the metals do not respond this way. Carbide, Titanium and copper are generally cut with negative polarity and hard alloy steel is cut by normal polarity.

- Dielectric Fluid:

The dielectric fluid carries out three most important purposes in the EDM. The first function of the dielectric fluid is to insulate the inter electrode gap and after breaking down at the appropriate applied voltages conducting the flow of current. The second function is to flush away the debris from the machined area, and lastly, the dielectric act as coolant to assists in heat transfer from the electrodes. Most commonly used dielectric fluids are hydrocarbon compounds, like light transformer oil and kerosene.

- Type of flushing and Pressure:

Flushing is an important factor in EDM because debris must be removed for efficient cutting, moreover it brings fresh dielectric in the inter electrode gap. Flushing is difficult if the cavity is deeper, inefficient flushing may initiate arcing and may create unwanted cavities which can destroys the work piece. There are several methods generally used to flush the EDM gap: jet or side flushing, pressure flushing, vacuum flushing and pulse flushing. In jet flushing, hoses or fixtures are used and directed at the inter electrode gap to wash away the debris, in pressure and vacuum flushing dielectric flow through the drilled holes in the electrode, work piece or fixtures. In pulse flushing the movement of electrode in up and down, orbital or rotary motion creates a pumping action to draw the fresh dielectric.

1.4 Problem Statement

EDM machining technology is widely used in mechanical manufacturing. The EDM process is not affected by material hardness and strength. Its low efficiency and poor surface quality have been the key problems restricting its application. Therefore, it was considered to be of prime importance to improve the machining efficiency and surface quality of the EDM technology. In previous research work Kerosene is used as dielectric fluid. Kerosene has adverse impact on the environment as well as health of the operator. So we are going to use commercially available EDM oil.

2. LITRETURERE VIEW

G. Antony Casmir and S. Ashok kumar, (2015), an attempt has been made to find the optimal combination of process parameters to obtain maximum material removal rate and minimum surface roughness using Taguchi technique as well as Grey relational analysis technique and the percentage contribution of process parameters and its influence on the output parameters were investigated using ANOVA. It is shown that the output parameters namely material removal rate (MRR) and surface roughness are improved in the optimal combination obtained by Taguchi technique and Grey relational analysis technique [2].

Pichai Janmanee, Kamonpong and Jamkamon Apiwat Muttamara,(2015), have Investigated Electrical Discharge Machining of Tungsten Carbide using EDM-C3 Electrode Material From their research, the following conclusions can be drawn: a. When the duty factor value was decreased, the material removal rate decreased, and The effectiveness of the, as evaluated by the MRR, increased with the discharge current intensity. b. Increasing the discharge current led to the greatest material removal rate and gave the greatest electrode wear ratio. Moreover, the maximum Cr.S.Dn was obtained at the surface of the workpiece, and the surface after EDM indicated poor surface quality. c. The results show that an electrode with a negative polarity performs very well, and the EDM-C3 electrode optimum parameters with negative polarity were an open-circuit voltage of 90 V, a current of 12 A, an on time of 25 µs and an off time of 200 µs. Moreover, the minimum Cr.S.Dn was obtained at the surface of the tungsten carbide workpiece [3].

Anurag Joshi, (2014), results obtained are analyzed using S/N Ratios, Response table and Response Graphs with the help of Minitab software. Minitab is a computer program designed to perform basic and advanced statistical functions. It is a popular statistical analysis package for scientific applications, in particular for design and analysis of experiments. In this experimental results are analyzed and Regression equation is developed to predict the metal removal rate [4].

Dragan Rodic and Marin Gostimirovic, (2014), In this paper an ANFIS, neural network (ANN) and estimate surface roughness in EDM. Experiment and estimated by ANFIS, ANN and GP model and those obtained experimentally. One of the most important advantages of GP of modeling is that specific equations are obtained and models can be used independently. Because of the scarcity of space and slight complexity of generated membership functions, they are not shown within this paper [5].

Dinesh Kumar.Kasdekar and Vishal Parashar, (2014), Taguchi method of experimental design has been applied for optimizing multi-response characteristics such as MRR (Material Removal Rate), Tool wear rate and Surface Roughness of En-353 during EDM process. For EDM while hard machining of hardened steel are optimized with L9 orthogonal array. Results obtained from taguchi method closely match with ANOVA.The conclusions of this work are summarized as follows: The optimal parameters combination MRR was determined as A3B3C3D3 i.e. Discharge current at 25A, pulse ON time at 87µs ,pulse OFF time at 11µs and Di-electric fluid at 5l/g [6].

Jigar Saliya, (2014), it is found that remarkable work has been done in the field of optimization of the wire EDM process. But very limited work has been done by researchers for the usage of conductive powders with dielectric in wire EDM through nozzle directly. Comparative study can be the done for checking the effect of powder (Graphite) mixing in dielectric (distilled water) on the performance measures (machining time, kerf width and surface finish) with varying input parameter values (Pulse on time, pulse off time and peak current) of workpiece [7].

Richa Garg and Saurabh Mittal, (2014), Genetic algorithms are based on evolutionary ideas of natural selection and genetics. Genetic algorithms solve the problems step by step and produce next generation. All evolutionary algorithms including Genetic Algorithm can find near optimal solution. A set of test functions including unmoral and multimodal benchmark functions is employed for optimization [8].

V.Chittaranjan Das and C.Srinivas, (2014), An application of the Taguchi method and grey relational analysis to improve the multiple performance characteristics of the electrode wear ratio, material removal rate and surface roughness in the electrical discharge machining of Ti–6Al–4V alloy has been reported in this paper. As a result, this method greatly simplifies the optimization of complicated multiple performance characteristics. The optimal process parameters based on grey relational analysis for the EDM of Ti–6Al–4V alloy include 5 amp discharge current, 200 V open voltage, 200 µs pulse duration and 75% duty factor. The machining performance of the electrode wear ratio decrease from 0.13 to 0.10mg/min, the material removal rate increases from 4.86 to 5.31 mg/min and the surface roughness decreases from 2.16 to 1.85µm, respectively. To conclude, as per the findings, GRA, an advanced statistical method of multi-factorial analysis, embodies rich philosophical thought of the unity of opposites, such as continuity and discontinuity, quality and quantity, statics and dynamics, etc. Empirical research on high-tech industries and systems are often constrained, since traditional statistical methods require large sets of data. On the other hand, grey system theory is designed to work with system where the available information is insufficient to characterize the system [9].

Vijaybabu.Tand Dr.D.V.Ravishankar, (2014), In this research, three different analyses are employed to obtain the following goals. Evaluating the effects on machining parameters on volume material removal rate, evaluating the effects on machining parameters on surface roughness and presenting the optimal machining conditions. Taguchi Analysis determines the factors which have significant impact on volume material removal rate. Equations which correlate machining parameters with material removal rate is found by regression analysis, and the optimal setting is found by S/N ratio analysis. The present work was carried out by Taguchi analysis; further this work can be extended by considering any combination of fuzzy control, Grey relational analysis with Taguchi's orthogonal array technique, response surface methodology techniques [10].

3. METHODOLOGY

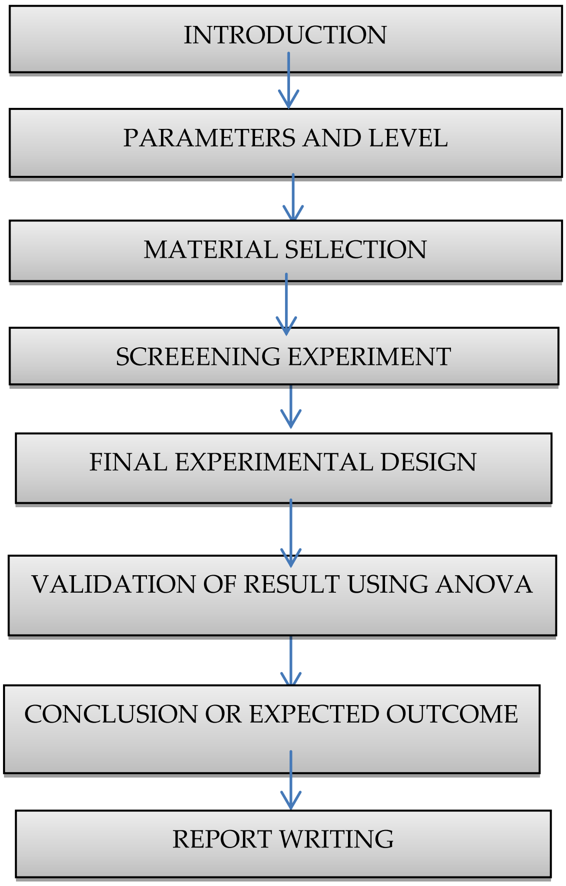

Fig.3.1 FLOW CHART OF OPTIMIZATION OF PMEDM

3.1 Introduction of Design of Experiment (DOE):

Experimental design is the process of planning a study to meet specified objectives. Design of experiments (DOE) is a systematic, rigorous approach to engineering problem-solving that applies principles and techniques at the data collection stage so as to ensure the generation of valid, defensible, and supportable engineering conclusions. Design of experiment is used to manipulate the conditions of the experiment and to control the factors that are irrelevant to the research objectives.

3.2. Parameters with their levels

3.2.1 Selection of input process parameters and their levels:

Input Factors with Notation and Units:

Factor	Notation	Units
Peak current	IP	Amp.
Pulse on time	T_{ON}	μsec.
Duty factor	D.F. (t)	-
Gap voltage	Vg	Volt.
Powder conc.	P.C	gm/liter

Table 4-1 Input Factors with Notation and Units

3.2.2 Selection of response variables:

Following response variables are considered in this experimental work

- Material Removal Rate
- Tool Wear Rate
- Surface Roughness

3.3 Selection of Materials:

3.3.1 Material for Work piece

The work piece material taken for this study was D3 tool steel. AISI D3 steel is an air hardening, high-carbon, high-chromium tool steel. It displays excellent abrasion/wear resistance and has good dimensional stability and high compressive strength. It is heat treatable and will offer hardness in the range 58-64 HRC.

Applications for D3 Steel:

a) Forming rolls
b) Blanking and forming dies
c) Press tools
d) Punches

3.3.2 Selection of Electrode/Tool Material:

Electrode material should be such that it would not undergo much tool wear when it is impinged by normal ions. Further, the tool should be easily workable as intricate shaped geometric features are machined in EDM.

Thus the basic characteristics of electrode materials are:

- ❖ High electrical conductivity
- ❖ High thermal conductivity- for the same heat load, the local temperature rise would be less due to faster heat conducted to the bulk of the tool and thus less tool wear.
- ❖ Higher density – for the same heat load and same tool wear by weight there would be less volume removal or tool wear and thus less dimensional loss or inaccuracy.
- ❖ Easy to manufacture.

3.3.3 Selection of Powder

Two powders are selected for the final experiment

1) Aluminum
2) Vanadium
3) Copper
4) Graphite

3.3.4 Selection of Dielectric fluid

DEF-92 is an economical EDM oil as compared to other EDM fluids available in market and eliminates all risks involved in using Kerosene like arching, nauseating, and debris settlement.

Advantages of DEF-92

- DEF-92 is highly fluid while in use thereby allowing debris settlement speedily. These properties not only increase the filter life but as well improve the finish.
- It is having the property of thermal resistance.
- High flash point of 105 ^{0}C makes this oil most desirable fluid on all sorts of EDM Machines.

3.4 DOE FOR SCREENING EXPERIMENTATION:

As the number of factors in a 2^k factorial design increases, the no. of runs required for a complete replicate of the design rapidly outgrows the resources of most experimenters. For example a complete replicate of the 2^8 design requires 256 runs.

The fractional factorial designs are among the most widely used types of designs for product and process design and for process improvement. A major use of fractional factorials is in screening experiments- experiments in which many factors are considered and the objective is to identify those factors that have large effects.

3.5 FINAL EXPERIMENTAL DESIGN

After conducting screening experiment we will select the most significant process parameters out of six process parameter such as Peak current (Ip), Pulse on time (Ton), Duty factor (t), Gap voltage (Vg), Powder concentration (PC) and Flow rate (FR) and final experiment will be conducted by keeping other parameters as constant. The final experiment is designed by factorial method.

Measurement of weight of workpiece and tool was carried out before and after each experiment and converted into volumetric material removal rates. MRR, TWR and SR were evaluated as response variables.

Measurement of MRR

MRR (mm^3/min) = **(**Workpiece weight loss (g)/ (Density (g/mm^3) × Machining time (min)**)**

Measurement of SR

The surface roughness **(SR)** of the workpiece is measured in terms of (Ra) by using Surface Roughness Tester.

Measurement of TWR

TWR (mm^3/min) = **(**Tool weight loss (g) / (Density (g/mm^3) × Machining time (min)**)**

3.6 ANOVA- ANALYSIS OF VARIANCE (ANOVA)

The terminology of ANOVA is largely from the statistical design of experiments. The experimenter adjusts factor and measures responses in an attempt to determine an effect. Factors are assigned to experimental units by a combination of randomization and blocking to ensure the validity of the results. Analysis of Variance is a mathematical technique which breaks total variation down in to accountable sources; total variation is decomposed into its appropriate components.Once all the parameters have been decided and level values are set, experimentation is performed. The results are tabulated section wise. After the experimental results have been obtained, analysis of the results is carried out analytically as well as graphically. For graphical analysis of the experimental results plots, showing effects of all the factors upon responses, are generated in MINITAB17. Then ANOVA of the experimental data has been done to calculate the contribution of each factor in each response.

3.7 Report writing

Finally the report writing is done for the Process parameter optimization of Powder Mixed Electric Discharge Machining (PMEDM) using design of experiment.

Conclusion

After conducting experiment we can conclude that how the various input parameters affects on the the material removal rate, tool wear rate and surface roughness.The result of aluminium and copper powder with EDM oil is shown on AISI D3 die-steel workpiece .The result obtained from the present study is extremely helpful for selecting the optimum machining conditions for AISI D3 die-steel work material, which is extensively used in moulds and dies industries.

References

Books

[1] Panday P.C., Shan H.S. (2007), "Modern Machining Processes", Tata McGraw-Hill, New Delhi, India, ISBN - 07-096553-6.Journal Papers,

[2] G.Antony Casmir and S. Ashok kumar, " Optimization of wire cut edm using hchcr by taguchi analysis", International conference on recent advancement in mechanical engineering & technology, pp.54-57, 2015.

[3] Pichai Janmanee, Kamonpong and Jamkamon Apiwat Muttamara(2015) "Investigation of Electrical Discharge Machining of Tungsten Carbide using EDM-C3 Electrode Material" European Journal of Scientific Research ISSN 1450-216X Vol.76 No.1 (2012), pp. 133-142 © EuroJournals Publishing, Inc. 2012

[4] Anurag Joshi, "Wire cut edm process limitations for tool and die steel", International Journal of Technical Research and Applications, vol 2,pp. 65-68, 2014.

[5] Dragan Rodic and Marin Gostimirovic, "Predicting of machining quality in electric discharge machining using intelligent optimization techniques", International Journal of Recent advances in Mechanical Engineering (IJMECH), Vol.3,pp 1-9, 2014.

[6] Dinesh Kumar Kasdekar and Vishal Parashar, "Taguchi Method and ANOVA: An Approach for Selection of Process Parameters of EDM of EN-353 Steel", International of Emerging Technology and Advanced Engineering, vol.4, pp.313-321, 2014.

[7] Jigar Saliya, "Comparative Study for the effect of Powder mixed dielectric on Performance of Wire EDM", International Journal of Engineering Development and Research, vol.2, pp.3671-3673 , 2014.

[8] Richa Garg and Saurabh Mittal, " Optimization by Genetic Algorithm", International Journal of Advanced Research in Computer Science and Software Engineering,vol 4, pp. 587-589, 2014.

[9] V.Chittaranjan Das and C.Srinivas, "Optimization of Multiple Response Characteristics on EDM Using the Taguchi Method and Grey Relational Analysis", International Journal of Scientific Research and Reviews, vol. 3 pp. 25-41, 2014.

[10] Vijaybabu.T and Dr.D.V.Ravishankar, " Parametric Optimization of Wire Electrical Discharge Machining (WEDM) Process Using Taguchi Method", The International Journal Of Engineering And Science (IJES),vol.3, pp. 52-58, 2014.-