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Effect of SiC, Mixed with EDM Oil on MRR, Surface Roughness & Tool Wear Rate

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***Abstract*— In this research work the effect of SiC powder mixed with EDM oil on Surface Roughness, Material Removal Rate (MRR) & Tool wear rate is investigated and the results are optimized. For conducting experiments, parameters like Voltage, Current, Pulse on time, Duty factor are kept constant and parameters i.e. Grain size of SiC Powder & Concentration of SiC powder are varied. For studying the performance characteristics of AISI 1020 Low Carbon Steel (LCS) using Powder mixed EDM machine Signal-to-noise (S/N) ratio is employed. The experimental result shows that surface roughness, Material Removal Rate (MRR) & Tool wear Rate is highly influenced by Grain size & Concentration of powder mixed with EDM oil. As a result we found that at medium Sized SiC powder and at concentration of 6 gm./ltr. of SiC powder we get the optimum level for MRR, Surface Roughness (Ra) & Tool Wear Rate (TWR). So to get larger value of MRR alongwith improved surface finish and lower tool wear rate machining should be done with SiC powder of medium grain size mixed with EDM oil in the concentration of 6 gm./ltr.**

***Index Terms*— AISI 1020 Low Carbon steel(LCS) work-piece, copper electrode, concentration of SiC powder, grain size of SiC powder, S/N ratio, MRR, Surface Roughness, Tool wear Rate.**

I. INTRODUCTION

Electric discharge machining (EDM) is one of the most extensively used non traditional machining technique. 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. 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 eliminate above mentioned problems, 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 and reduces the tool wear rate.

In PMEDM, a suitable material (aluminum, chromium, copper, silicon carbide, etc.) in powder form is mixed into the dielectric fluid(EDM oil) used in EDM. An electric field is generated when a voltage is applied between the tool electrode and the work piece placed close to each other. The spark gap is filled up by the additive particles. The powder particles are energized by high electric field. These particles act as conductors. These conductive particles form chains or bonds at different places under sparking area, which bridges the gap between tool electrode and work piece material. The gap voltage and insulating strength of dielectric fluid reduces due to this bridging effect. Due to this, series discharges takes place within the gap. As aresult of the increase in number of discharging per unit time, rapid sparking takes place that causes faster material removal rate, because of which electric density decreases and hence uniform distribution of sparking takes place. This results in uniform erosion on work piece which further results in better surface finish.

The study also demonstrates detailed methodology of the proposed optimization technique which is based on Taguchi method; and ranks the parameters namely grain size of SiC powder and concentration of SiC powder through S/N ratio. MRR, & Surface roughness of a machined work piece along with Tool Wear Rate of electrode (tool) have been optimized.

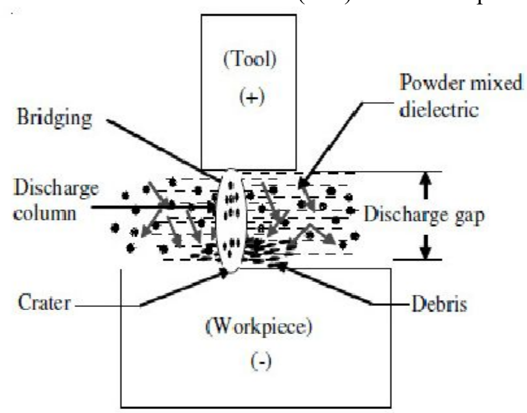

Fig.1: Principle of Powder Mixed EDM Machine

Powder Mixed EDM machine (Press Mach-A25)

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

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

Pulse Generator	A25
Working Current	9 amps
Type of Pulse	STD/EQUI-ENERGY
Pulse Time ON/OFF	2-2000 micro sec.
Max. MRR	165mm./min
Working Voltage	220 volts

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Surface Finish Cu-Steel	≤ 0.5 microns CLA
Electrode Wear	≤ 0.3 %

Selection of Machining Tool (Electrode)

The machining tool selected for present work is trapezoidal shaped copper electrode.

Density of copper is 8.96 gm/cm³.

Selection of Work Piece Material

The work piece material used for current work is AISI 1020 Steel.

Density of AISI 1020 Steel is 7.87 gm/cm³.

TABLE – 2: COMPOSITION OF AISI 1020 STEEL

Elements	Weight %
Carbon, C	0.17 - 0.23
Iron, Fe	99.08 - 99.53
Manganese, Mn	0.30 - 0.60
Phosphorus, P	≤0.04
Sulphur, S	≤0.05

Selection of Conductive Material (Powder)

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

ABLE – 3: PROPERTIES OF SiC POWDER

Powder	SiC
Density	3.1 (g/cm^3)
Thermal Conductivity (at 300K)	120 W.m^{-1}.K^{-1}
Hardness	2800kg/mm^2
Elastic Modulus	410 GPa
Specific heat capacity	750 J/kgK

TABLE – 4: EXPERIMENTAL SETTINGS

Polarity	Positive
Current	9 Amp
Voltage	220Volt
Pulse on time	150 µs.
Duty factor	0.7

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 SiC powder & Concentration of SiC powder. The parameters and levels used in the experiment are shown in Table.

TABLE – 5: PROCESS PARAMETERS AND LEVELS

Levels	Variables	
	Grain Size of Aluminium Powder	Concentration of Aluminium Powder
Level 1	Fine (< 150)	3
Level 2	Medium (150-250)	6
Level 3	Coarse (250 – 350)	9

Design Matrix

The present work consists of two factors and three levels. According to Taguchi approach L9 has been selected. 10 experiments instead of 9 experiments were performed to get the clear difference between the readings found with the use of SiC powder and without the use of SiC 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	Null	0
2	Fine (< 150)	3
3	Fine (< 150)	6
4	Fine (< 150)	9
5	Medium (150-250)	3
6	Medium (150-250)	6
7	Medium (150-250)	9
8	Coarse (250 – 350)	3
9	Coarse (250 – 350)	6
10	Coarse (250 – 350)	9

RESULTS AND DISCUSSIONS

Material Removal Rate (MRR)

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

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

The density of the Low Carbon steel is taken as 7.870 x 10^{-3} g/mm^3.

Surface Roughness (R_a)

Roughness measurement has been done using a portable stylus-type profilometer, Mitutoyo- Surftest SJ- 201P/M. The evaluation length of 0.8 mm is used to measure response R_a value in µm.

Tool Wear Rate (TWR)

The Tool Wear Rate is defined as the volume of metal removed per unit time. To calculate TWR, following equation is used:

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

Response Table

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

TABLE – 7: RESPONSETABLE OF MRR, R_a & TWR

Experiment No.	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=0.8MM	Tool Weight Loss (gm)	Tool wear Rate
1	0	0	0.603043	5	15.324886	3.1333	0.00171	0.03816964
2	FINE (< 150)	3	0.691739	5	17.578871	3.0647	0.00162	0.03616071
3	FINE (< 150)	6	0.695217	5	17.667263	3.0325	0.001395	0.03113839
4	FINE (< 150)	9	0.696086	5	17.58889	2.9901	0.00153	0.03415179
5	MEDIUM(150–250)	3	0.700434	5	17.79985	3.0434	0.001305	0.02912946
6	MEDIUM(150–250)	6	0.704782	5	17.91034	2.9647	0.00126	0.028125
7	MEDIUM(150–250)	9	0.691739	5	17.57887	2.656	0.001395	0.03113839
8	COARSE (250 – 350)	3	0.661739	5	16.816494	3.0547	0.001575	0.03515625
9	COARSE (250 – 350)	6	0.664347	5	16.882788	2.9434	0.00153	0.03415179
10	COARSE (250 – 350)	9	0.674913	5	16.877253	2.855	0.001755	0.03917411

Analysis of Single Response Stage

The individual optimal values of MRR, surface roughness and TWR and its corresponding settings of the process parameters for the specified performance are obtained by Taguchi's method and its characteristics is shown in table.

TABLE – 8: MEANS OF MRR, Ra & TWR AT DIFFERENT LEVELS

Level	Mean Value of MRR		Mean Value of Ra		Mean Value of TWR	
	Grain Size	Concentration	Grain Size	Concentration	Grain Size	Concentration
1	17.611	17.398888405	3.0291	3.0542	0.0338163	0.033482
2	17.76202	17.486797	2.888	2.9802	0.029464	0.0312
3	16.858	17.34	2.951	2.8337	0.0361603	0.0348

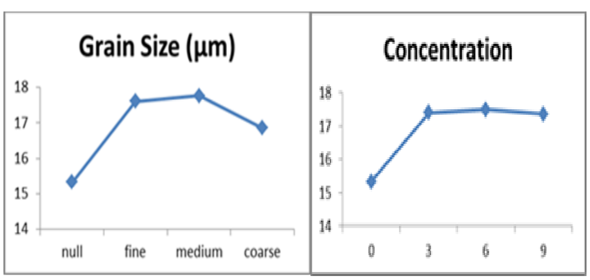

Fig 3: RESPONSE GRAPH FOR MRR

ANALYSIS OF PLOT FOR MRR

Based on Grain Size of Powder

MRR increases with the mixing of SiC powder with EDM oil. At medium size Powder particle, we get maximum MRR.

Based on Concentration of Powder

MRR is low in absence of powder mixed with EDM oil. As we mix SiC powder in the EDM oil in 3 gm/ltr. concentration, MRR increases. With further increase in concentration of SiC powder, MRR also increases. As a result we get best MRR on concentration 6 gm/ltr. of SiC Powder mixed with EDM oil.

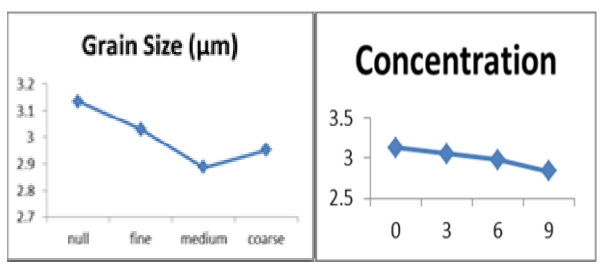

Fig. 3: RESPONSE GRAPH FOR Ra

ANALYSIS OF PLOT FOR SURFACE ROUGHNESS

Based on Grain Size of Powder

Initially the surface roughness is high in the absence of SiC powder and it decreases on the addition of fine sized SiC powder in EDM oil. We get the best result and lowest surface roughness by mixing medium sized SiC powder because surface roughness decreases on the addition of medium sized powder, but further it increases on the addition of coarse grain size of SiC powder.

Based on Concentration of Powder

Initially surface roughness is high in the absence of SiC powder, but when we mix SiC powder in the concentration

3gm/ltr surface roughness decreases slightly, which keeps on decreasing when SiC powder is mixed in the concentration of 6gm/ltr. When we add SiC powder in concentration of 9gm/ltr best surface finish is achieved. So it is observed that the surface roughness decreases with increase in concentration of powder.

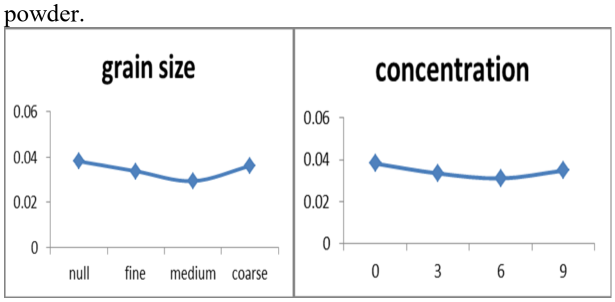

Fig. 4: RESPONSE GRAPH FOR TWR

ANALYSIS OF PLOT FOR TOOL WEAR RATE

Based on Grain Size of Powder

Initially the TWR is high in the absence of SiC powder and it decreases on the addition of fine sized SiC powder in EDM oil. We get the best result and lowest TWR by mixing medium sized SiC powder because TWR decreases on the addition of medium sized powder, but further it increases on the addition of coarse grain size of SiC powder. Hence best results are otained at medium grain size of SiC powder.

Based on Concentration of Powder

When there is no SiC powder mixed with EDM oil, Tool Wear Rate (TWR) is high. As we mix SiC powder in the EDM oil in 3 gm/ltr. Concentration, Tool Wear Rate decreases slightly. With the increament in the concentration of SiC powder upto 6 gm/ltr., Tool Wear Rate decreases further. With the further increase in the concentration of SiC powder upto 9 gm/ltr., Tool Wear Rate sudenly increases.

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 MRR, Ra & TWR. Taguchi proposed many different possible S/N ratios to obtain the optimal process efficiency. Two of them are selected for the present work. Those are,

Larger the better S/N ratio for MRR

$$\eta_1 = -10\log_{10}[\frac{1}{MRR^2}]$$

Smaller the better type S/N ratio for R_a

$$\eta_2 = -10\log_{10} Ra^2$$

Smaller the better type S/N ratio for TWR

$$\eta_3 = -10\log_{10} TWR^2$$

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

$$\eta_{obs} = W_1\eta_1 + W_2\eta_2 + W_3\eta_3$$

Where W_1, W_2 & W_3 are the weights assigned to the MRR, R_a & TWR. Weights are defined according to the importance and choice of the operator, customer's requirements. Weights values taken for W_1, W_2 & W_3 are as follows:

W_1 for MRR = 0.4, W_2 for Ra = 0.35.

W_3 for TWR = 0.25.

The best combination for process parameters for simultaneous optimization of MRR, R_a, & TWR is obtained by the mean values of the multi-response S/N ratio shown in Table.

TABLE – 10: DESIGN MATRIX WITH MULTI-RESPONSE S/N RATIO

S. No.	Grain/Mesh Size of Aluminium Powder (μm)	Concentration of Aluminium Powder	MRR (mm^3/min.)	H_1 for Ra	Surface Roughness (μm)	H_2 for MRR	TWR (mm^3/min.)	H_3 for TWR	H_{obs}
1	0	0	15.32488	-9.920039	3.1333	23.707945	0.038169	28.365638	13.1025738
2	Fine (< 150)	3	17.57887	-9.727759	3.0647	24.899819	0.036160	28.835265	13.7640271
3	Fine (< 150)	6	17.66726	-9.636016	3.0325	24.943385	0.031138	30.134076	14.13826752
4	Fine (<150)	9	17.58889	-9.513714	2.9901	24.904768	0.034151	29.331731	13.96504039
5	Medium(150–250)	3	17.79985	-9.667180	3.0434	25.008326	0.029129	30.713358	14.29815502
6	Medium(150-250)	6	17.91034	-9.439615	2.9647	25.062076	0.028125	31.018149	14.47550263
7	Medium(150–250)	9	17.57887	-8.484561	2.656	24.899784	0.031138	30.134076	14.52383634
8	Coarse(250 – 350)	3	16.81649	-9.699371	3.0547	24.514709	0.035156	29.079949	13.68109099
9	Coarse(250 – 350)		16.88278	-9.376985	2.9434	24.548883	0.034151	29.331731	13.87054119
10	Coarse(250 – 350)	9	16.87725	-9.112122	2.855	24.546035	0.039174	28.140017	13.66417576

TABLE – 11: MEAN VALUES OF η_{obs} AT DIFFERENT LEVELS

Levels	Mean Value of η_{obs} for Process Parameters

	Grain Size	Concentration
Level 1	13.9557783	13.91442437
Level 2	14.432498	14.16143711
Level 3	13.73860265	14.0510175

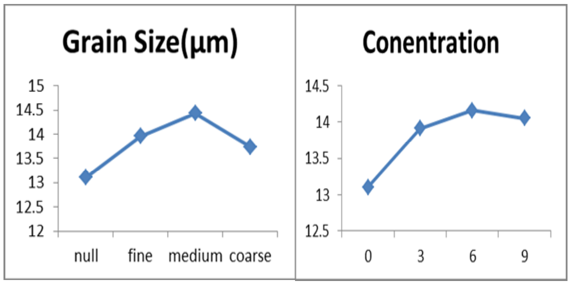

Fig 5:MULTI-RESPONSE S/N RATIO GRAPH

INTERPRETATION OF PLOTS

Based on Grain Size of Powder

This graph gives the combined result for MRR, TWR and Surface Roughness. Initially the multi response value is low in the absence of SiC powder. The multi response value increases with the addition of fine sized SiC powder. It keeps on increasing with the addition of medium sized powder and decreases with the addition of coarse sized SiC powder.

Based on Concentration of powder:

This graph gives the combined result for MRR, TWR and Surface Roughness. Initially the optimum value is low without the addition of powder, it increases on addition of powder in concentration of 3gm/ltr and we get the best result and optimum value of MRR, Ra, and TWR by further increasing the concentration of powder to 6gm/ltr. At 9gm/ltr the optimum value decreases.

CONCLUSION

Based on the results obtained, the following conclusions have been made:

- Grain size of SiC powder and concentration of SiC powder mixed with EDM oil have a great influence on MRR, Surface finish and TWR.
- Too low and too high Grain size of SiC powder in EDM oil reduces MRR of AISI 1020 Steel. So we get the best MRR on medium sized SiC powder. Further increase in concentration of SiC powder in EDM oil, MRR of AISI 1020 Steel increases.
- Too low and too high Grain size of SiC powder in EDM oil reduces Surface finish of AISI 1020 Steel. So we get the best surface finish on medium sized SiC powder mixed with EDM oil.With the increase in concentration of SiC powder in EDM oil, Surface finish of AISI 1020 Steel increases.
- At medium sized SiC powder mixed with EDM oil, we get the least Tool wear Rate.At low and high concentration of SiC powder in EDM oil, TWR is also high. We get least TWR at medium concentration of SiC powder i.e. 6 gm./ltr.
- If we give 40 % weightage to MRR, 35% weightage to Ra, and 25% weightage to TWR, then at medium grain sized SiC powder mixed with EDM oil, and at concentration 6 gm./ltr. of SiC powder we get the optimum level for MRR, Ra & TWR.

REFERENCES

[1] Dr. S. Senthil, Unconventional Machining Process (A.R.S. Publications)
[2] 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.
[3] 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.
[4] 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.
[5] 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.
[6] 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.
[7] 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.
[8] Goyal S. and Singh R.K. (2014), "Parametric Study of Powder Mixed EDM and Optimization of MRR & Surface Roughness", International Journal of Scientific Engineering and Technology, Volume 3, Issue 1 pp.56-62.
[9] Gudur S. and Potdar V. (2015) "Effect of Silicon Carbide powder mixed EDM on Machining Characteristics of SS 316L Material . International journal of innovative research in science, Engineering and technology. Vol.4, issue 4, (2015) 2003-2007
[10] Gudur S. , Potdar V. and Gudur S. (2014) "A Review on Effect of aluminium and Silicon Powder Mixed EDM on Response Variables of Various Materials. Vol 3, Issue 12, (2014) 17937-17945
[11] Unses E. and Cogun C.(2015) "Improvement of electrical discharge machining (EDM) performance of Ti-6AI-4V with added graphite powder to dielectric" strojnŠki vestnik-journal of mechanical engineering 61(2015)6, 409-418
[12] Kumar K. and Khempal (2015)" Key engineering of electrical discharge machining: A Review". International journal for research in applied science and engineering technology (ijraset). Volume 3 issue VII, (2015) 384-395
[13] Jassal N. , Verma S. , Chattopadhyay K. and Pabla B. (2015) "Surface Modification of Aluminium using pm electrode on EDM" International research of scientific research volume 4, issue 10, 91-95
[14] Goyal S. and Rastogi S.(2016), "Experimental Investigation of Machining Parameters of Powder Mixed EDM and optimization of MRR,surface roughness and tool wear rate using Taguchi method" International Journal of aerospace and mechanical Engineering.Vol. 3 No. 2 pp. 39-46