PARAMETRIC OPTIMIZATION OF POWDER MIXED ELECTRONIC DISCHARGE MACHINE.

VISHWAKARMA NIRAJ VIJAY[1], UPADHYAY UMESH KAMALNAYAN[2], MAURYA SANJAY SWAMINATH[3], CHAURASIYA SURAJ SHESHNATH[4]

Students, Department Of Mechanical Engineering, Theem College Of Engineering, Boisar 401501, Maharashtra, India.

Abstract- *In the present work, a study has been made to optimize the process parameters of powder mixed electrical discharge machining (PMEDM). The objective of present research work is to study the influence of process parameters such as peak current (Ip), pulse on time (Ton) and Aluminium powder concentration on machining characteristics of AISI D3 die steel with round copper electrode. The machining characteristics are evaluated in terms of material removal rate (MRR), tool wear rate (TWR) and surface roughness (SR). It is found that Aluminium powder mixed in dielectric fluid significantly affect the machining performance. Taguchi methodology has been adopted to plan and analyze the experimental results. In this study seven factors with three levels are investigated using Orthogonal Array (OA) L27. The result of the experiment then was collected and analyzed using MINITAB 18 software. The recommended best parametric settings have been verified by conducting confirmation experiments for MRR, TWR, SR.*

Key Words: **Powder mixed EDM; Surface roughness; Material removal rate; Process optimization; Taguchi method; MINITAB software; Aluminium powder.**

1. INTRODUCTION

Electrical discharge machining (EDM), also known as spark machining, spark eroding, burning, die sinking, wire burning or wire erosion, is a manufacturing process whereby a desired shape is obtained by using electrical discharges. Material is removed from the work piece 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 "work piece." The process depends upon the tool and work piece not making actual contact.

When the voltage between the two electrodes is increased, the intensity of the electric field in the volume between the electrodes becomes greater than the strength of the dielectric, which breaks down, allowing current to flow between the two electrodes. This phenomenon is the same as the breakdown of a capacitor. As a result, material is removed from the electrodes. Once the current stops, new liquid dielectric is usually conveyed into the inter-electrode volume, enabling the solid particles to be carried away and the insulating properties of the dielectric to be restored. Adding new liquid dielectric in the inter-electrode volume is commonly referred to as "flushing." Also, after a current flow, the difference of potential between the electrodes is restored to what it was before the breakdown, so that a new liquid dielectric breakdown can occur.

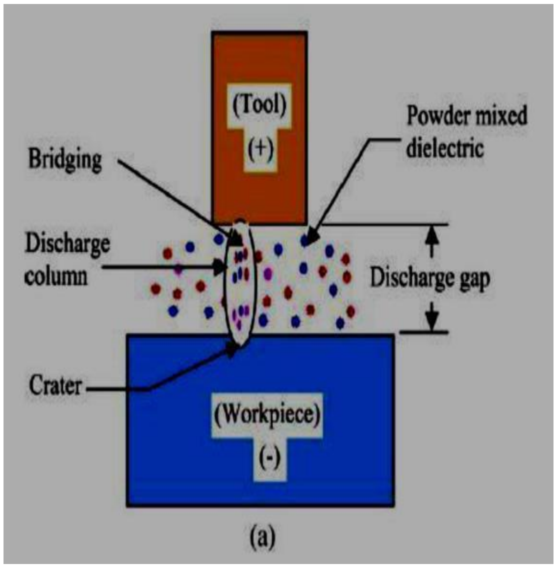

Figure1. Mechanism of EDM

Since there is no direct contact between work piece and tool electrode in EDM, machining problems like mechanical stresses, chattering and vibrations dose not arise during machining. In spite of remarkable advantages of the process, disadvantages like poor surface finish and low volumetric material removal limits its use in the industry. To diffuse this problem, EDM in the presence of powder suspended in the dielectric fluid is used and known as powder mixed EDM (PMEDM). It has been experimentally demonstrated that the presence of suspended particle in dielectric fluid significantly increases the surface finish and machining efficiency of EDM process. In PMEDM, a suitable material (aluminium, chromium, copper, silicon carbide, etc.) in powder form is mixed into the dielectric fluid used in EDM.

In PMEDM, the electrically conductive powder is mixed in the dielectric of EDM, which reduces the insulating strength of the dielectric fluid and increases the spark gap between the tool and work piece. As a result, the process becomes more stable, thereby, improving the material removal rate (MRR) and surface finish.

Several researchers carried out various investigations for improving the process performance. The important output parameters of the process are the material removal rate (MRR) and surface roughness (*R*a). Optimizations of the EDM process is concerned with maximising MRR while minimising TWR, and also producing the optimum (Ra) usually, the finish should be as smooth as possible. Optimisation is concerned with maximising material removal rate, minimising the tool wear ratio and obtaining a good surface finish. There are many input parameters which can be varied in the EDM process which have different effects on the EDM performance characteristics. Taguchi proposes a procedure that applies orthogonal arrays from statistical design of experiments to efficiently obtain the best model with the least number of experiments.

1.1 Important Parameters of EDM.

There are different parameters like spark on time, spark off time, breakdown voltage, gap current, duty cycle etc., which play very vital role in erosion of material. Among them the three most effective parameter for our research are discharge current, pulse on time and powder concentration which are explained below in detail.

Discharge current (IP): Current is measured in amp Allowed to per cycle. Discharge current isdirectly proportional to the Material removal rate. The current increases until it reaches a preset level which is ex-pressed 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.

Pulse on time (Ton): The duration of time (μs) the current is allowed to flow per cycle. Material removal is directly proportional to the amount of energy applied during this on-time. This energy is really controlled by the peak current and the length of the on-time.

Powder concentration (PC): In conventional EDM, normal pulse discharges regularly cause arcing due to insufficient pure dielectric deionization and excessive local debris. However, adding sufficient powder to the dielectric decreases the electrical resistivity and expands the gap, subsequently stabilizing the process through better flushing and servo-hunting. A wider discharge gap also decreases the heat flux, which reduces the material removal of a single spark and enhances the surface quality. However, such gap expansion is not possible with all powder materials, since powder density, electrical resistivity, and thermal conductivity along with particle size and concentration are highly determinative.

1.2 Aims and Objectives:

The aim of the present research work was to set the optimum process parameters of the PMEDM process to maximize the Material Removal Rate (MRR) of AISI D3 die steel and reduction in Tool wear rate (TWR) of copper tool. The MRR & TWR is estimated by calculating the difference between the initial weight and the final weight of the work piece after processing at a specified set of conditions by EDM or PMEDM.

1.2.1 Objective:

- ✓ To study the influence of powder-mixed EDM (PMEDM) on the performance of conventional roughing EDM
- ✓ To study the effect of PMEDM on the metal removal rate (MRR) with respect to conventional EDM.
- ✓ To study the effect of PMEDM on tool wear rate (TWR).
- ✓ To study the effect of PMEDM on surface roughness (SR).
- ✓ To optimizes the process parameters of the PMEDM process for maximum MRR, minimum TWR.

2. Design of Experiment:

Design of experiments is a series of tests in which purposeful changes are made to the input variables of a system or process and the effects on response variables are measured. Design of experiments is applicable to both physical processes and computer simulation models. Experimental design is an effective tool for maximizing the amount of information gained from a study while minimizing the amount of data to be collected. Factorial experimental designs investigate the effects of many different factors by varying them simultaneously instead of changing only one factor at a time. Factorial designs allow estimation of the sensitivity to each factor and also to the combined effect of two or more factors.

2.1 Parameters and their levels

2.1.1 Selection of input process parameters and their levels

Table 1.Input Factors with Units and Notation

Factor	Notation	Units
Peak current	IP	Amp.
Pulse on time	TON	µsec.
Powder conc.	P.C	gm/liter

2.2 Selections of response variables

The three response variables which are selected for this experiment is mentioned below:

- ✓ Material Removal Rate(MRR)
- ✓ Tool Wear Rate (TWR)
- ✓ Surface Roughness(SR)

2.3 Material Selections

For tool – copper tool
For workpiece – AISI D3 steel
For powder – Aluminium powder
For oil – EDM oil

2.4 Machines used for experiment

2.4.1 Technical specification of EDM machine

Mechanism of Process	Controlled erosion through a series of electric spark
Peak Current (Ip)	0-20 (Amp)
Pulse on Time (Ton)	0-100 (microsecond)
Gap Voltage (Vg)	0-100 (volt)
Spark gap	0.010 -0.500 mm

Table no. 3 specification

Spark frequency	200-500 kHz
Peak voltage across the gap	30-250 V
Shapes	Micro holes, Narrow slots, Blind Cavities
Dielectric Fluid	EDM oil, Kerosene liquid paraffin, Silicon oil, deionized water etc.
Specific Power Consumption	2-10 W/mm3/min
Metal Removal Rate (Max.)	5000 mm3/min
Tool Material	Copper, Brass, Graphite ,Ag-W Alloys, Cu-W Alloys

3. Final Experimental Design

We have total 3 response variables and 3 factors, thus we will be doing total 27 observations i.e. $3^3 = 27$

Structure design of DOE (OA27) .

In minitab software using Taguchi method we get the table of DOE as shown.

Table no. 4 Structure of DOE

	1	2	3
IP	4	8	12
PC	0	4	8
Ton	300	500	1000

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

a) Measurement of MRR

MRR (mm3/min) = (Workpiece weight loss (g)/ (Density (g/mm3) × Machining time (min))

b) Measurement of SR

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

c) Measurement of TWR

TWR (mm3/min) = (Tool weight loss (g) / (Density (g/mm3) × Machining time (min))

Table no. 5 DOE with experimental value

SR NO	IP	PC	Ton	MRR	TWR	SR
1	4	0	300	0.574	0.053	2.317
2	4	0	300	0.582	0.067	2.321
3	4	0	300	0.590	0.060	2.325
4	4	4	500	0.680	0.012	2.052
5	4	4	500	0.684	0.017	2.061
6	4	4	500	0.682	0.022	2.070
7	4	8	1000	0.625	0.017	1.929
8	4	8	1000	0.633	0.014	1.934
9	4	8	1000	0.629	0.020	1.939
10	8	0	500	12.638	0.101	6.102
11	8	0	500	12.641	0.094	6.107
12	8	0	500	12.644	0.108	6.097
13	8	4	1000	13.157	0.072	5.716
14	8	4	1000	13.161	0.062	5.723
15	8	4	1000	13.165	0.067	5.699
16	8	8	300	13.008	0.058	5.685
17	8	8	300	13.012	0.051	5.672
18	8	8	300	13.016	0.065	5.698
19	12	0	1000	20.630	0.506	8.218
20	12	0	1000	20.622	0.478	8.212
21	12	0	1000	20.614	0.534	8.224
22	12	4	300	22.306	0.540	7.904
23	12	4	300	22.312	0.533	7.922
24	12	4	300	22.318	0.547	7.940
25	12	8	500	22.904	0.545	7.750
26	12	8	500	22.913	0.537	7.723
27	12	8	500	22.922	0.553	7.777

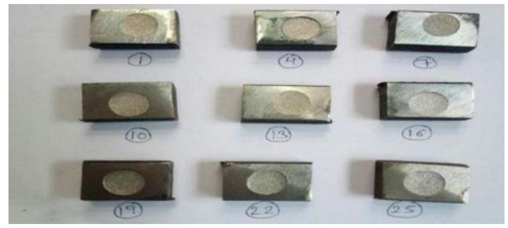

Figure2. Machined workpiece

3. Analysis of the Experiment

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 MINITAB18 using Taguchi method.

4.1 For analysis of MRR

Table no. 6 Response Table for Signal to Noise Ratios

Level	IP	PC	Ton
1	-4.018	14.540	14.851
2	22.236	15.344	15.304
3	26.820	15.154	14.882
Delta	30.838	0.804	0.453
Rank	1	2	3

Table no. 7 Response table for means

Level	IP	PC	Ton
1	0.6310	11.2817	11.9687
2	12.9380	12.0517	12.0787
3	21.9490	12.1847	11.4707
Delta	21.3180	0.9030	0.6080
Rank	1	2	3

Main Effect Plot and S/N Ratio Plot

Figure2. Main Effects Plot for Means

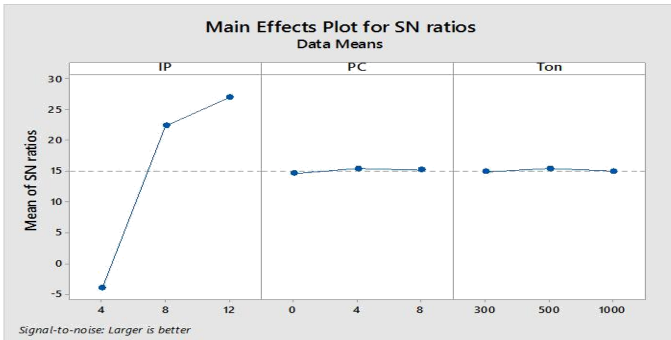

Figure3. Main Effects Plot for SN ratios

4.2 For analysis of TWR

Table no. 8 Response Table for Signal to Noise Ratios

Level	IP	PC	Ton
1	31.616	16.735	18.146
2	22.684	21.321	20.106
3	5.510	21.754	21.557
Delta	26.105	5.019	3.411
Rank	1	2	3

Table no. 9 Response table for means

Level	IP	PC	Ton
1	0.03133	0.22233	0.21933
2	0.07533	0.20800	0.22100
3	0.53033	0.20667	0.19667
Delta	0.49900	0.01567	0.02433
Rank	1	3	2

Main Effect Plot and S/N Ratio Plot

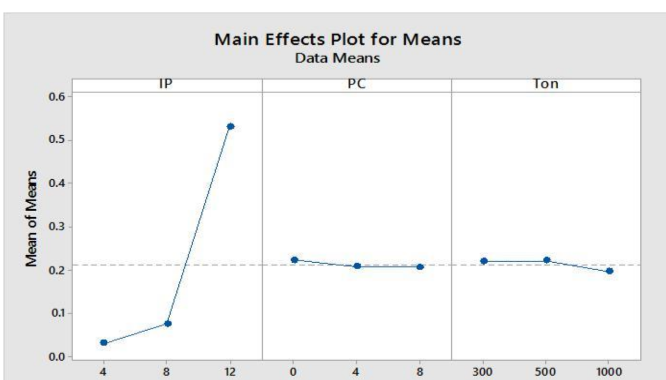

Figure4. Main Effects Plot for Means

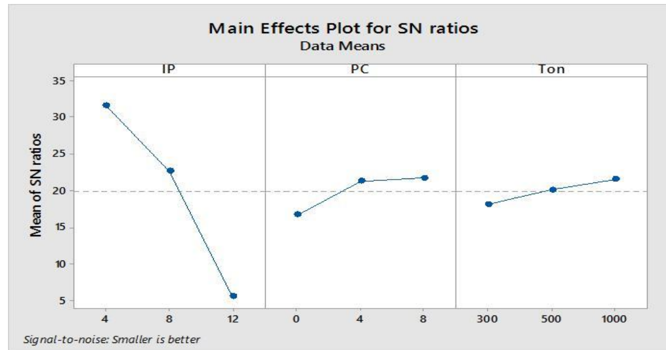

Figure5. Main Effects Plot for SN ratios

4.3 For analysis of SR.

Table no.10 Response Table for Signal to Noise Ratios

Level	IP	PC	Ton
1	-6.441	-13.773	-13.462
2	-15.314	-13.132	-13.259
3	-18.019	-12.870	-13.054
Delta	11.578	0.903	0.408
Rank	1	2	3

Table no. 11.Response table for means

Level	IP	PC	Ton
1	2.105	5.547	5.309
2	5.833	5.232	5.304
3	7.963	5.123	5.288
Delta	5.858	0.424	0.021
Rank	1	2	3

Main Effect Plot and S/N Ratio Plot

Figure6. Main Effects Plot for Means

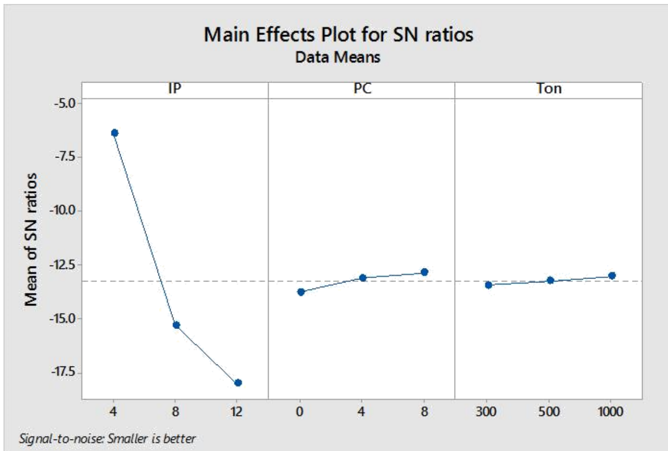

Figure7. Main Effects Plot for SN ratios

5. Confirmation of Experiments

The final step of the Taguchi method is the confirmation experiments conducted for examining the quality characteristics. The model used in the confirmation tests is defined with the total effect generated by the control factors.

The confirmation experiment is a crucial step and is highly recommended by Taguchi to verify the experimental conclusions. The purpose of the confirmation experiment in this study is to validate the optimum cutting condition that is suggested by the experiment. The optimum conditions are set for the significant factors and the insignificant factors are set at economic level. Selected numbers of tests are run under constant specified conditions. The average of the results of the confirmation experiment is compared with the anticipated average based on the parameters and levels tested. The estimated mean of the response characteristic is computed. A confidence interval for the predicted mean on a confirmation run is calculated using the Equation below

$$CI_{CE} = \sqrt{F_{\alpha}(1, f_e)V_e\left[\frac{1}{n_{eff}} + \frac{1}{R}\right]}$$

Where, F ;(1,f_e) = F0.05; (1,2) = 18.511(tabulated). = risk = 0.05,
f_e = error, DOF = 4
N = total number of experiments = 27 V_e
= error variance
Total trial= 27,
N =27 *1 = 27,
neff = effective number of replications
=N/ {1 + [total DOF associated in the estimate of mean]}
=27/ (1 + 4) = 5.4
R = number of repetitions for confirmation experiment = 1.

5.1 Validation for MRR

For MRR
V_e = error variance = 0.457
neff = 5.4
Putting the above values in equation of CICE
CICE = 3.1633

The optimal material removal rate (μMRR) is predicted at the selected optimal setting of process parameters. The parameters and their selected levels are shown in table no.7

μMRR = TMRR + (A3 & TMRR) + (B3 & TMRR) + (C2 & TMRR)
where, TMRR = overall mean of material removal rate = 11.8393 mm3/s
A3= 21.9490, B3= 12.1847, C3=12.0787
Thus μMRR = 22.5338
A confidence interval for the predicted mean on a confirmation run is calculated using the Equation 4: The 95% confidence interval of the population is: [μMRR + CI]< μMRR < [μMRR + CI]
[22.5338 & 3.1633]< μMRR < [22.5388 + 3.1633]
19.3675< μMRR<25.7001
From the response table of SN ratio for combination of 3-3-2

μ SN = 22.913

From above calculation we can say that the value of μSN is in the range of 19.3675 to 25.7001

5.2 Validation for TWR

For TWR
V_e = error variance = 0.0008
neff = 5.4
Putting the above values in equation of CICE
CICE = 0.13247

The optimal material removal rate (μMRR) is predicted at the selected optimal setting of process parameters. The parameters and their selected levels are shown in table no.9

μ TWR = TMRR + (A1 & TMRR) + (B3 & TMRR) + (C3 & TMRR)
where, TMRR = overall mean of material removal rate = 0.2123 mm3/s
A1= 0.03133, B3= 0.20667, C3=0.19667
Thus μTWR = 0.01003
A confidence interval for the predicted mean on a confirmation run is calculated using the Equation 4:

The 95% confidence interval of the population is:
[TWR & CI]< TWR < [TWR + CI]
[0.1003 & 0.13247]< μ TWR < [0.1003 + 0.13247] -
0.1224< μ TWR <0.1425

From the response table of SN ratio for combination of 1-3-3

μ SN = 0.017

From above calculation we can say that the value of μSN is in the range of -0.1224 to 0.1425.

5.3 Validation for SR

V_e = error variance = 0.0035, neff = 5.4

Putting the above values in equation of CICE

CICE = 0.2770

The optimal material removal rate (μSR) is predicted at the selected optimal setting of process parameters. The parameters and their selected levels are shown in table no.11

μ SR = TSR + (A1 & TSR) + (B3 & TSR) + (C3 & TSR)

where, TSR = overall mean of material removal rate = 5.2939 mm3/s

A1= 2.105, B3= 5.123, C3=5.288

Thus μSR = 1.9282

A confidence interval for the predicted mean on a confirmation run is calculated.

The 95% confidence interval of the population is:

[SR + CI]< SR < [SR + CI]

[1.9282 & 0.2770]< μ SR < [1,9282 + 0.2770]

1.6512< TWR <2.2052

From the response table of SN ratio for combination of 1-3-3

μ SN = 1.934

From above calculation we can say that the value of μSN is in the range of 1.6512 to 2.2052

6. Conclusion

The objective of this work is to study the effect of powder mixed dielectric (PMEDM) upon important parameters of EDM i.e. material removal rate, tool wear rate and surface roughness. The machine has the capability to vary the peak current, pulse on time, pulse off time, gap voltage etc. Considering the capability of the machine and the output required for the experimentation, peak current, pulse on time and powder concentration were decided to taken as the input variables and all other factors have kept constant. Powder mixed into EDM oil in order to study the effect of PMEDM on machining performance of AISI D3 steel. To obtained the desired levels for final experimentation with minimum possible number of experiment.

Within the range of parameters selected the following specific conclusions are drawn from the experimental results.

1.Maximum Material Removal Rate (MRR) is obtained at a high peak current of 12Amp, higher Ton of 500μs, and high concentration of Al powder 8g/lit.

2. Low Tool Wear Rate (TWR) is achieved with low peak current of 4Amp, higher Ton of 1000μs and higher concentration of Al powder of 8g/lit.

3. Low surface roughness is achieved with a low peak current of 4Amp, a higher Ton of 1000μs and higher concentration of Al powder of 8g/lit.

References

[1] Meenu Gupta, Surinder Kumar Investigation of surface roughness and MRR for turning of UD-GFRP using PCA and Taguchi method.

[2] Vijaykumar S. Jatti , Shivraj BaganeG. Thermo-electric modelling, simulation and experimental validation of powder mixed electric discharge machining (PMEDM) of BeCu alloys.

[3] Chethan Roy, Khalid Hussain Syed, Kuppan P. Machinablity of al/ 10%sic/ 2.5%tib2 metal matrix composite with powder-mixed Electrical Discharge machining.

[4] Ryota Toshimitsu, Akira Okada,, Ryoji Kitada and Yasuhiro Okamoto.Improvement in Surface Characteristics by EDM With Chromium Powder Mixed Fluid

[5] 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.

[6] 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

[7] 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.