International Journal of Scientific Engineering and Technology (ISSN : 2277-1581)
Volume No.3, Issue No.1 pp : 56-62 1 Jan 2014

# Parametric Study of Powder Mixed EDM and Optimization of MRR & Surface Roughness

**Shivam Goyal[1], Rakesh Kumar Singh[2]**

[1]PG Student, Mechanical Engineering, IIMT Engineering College, Meerut, India.

[2]Assistant Professor, Department of Mechanical Engineering, IIMT Engineering College, Meerut, India
Corresponding Author: shivam_gyl0001@yahoo.co.in

***ABSTRACT: Electrical discharge machining (EDM) is a well-established non-conventional machining process, used for manufacturing geometrically complex or hard and electrically conductive material parts that are extremely difficult to cut by other conventional machining processes. But sometimes poor surface finish and low volumetric material removal rate 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). In this research work the effect of machining parameters on Surface Roughness and Material Removal Rate (MRR) in a machining operation on Powder Mixed EDM Machine is investigated and the results are optimized by using the Taguchi method. The experimental studies are conducted by keeping various parameters like Current, Voltage, Pulse on time, Duty factor constant and by varying two parameters i.e. Grain size of Aluminium powder & Concentration of Aluminium powder. An L9 orthogonal array, the signal-to-noise (S/N) ratio are employed to study the performance characteristics in the machining of AISI 1045 steel using Powder mixed EDM machine. The results revealed that grain size of powder and concentration of powder have a great influence on the surface roughness and Material Removal Rate (MRR) in powder mixed EDM.***

**KEYWORDS:** AISI 1045 steel work-piece, copper electrode, concentration of aluminium powder, grain size of aluminium powder, S/N ratio, MRR, Surface Roughness.

## 1. INTRODUCTION

The development of super tough electrical conductive materials such as carbides, stainless steels, hastalloy, nitralloy, waspalloy, nomonics, etc., arisen the requirement of non-traditional manufacturing processes. These materials are very difficult to machine by conventional methods. Many of these materials find applications in industry where high strength to weight ratio, hardness and heat resisting qualities are required. Electric discharge machining (EDM) is one of the most extensively used non conventional machining processes. It uses thermal energy to machine all electrically conductive materials of any hardness and toughness for applications like manufacturing of dies, automobile components and aerospace parts. 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.

As a result of the exhaustive review of work done by previous researchers [1- 19], it is found that a limited work, related to Powder Mixed EDM has been published.

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.

The study demonstrates detailed methodology of the proposed optimization technique which is based on Taguchi method; and ranks the parameters namely grain size of aluminium powder and concentration of aluminium powder through S/N ratio. MRR of a machined work piece along with surface finish of work piece have been optimized.

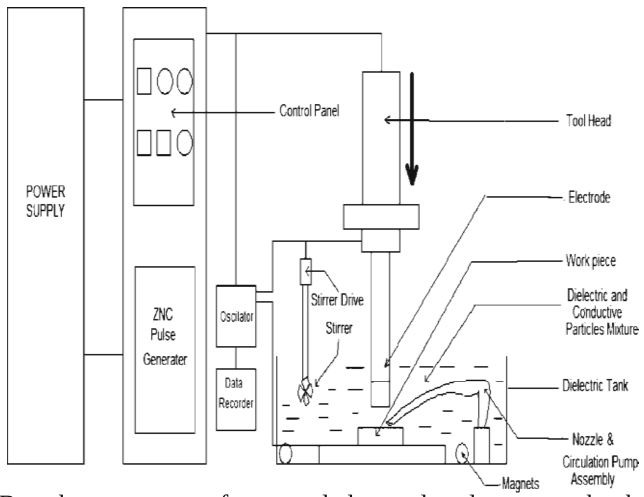
### 1.1 Powder Mixed Electro-Discharge Machining (PMEDM)

Powder mixed electro-discharge machining (EDM) is being widely used in modern metal working industry for producing complex cavities in dies and moulds which are otherwise difficult to create by conventional machining route. 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. Concentration of powder (Aluminium) in the dielectric fluid, Grain Size of powder, pulse on time, duty cycle, and peak current are taken as independent variables on which the machining performance was analyzed in terms of material removal rate (MRR) and surface roughness (SR).

The electrically conductive powder 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 and thereby improves material removal rate (MRR) and surface finish (SF). The presence of powder increases the gap distance as compared to traditional EDM by at least a factor of two. The enlarged and widened discharge channel lowers the break down strength of the dielectric fluid and reduces the electrical density on the machining spot. By reducing the spark energy and dispersing the discharges more uniformly throughout the surface, shallow craters are generated.

**1.1.1 Construction and Working of Powder Mixed Electro-Discharge machining (PMEDM):**

Machining mechanism in PMEDM is slightly different from conventional EDM process. In this process, a suitable material in the powder form is mixed into the dielectric fluid in the machining tank. Machining is performed in this tank and workpiece is placed in it, holding it with the help of a workpiece fixture assembly. The machining tank is filled up with dielectric fluid (kerosene oil) and to avoid particle settling, a stirring system is incorporated. A small dielectric circulation pump is installed for proper circulation of the powder mixed dielectric fluid into the discharge gap. The distance between powder mixed dielectric suction point and nozzle outlet is kept as short as possible (250 mm) in order to ensure the complete suspension of powder in the discharge gap. Two permanent magnets are placed at the bottom of machining tank to separate the debris from the dielectric fluid. Electric sparks are generated between two electrodes when the electrodes are held at a small distance from each other in a dielectric medium and a high potential difference is applied across them in conventional EDM.




But the presence of suspended powder decreases the break down strength of the dielectric fluid and reduces the electrical density on the machining spot. Localized regions of high temperatures are formed due to the sparks occurring between the two electrode surfaces. Workpiece material in this localized zone melts and vaporizes. Most of the molten and vaporized material is carried away from the inter-electrode gap by the dielectric flow in the form of debris particles. To prevent excessive heating, electric power is supplied in the form of short pulses. Spark occurs wherever the gap between the tool and the workpiece surface reaches a point to which the powder had lowered the electric density. The spark gap used to produce spark in PMEDM is twice as much as the gap needed to produce spark in conventional EDM. This way several sparks occur at various locations over the entire surface of the work piece corresponding to the workpiece–tool gap. A schematic diagram of PMEDM is shown in figure.

## 2. MATERIALS AND METHODS

**2.1 Powder Mixed EDM machine (Press Mach-A25)**

A Powder Mixed EDM Machine “Press Mach-A25” made by TOOLCRAFT is used to carry out the experimentation.

**TABLE - 1**
**SPECIFICATION OF THE PMEDM MACHINE (PRESS MACH - A25)**

| | |
|---|---|
| Pulse Generator | A25 |
| Working Current | 35 amps |
| Type of Pulse | STD/EQUI-ENERGY |
| Pulse Time ON/OFF | 2-2000 micro sec. |
| Max. MRR Cu-Steel<br>Gr-Steel | 165 mm./min.<br>190 mm./min. |
| Working Voltage | 35 volts |
| Surface Finish Cu-Steel | ≤ 0.5 microns CLA |
| Electrode Wear | ≤ 0.3 % |

**2.2 Selection of Machining Tool (Electrode)**

The cutting tool selected for present work is copper circular electrode of diameter 12 mm.

**2.3 Selection of Work Piece Material**

The work piece material used for current work is AISI 1045 Steel.

**TABLE – 2**
**COMPOSITION OF AISI 1045 STEEL**

| Elements | Weight % |
|---|---|
| Carbon, C | 0.43- 0.5 |
| Manganese, Mn | 0.6- 0.9 |
| Phosphorus, P | 0.04 max. |
| Sulphur, S | 0.05 max. |

**2.4 Selection of Conductive Material (Powder)**

We used aluminium powder as conductive material (powder) to mix with EDM oil.

**TABLE – 3**
**PROPERTIES OF ALUMINIUM POWDER**

| Powder | Aluminium |
|---|---|
| Density | 2.70 ($g/cm^3$) |
| Thermal Conductivity (at 300K) | 237 $W.m^{-1}.K^{-1}$ |
| Electrical Resistivity (at 20˚C) | 28.2 nΩ.m |
| Melting Point | 933.47 K |
| Specific heat capacity (at 25˚C) | 24.200 $J.mol^{-1}.K^{-1}$ |

### 2.5 Selection of Machining Parameters

The various machining parameters, used in this work, are shown in figure.

**TABLE – 4**
**EXPERIMENTAL SETTINGS**

| Polarity | Positive |
|---|---|
| Current | 6 Amp. |
| Voltage | 35 Volt |
| Pulse on time | 150 µs. |
| Duty factor | 0.7 |

### 2.6 Process Parameters & Levels used in the Experiment

The machining is done on Powder mixed EDM by keeping various parameters like Current, Voltage, Pulse on time, Duty factor constant and by varying two parameters i.e. Grain size of aluminium powder & Concentration of aluminium powder. The parameters and levels used in the experiment are shown in Table-5.

**TABLE – 5**
**PROCESS PARAMETERS AND LEVELS**

| **Levels** | **Variables** | |
|---|---|---|
| | **Grain Size of Aluminium Powder** | **Concentration of Aluminium Powder** |
| Level 1 | Fine ( < 150 ) | 2 |
| Level 2 | Medium (150 – 225) | 4 |
| Level 3 | Coarse (225 – 300) | 6 |

### 2.7 Design Matrix

In the present work there are three levels, two factors. According to Taguchi approach L9 has been selected. We performed 10 experiments instead of 9 experiments to get the clear difference between the readings found with the use of aluminium powder and without the use of aluminium powder. So the first reading is the reference readings and remaining 9 are according to L9 array. According to Taguchi L9 array design matrix of variables are formed.

**TABLE – 6**
**DESIGN MATRIX OF VARIABLES**

| **Experiment** | **Grain/Mesh Size of Aluminium Powder (µm)** | **Concentration of Aluminium Powder (gm/ltr.)** |
|---|---|---|
| 1 | 0 | 0 |
| 2 | Fine ( < 150 ) | 2 |
| 3 | Fine ( < 150 ) | 4 |
| 4 | Fine ( < 150 ) | 6 |
| 5 | Medium (150 – 225) | 2 |
| 6 | Medium (150 – 225) | 4 |
| 7 | Medium (150 – 225) | 6 |
| 8 | Coarse (225 – 300) | 2 |
| 9 | Coarse (225 – 300) | 4 |
| 10 | Coarse (225 – 300) | 6 |

## 3. RESULTS AND DISCUSSIONS

### 3.1 Material Removal Rate (MRR)

The material removal rate is generally described as the volume of metal removed per unit time. To calculate MRR following equation is used to calculate the Material Removal Rate (MRR):

$$MRR(mm^3/min) = \frac{[\text{Initial Weight of workpiece(gm) - Final Weight of workpiece(gm)}]}{\text{Density}(gm/mm^3) \times \text{Machining Time (min)}}$$

The density of the mild steel is taken as 7.69612 x $10^{-3}$ $g/mm^3$.

### 3.2 Surface Roughness ($R_a$)

Roughness measurement has been done using a portable stylus-type profilometer, Mitutoyo- Surftest SJ- 201P/M. The evaluation length of 2.5 mm is used to measure response $R_a$ value in µm.

### 3.3 Response Table

Response table for the experimental design matrix is shown in table 7.

**TABLE – 7**
**RESPONSETABLE OF $R_a$ AND MRR**

| **Experiment** | **Grain /Mesh Size of Aluminium Powder (µm)** | **Concentration of Aluminium Powder (gm/ltr.)** | **Work-piece Material Loss(gm.)** | **Machining Time (Min.)** | **MRR (mm3/Min.)** | **Surface Roughness (µm) Length Of Cut =2.5 mm** |
|---|---|---|---|---|---|---|
| 1 | 0 | 0 | 1.455 | 9 | 21.006 | 5.315 |
| 2 | Fine ( < 150 ) | 2 | 1.49 | 9 | 21.511 | 5.585 |
| 3 | Fine ( < 150 ) | 4 | 1.516 | 9 | 21.887 | 5.465 |
| 4 | Fine ( < 150 ) | 6 | 1.572 | 9 | 22.695 | 5.205 |
| 5 | Medium 150 – 225 | 2 | 1.624 | 9 | 23.446 | 5.4 |
| 6 | Medium 150 – 225 | 4 | 1.685 | 9 | 24.327 | 5.365 |
| 7 | Medium 150 – 225 | 6 | 1.62 | 9 | 23.388 | 5.005 |
| 8 | Coarse 225 – 300 | 2 | 1.287 | 9 | 18.581 | 4.86 |
| 9 | Coarse 225 – 300 | 4 | 1.473 | 9 | 21.266 | 4.66 |
| 10 | Coarse 225 – 300 | 6 | 1.473 | 9 | 21.266 | 4.4 |

### 3.4 Analysis of Single Response Stage

The optimal settings and the predicted optimal values for surface roughness and MRR are determined individually by Taguchi's approach. Table VII shows these individual optimal values and its corresponding settings of the process parameters for the specified performance characteristics. It is observed that the grain size of aluminium powder and concentration of aluminium powder have a great influence on MRR and surface roughness.

**TABLE – 8**
**MEANS OF MRR & SURFACE ROUGHNESS AT DIFFERENT LEVELS**

| Level | Mean Value of $R_a$ | | Mean Value of MRR | |
|---|---|---|---|---|
| | Grain Size | Concentration | Grain Size | Concentration |
| 1 | 5.418 | 5.282 | 22.031 | 21.179 |
| 2 | 5.257 | 5.163 | 23.720 | 22.493 |
| 3 | 4.640 | 4.870 | 20.371 | 22.450 |

**TABLE – 9**
**INDIVIDUAL OPTIMAL VALUES & CORRESPONDING SETTING OF PROCESS PARAMETERS**

| Performance Characteristic | Optimal Parameter Level | Optimum Level |
|---|---|---|
| $R_a$ (µm) | A3-B3 | 4.4 |
| MRR ($mm^3$/min) | A2- B2 | 24.327 |

**TABLE – 10**
**OPTIMAL VALUES FOR MRR**

| Grain/Mesh Size | Concentration |
|---|---|
| 21.006 | 21.006 |
| 22.031 | 21.179 |
| 23.72 | 22.493 |
| 20.371 | 22.45 |

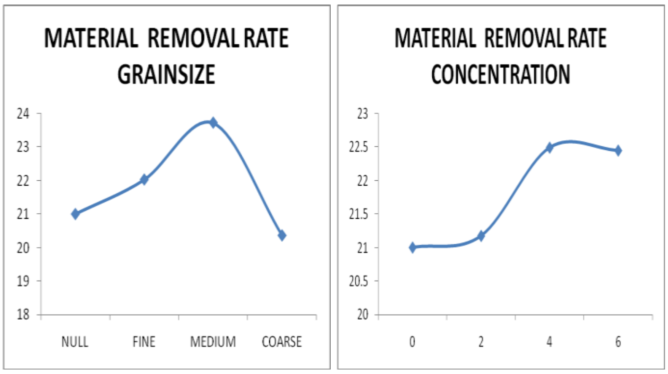



**Fig. 1 - RESPONSE GRAPH FOR MRR**

**ANALYSIS OF PLOT FOR MRR**

The data gathered from the experimental work is analysed using single response S/N ratio method to obtain the optimal values of the process parameters. These optimal values for MRR are plotted in two graphs: one based on Grain size of powder and other based on concentration of powder.

**Based on Grain Size of Powder**

As shown in graph MRR is low when no aluminium powder is mixed with EDM oil. As we mix fine sized aluminium powder in the EDM oil, MRR increases. With the further increase in Grain size of aluminium powder i.e. medium size powder particles, MRR increases further. But as we increase the grain size of aluminium powder further i.e. coarse grain size, MRR decreases. So as a result we get best MRR on Medium sized Powder mixed with EDM oil.

**Based on Concentration of Powder**

As shown in graph initially when there is no powder mixed with EDM oil, MRR is low. As we mix aluminium powder in the EDM oil in 2 gm/ltr. concentration, MRR increases. As we further increases the concentration of aluminium powder upto 4 gm/ltr., MRR also increases. But as we increase the concentration of aluminium powder further as 6 gm/ltr., MRR reduces. So as a result we get best MRR on concentration 4 gm/ltr. of aluminium Powder mixed with EDM oil.

**TABLE – 11**
**OPTIMAL VALUES FOR SURFACE ROUGHNESS**

| Grain/Mesh Size | Concentration |
|---|---|
| 5.315 | 5.315 |
| 5.418 | 5.282 |
| 5.257 | 5.163 |
| 4.64 | 4.87 |

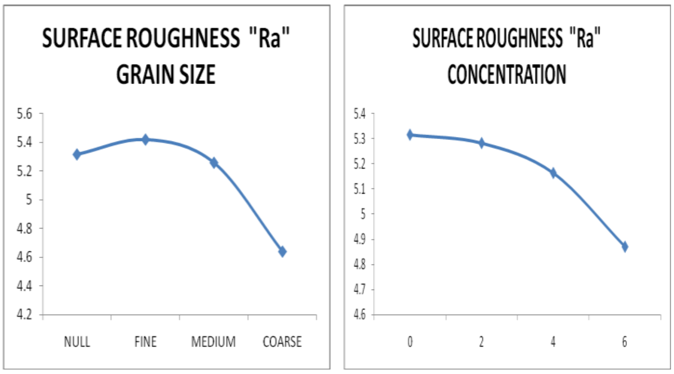



**Fig. 2 - RESPONSE GRAPH FOR Ra**

**ANALYSIS OF PLOT FOR SURFACE ROUGHNESS**

The optimal values for Surface Roughness obtained from single response S/N ratio Table are plotted in two graphs: one based on Grain size of powder and other based on concentration of powder.

**Based on Grain Size of Powder**

As shown in graph Surface Roughness is high when no aluminium powder is mixed with EDM oil. As we mix fine sized aluminium powder in the EDM oil, Surface Roughness increases slightly. With the further increase in Grain size of aluminium powder i.e. medium size powder particles, Surface Roughness starts reducing. As we further increase the grain size of aluminium powder i.e. coarse grain size, Sourface Roughness keeps on decreasing. So as a result we get lowest surface roughness on Coarse sized Aluminium Powder. Lower surface roughness shows the better surface finish. This means that Coarse sized Aluminium Powder gives the best surface finish.

**Based on Concentration of Powder**

As shown in graph initially when there is no powder mixed with EDM oil, Surface Roughness is high. As we mix aluminium powder in the EDM oil in 2 gm/ltr. Concentration, Surface Roughness decreases slightly. As we further increases the concentration of aluminium powder upto 4 gm/ltr., Surface Roughness reduces further. With the further increase in the concentration of aluminium powder upto 6 gm/ltr., Sourface Roughness keeps on decreasing. So as a result we get lowest surface roughness on concentration 6 gm/ltr. Of aluminium Powder mixed with EDM oil. Lower surface roughness shows the better surface finish. This means that the best surface finish is achieved on concentration of 6 gm/ltr. Of aluminium Powder mixed with EDM oil.

### 3.5 Analysis of Multi-Response Stage

The S/N ratio considers both the mean and the variability. In the present work, a multi- response methodology based on Taguchi technique and Utility concept is used for optimizing the multi-responses (Ra and MRR). Taguchi proposed many different possible S/N ratios to obtain the optimum parameters setting. Two of them are selected for the present work. Those are, Smaller the better type S/N ratio for $R_a$

$$[\eta_1] = -10\log_{10}\left[R_a^2\right];$$

Larger the better S/N ratio for MRR

$$[\eta_2] = -10\log_{10}\left[\frac{1}{MRR^2}\right]$$

From the utility concept, the multi-response S/N ratio of the overall utility value is given by

$$\eta_{obs} = W_1\eta_1 + W_2\eta_2$$

Where $W_1$ & $W_2$ are the weights assigned to the $R_a$ and MRR. Assignment of weights to the performance characteristics are based on experience of engineers, customer's requirements and their priorities. In the present work equal importance is given for both Ra and MRR. Therefore $W_1$ & $W_2$ = 0.5.

The optimal combination of process parameters for simultaneous optimization of Surface roughness ($R_a$) and material removal rate (MRR) is obtained by the mean values of the multi-response S/N ratio of the overall utility value are shown in Table 12.

**TABLE – 12**

**DESIGN MATRIX WITH MULTI-RESPONSE S/N RATIO**

| S. No. | Grain/Mesh Size Of Aluminium Powder (μm) | Concentration Of Aluminium Powder (gm/ltr.) | Surface Roughness (μm) | $\eta_1$ for Ra | MRR ($mm^3$/min.) | $\eta_2$ for MRR | $\eta_{obs}$ |
|---|---|---|---|---|---|---|---|
| 1 | 0 | 0 | 5.315 | -14.51 | 21.006 | 26.447 | 5.969 |
| 2 | Fine ( < 150 ) | 2 | 5.585 | -14.94 | 21.511 | 26.653 | 5.857 |
| 3 | Fine ( < 150 ) | 4 | 5.465 | -14.751 | 21.887 | 26.804 | 6.027 |
| 4 | Fine ( < 150 ) | 6 | 5.205 | -14.328 | 22.695 | 27.118 | 6.395 |
| 5 | Medium 150 – 225 | 2 | 5.4 | -14.647 | 23.446 | 27.41 | 6.382 |
| 6 | Medium 150 – 225 | 4 | 5.365 | -14.591 | 24.327 | 27.722 | 6.566 |
| 7 | Medium 150 – 225 | 6 | 5.005 | -13.988 | 23.388 | 27.380 | 6.696 |
| 8 | Coarse 225 – 300 | 2 | 4.86 | -13.732 | 18.581 | 25.381 | 5.825 |
| 9 | Coarse 225 – 300 | 4 | 4.66 | -13.368 | 21.266 | 26.554 | 6.593 |
| 10 | Coarse 225 – 300 | 6 | 4.4 | -12.869 | 21.266 | 26.554 | 6.843 |

**TABLE – 13**

**MEAN VALUES OF $\eta_{obs}$ AT DIFFERENT LEVELS**

| Levels | Mean Value of $\eta_{obs}$ for Process Parameters | |
|---|---|---|
| | Grain Size | Concentration |
| Level 1 | 6.093 | 6.021 |
| Level 2 | 6.548 | 6.395 |
| Level 3 | 6.420 | 6.645 |

**TABLE – 14**

**INDIVIDUAL OPTIMAL VALUES AND ITS CORRESPONDING SETTINGS OF PROCESS PARAMETERS**

| Performance Characteristics | Optimum Parameter Level | Optimum Level |
|---|---|---|
| $\eta_{obs}$ | A2-B3 | 6.696 |

International Journal of Scientific Engineering and Technology (ISSN : 2277-1581)
Volume No.3, Issue No.1 pp : 56-62 1 Jan 2014

**TABLE – 15**
**OPTIMAL VALUES FOR MRR & SURFACE ROUGHNESS**

| Grain Size | Concentration |
|---|---|
| 5.969 | 5.969 |
| 6.093 | 6.021 |
| 6.548 | 6.395 |
| 6.42 | 6.645 |

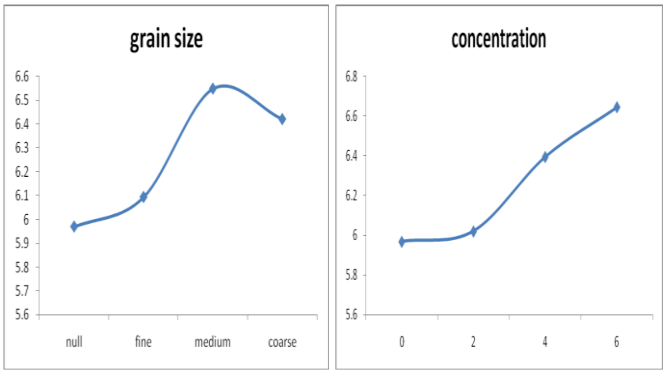



**Fig. 3 – MULTI-RESPONSE S/N RATIO GRAPH**

## INTERPRETATION OF PLOTS

A set of experiments are performed on AISI 1045 Steel Work pieces by using copper electrode in aluminium powder mixed EDM. The data obtained from experiments is optimized using S/N ratio optimization method. Multi-response table has been developed and the optimum values are plotted in the form of graph. The plots show the variation of individual response with the variation in parameters i.e. Grain Size of aluminium powder and Concentration of aluminium powder. In the plots, the x-axis indicates the value of each process parameter at different levels and y-axis indicates the response value. As there are two process parameters, so there are two graphs: one based on Grain size of powder and other based on concentration of powder.

**Based on Grain Size of Powder**

This graph is a plot between the process parameter i.e. Grain size of aluminium powder on x-axis and the optimum values obtained from Multi-response table on y-axis. This graph gives the combined result for MRR and Surface Roughness. Initially when there is no powder mixed with EDM oil, the optimum value plotted on y-axis is low. As we mix fine sized aluminium powder in the EDM oil, the optimum value on y-axis increases. With the increase in Grain size of aluminium powder i.e. medium size powder particles, the optimum value on y-axis increases further. As we further increase the grain size of aluminium powder i.e. coarse grain size, the optimum value on y-axis reduces. So we get the best result on medium sized Aluminium Powder. On medium sized aluminium powder mixed with EDM oil we get the optimum value for MRR and Surface Finishing.

**Based on Concentration of Powder**

This graph is a plot between the Concentration of aluminium powder on x-axis and the optimum values obtained from Multi-response table on y-axis. This graph shows the combined result for MRR and Surface Roughness. Initially when no powder is mixed with EDM oil, the optimum value plotted on y-axis is low. As we mix aluminium powder in the EDM oil in concentration of 2 gm./ltr., the optimum value on y-axis increases. With the increase in concentration of aluminium powder i.e. at 4 gm./ltr., the optimum value on y-axis increases further. As we further increase the concentration of aluminium powder upto 6 gm./ltr., the optimum value on y-axis keeps on increasing. So as a result optimum value of MRR and Surface finish is achieved at a concentration of 6 gm./ltr. Of aluminium powder mixed with EDM oil.

## 4. CONCLUSION

A set of experiments are performed on AISI 1045 steel work pieces by using copper electrode in aluminium powder mixed EDM. The experimental studies are conducted by keeping various parameters like Current, Voltage, Pulse on time, Duty factor constant and by varying two parameters i.e. Grain size of aluminium powder & Concentration of aluminium powder. Mixing of Aluminium powder in Di-electric fluid ensures improved MRR and surface finishing. Based on the results obtained, the following conclusions have been drawn:

- The analysis of the experimental observations highlights that Grain size of aluminium powder and concentration of aluminium powder mixed with EDM oil have a great influence on MRR and Surface finish.
- Too low and too high concentration of aluminium powder in EDM oil reduces MRR of AISI 1045 Steel.
- Too low and too high Grain size of aluminium powder in EDM oil reduces MRR of AISI 1045 Steel.
- As the concentration of aluminium powder in EDM oil increases, surface roughness starts decreasing and keeps on decreasing. So as a result we get lowest surface roughness on concentration 6 gm/ltr. of aluminium Powder mixed with EDM oil. Lower surface roughness shows the better surface finish. This means that the best surface finish is achieved on concentration of 6 gm/ltr. of aluminium Powder mixed with EDM oil.
- As the Grain Size of aluminium powder in EDM oil increases, surface roughness starts decreasing and keeps on decreasing. So as a result we get lowest surface roughness on coarse sized Aluminium Powder. Lower surface roughness shows the better surface finish. This means that coarse sized Aluminium Powder gives the best surface finish.
- If we consider MRR and Surface roughness equally important then too low and too high Grain size of aluminium powder in EDM oil gives lower MRR and lower Surface finish on AISI 1045 Steel. On medium sized aluminium powder mixed with EDM oil we get the best MRR and Surface finish.
- If we consider MRR and Surface roughness equally important then with the increase in concentration of aluminium powder MRR and surface finish of AISI 1045 Steel increases. And at concentration of 6 gm./ltr. we get the best MRR and Surface finish.

**REFERENCES**


i. *Dr. S. Senthil, Unconventional Machining Process (A.R.S. Publications)*

ii. *Wong Y. S., Lim L. C., Rahuman I., and Tee W. M. (1988), "Near-mirror-finish phenomenon in EDM using powder-mixed dielectric", Journal of Materials Processing Technology Volume 79, Issues 1–3, pp.30–40.*

iii. *Uno Y., Okada A. and Cetin S. (2001), "Surface Modification of EDMed surface with Powder Mixed Fluid", 2nd International Conference on Design and Production of Dies and Molds.*

iv. *Pecas P. and Henriques E. (2003), "Influence of silicon powder-mixed dielectric on conventional electrical discharge machining", International Journal of Machine Tools and Manufacture Volume 43, Issue 14, pp.1465–1471.*

v. *Wu K. L., Yan B. H., Huang F. Y. and Chen S. C. (2005), "Improvement of surface finish on SKD steel using electro-discharge machining with aluminum and surfactant added dielectric", International Journal of Machine Tools and Manufacture Volume 45, Issue 10, pp.1195–1201.*

vi. *Cogun C., Zrrkan B.O. and Cay T. K. (2006), "An experimental investigation on the effect of powder mixed dielectric on machining performance in electric discharge machining", DOI: 10.1243/09544054JEM320.*

vii. *Kansal H. K., Singh S. and Kumar P. (2007), "Technology and research developments in powder mixed electric discharge machining (PMEDM)", Journal of Materials Processing Technology Volume 184, Issues 1–3, pp.32–41.*

viii. *Tzeng Y. F. and Chen F. C. (2007), "Multi-objective optimisation of high-speed electrical discharge machining process using a Taguchi fuzzy-based approach", Materials & Design, Volume 28, Issue 4, pp.1159–1168.*

ix. *Kansal H. K., Singh S. and Kumar P. (2007), "Effect of Silicon Powder Mixed EDM on Machining Rate of AISI D2 Die Steel", Journal of Manufacturing Processes Volume 9, Issue 1, pp.13–22.*

x. *Wang Y., Zhao F. and Liu Y. (2008), "Behaviors of Suspended Powder in Powder Mixed EDM", Key Engineering Materials Vols. 375-376, pp.36-41.*

xi. *Pecas P. and Henriques E.(2008), "Electrical discharge machining using simple and powder-mixed dielectric: The effect of the electrode area in the surface roughness and topography", Journal of Materials Processing Technology Volume 200, Issues 1–3, Pages 250–258.*

xii. *Kumar S., Singh R., Singh T. P. and Sethi B.L. (2009), "Surface modification by electrical discharge machining: A review", Journal of Materials Processing Technology Volume 209, Issue 8, pp.3675–3687.*

xiii. *Wu K. L., Yan B. H., Lee J. W. and Ding C. G. (2009), "Study on the characteristics of electrical discharge machining using dielectric with surfactant", Journal of Materials Processing Technology Volume 209, Issue 8, pp.3783–3789.*

xiv. *Singh P., Kumar A., Beri N. and Kumar V. (2010), "Some experimental investigation on aluminum powder mixed EDM on machining Performance of hastelloy steel", International Journal of Advanced Engineering Technology, E-ISSN 0976-3945 IJAET/Vol. I, Issue II, pp.28-45.*

xv. *Sharma S., Kumar A. and Beri N.(2011), "Study of tool wear rate during powder mixed EDM of hastelloy steel", International Journal of Advanced Engineering Technology, E-ISSN 0976-3945 IJAET/Vol.II, Issue II, pp.133-139.*

xvi. *Singh S. and Bhardwaj A.(2011), "Review to EDM by Using Water and Powder-Mixed Dielectric Fluid", Journal of Minerals & Materials Characterization & Engineering, Vol. 10, No.2, pp.199-230.*

xvii. *Singh S., Singh H., Singh J. and Bhatia R. (2011), "Effect of Composition of Powder Mixed Dielectric Fluid on Performance of Electric Discharge Machining", International Journal of Materials Science and Engineering, Vol. 2, No. 1-2, pp.7-8.*

xviii. *Padhee S., Nayak N., Panda S. K., Dhal P. R. And Mahapatra S. S. (2012), "Multi-objective parametric optimization of powder mixed electro-discharge machining using response surface methodology and non-dominated sorting genetic algorithm", Indian Academy of Sciences, Sadhana ,Vol. 37, Part 2, pp. 223–240.*

xix. *Kumar S. and Batra U. (2012), "Surface modification of die steel materials by EDM method using tungsten powder-mixed dielectric", Journal of Manufacturing Processes Volume 14, Issue 1, pp.35–40.*