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Effect of Powder Mixed Dielectric Fluid on MRR And SR During Electrical Discharge Machining of RENE 80

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ABSTRACT: This paper mainly focussed to investigate the machining characteristics of RENE 80 Nickel Alloy during powder mixed electrical discharge machining. The experiments were conducted considering electrical parameters (pulse on time, peak current and pulse off time) at optimal combination to get maximum material removal rate by varying powders like aluminium, graphite and combination of aluminium and graphite powders and their concentrations. The experimental results reveal that improvement in material removal rate with addition of powders into dielectric fluid. The maximum material removal rate (75.08 mm^3/min) was noticed with graphite powder substances at 9 g/l. Minimum surface roughness (4.44µm) was noticed at the combination of aluminium and graphite powders (1:1 ratio) substance of 4.5 g/l. However considering simultaneously better values of all two responses namely material removal rate (71.90 mm^3/min) and surface roughness (4.44µm) are obtained with the combination of aluminium and graphite powders (1:1 ratio) of 4.5 g/l.

Keywords: Aluminium Powder Concentration, Graphite Powder Concentration, Combination of Aluminium and Graphite Powders, Material Removal Rate and Surface Roughness.

I. INTRODUCTION

Electrical discharge machining (EDM) involves two electrodes separated by a dielectric medium. When the field strength between the two electrodes is high enough, the dielectric breaks down, current flows across, and material is removed from both electrodes. The current flow between electrodes produces debris which is flushed out by the fluid. This can be done continually to erode a finely controlled element that would be unattainable to machine with traditional machining methods. However certain defects like porosity, residual stress and micro cracks in the recast layer due to enormous temperature followed by sudden cooling are usually found on the machined surface.

The wide applications and usage of this process made many manufacturing research engineers to pay more attention into this process to enhance the process capabilities and applications. Jeswani [1] reported the consequences of graphite powder when mixed into dielectric medium of EDM. It was observed that addition of fine graphite powder in kerosene resulting in improving machining stability, and also increases in tool wear rate (TWR) and MRR. This effect was ascribed to inter space enlargement for initiation of electric discharge and decrease the medium breakdown strength. Yan and Chen [2] studied the consequences of aluminium powder mixed in to dielectric medium. It was observed that increase of spark gap and progress in dispersion of energy causing better MRR. Kung [3] et al reported increase in machining efficiency when Al powder was mixed in medium during EDM of cobalt–bonded tungsten carbide. Anil Kumar [4] et al noticed that MRR increased, when graphite powder was mixed in fluid during PMEDM of Inconel 718. Kuldeep Ojha [5] et al studied the PMEDM performance in respect of MRR and TWR by choosing diameter of electrode, pulse on time, Peak current, and chromium powder as process parameters. Behzad Jabbaripour [6] et al performed PMEDM of titanium alloy by means of different powders like iron, silicon carbide, graphite, aluminium and chromium to investigate the surface topography, MRR and electrochemical corrosion resistance of machined surfaces. V. Vikram Reddy [7] et al reported the effect of graphite powder and surfactant mixed dielectric medium on output parameters like WLT, MRR, SCD and SR during EDM of PH17-4 steel. Murahari Kolli and Adepu Kumar [8] have optimized the surfactant and graphite powder substance into dielectric medium during Titanium alloy (Ti-6Al-4v) machining. Uyyala S.B [9] et al obtained optimal process parameter combination during EDM of RENE 80 alloy.

It was noticed from literature that the suspended powder particles creates higher discharge probability which facilitate ignition process. Further, decrease in breakdown strength of dielectric fluid resulting increase in sparking efficiency. Mixing of conductive powders into dielectric medium, increases the gap distance that reducing spark energy and more uniform distribution of the discharges throughout the surface and ploughing effect of powder substances resulting in surface finish improvement. A number of researchers have conducted experiments to know the effects of various powders with different proportions, grain sizes, and powder properties like density, electrical resistivity, thermal conductivity and other process conditions.

EDM is also being increasing used to machine wide variety of exotic, high strength, high temperature and corrosion resistant and difficult to machine alloys used in aerospace and automobile industries. One such material is nickel super alloy RENE80 which is gaining importance because of its wide usage. RENE80 nickel alloy having high hardness, high strength and creep properties combined with corrosion resistance and oxidation at high temperatures. The RENE80 nickel alloy is widely used in manufacture of turbine blades and engine parts of high speed fighter planes. The demand of high quality components is due to hot sections of gas turbines which are subjected to high mechanical and thermal stresses in the service. Also this RENE80 is not easy to machine owing to its low thermal conductivity, high hardness and high resemblance to react with the cutting materials during machining due to high temperatures generated. Hence it may require non-traditional machining methods to cut this super alloy. Among the non-traditional machining processes, EDM is perhaps the most popular one and adopted by manufacturing industries. Hence it is essential to know the features of electric discharge machining of RENE80 alloy. Still, the available research data in the form of published work pertaining to EDM of RENE80 nickel super alloy is very little. In this study, experiments are conducted to explore the machining characteristics of RENE80 nickel super alloy during EDM process using various powders with varying concentrations mixed into the dielectric fluid.

II. EXPERIMENTATION

In the present work, experiments were carried out by varying the powders namely aluminium, graphite and combination of aluminium and graphite and their concentrations in the dielectric medium. Optimal combination of EDM input parameters such as pulse on time, peak current, and pulse off time values obtained for maximum metal removal rate by conducting preliminary experimentation on work material and were kept unchanged during experimentation. For conducting experiments RENE80 nickel super alloy was chosen as work material and is cut into size of $70 \times 35 \times 4$ mm^3 by wire cut EDM process. The elemental composition of RENE80 nickel alloy is presented in Table I. Physical and Mechanical properties of RENE80 are presented in Table II. Tool electrode material, electrolyte copper of 14 mm diameter and 70 mm length was selected for conducting experiments and its properties were shown in Table III.

Table I: Elemental composition of RENE 80 Nickel super alloy (wt %)

Element	Weight %
Al	5 – 6
C	0.13 – 0.2
W	4.5 – 5.5
Mo	3.5 – 4.8
Ti	2.5 – 3.2
Si	< 0.4
Cr	9.5 – 12
Fe	0.5 max
Ce	0.015max
Co	4 – 4.5
Mn	<0.4
B	0.02 max
Ni	Balance

Table II: Mechanical and Physical properties of RENE 80 Nickel alloy

Work Material	RENE 80 Nickel Super Alloy
Hardness (HRC)	43-45
Ultimate tensile strength (Kg/mm^2)	85
Electrical resistivity nΩ	1300
Thermal conductivity (W/m° K)	11.5
Melting range (°C)	1320 – 1380
Density (g/cm^3)	8.16
Elongation %	3
Reduction in Area %	5 – 7
Creep strength (°C)	975
Creep rupture (Kg/mm^2)	25

Table III: Physical properties of Electrolyte copper

Specific capacity	383 (J/kg °C)
Density	8.95 (g/cm³)
Melting point	1083°C
Thermal conductivity	394 (W/m °C)
Electrical resistivity	1.673×10^{-8} Ω m

The EDM oil grade SAE450 was used as dielectric medium for experimentation. All the experiments were conducted on die sinking FORMATICS 50 EDM which contains controller ELECTRONICA PRS 20 and customized working medium circulating system has been intended for conducting experiments. In custom-made system, for better flow of powders which are mixed into the medium, a micro pump is incorporated. A motorized stirrer system is also installed to avoid settling of powder substances. The customized experimental setup is given in Fig. 1.

Fig. 1: Modified experimental set up

Each experiment was conducted thrice to reduce the experimental error and average value is considered for analysis. The time for machining chosen for each experiment is 3minutes. Many trials were conducted for machining of Nickel based alloy and in 3 minutes the results were obtained after machining and found to be very small variation within the results. Hence 3 minutes machining time is chosen. Various powders namely aluminium, graphite and combination of aluminium and graphite are chosen based on the literature review and also from preliminary investigations, for mixing into the dielectric medium for conducting experiments by varying each powder concentration separately. The physical properties of Al and graphite powders are shown in Table IV.

Table IV: Properties of Al and Graphite powders

Properties	Aluminium Powder	Graphite powder
Thermal conductivity	237 (W/m °k)	3000 (W/m °k)
Electrical resistivity	0.377 (μΩ- cm^{-1})	0.003 (μΩ- cm^{-1})
Density	2.37 to 2.68 (g/cm³)	1.80 to 2.10 (g/cm³)
Particle size	20 to 30 μm	20 to 30 μm
Melting Point	660.32 °C	3419 – 3424°C

The present work focused on to identify the consequences of the above powders and their concentrations on EDM features like MRR, and SR. The electrodes and work pieces were cleaned and polished before machining. The preferred investigational conditions are presented in the Table V.

Table V: Conditions for Experiments

Work piece	70mm X 35mm X4mm
Electrode	Electrolyte copper tool (14mm diameter)
Dielectric Medium	Commercial EDM Oil grade SAE 450+ powder
Polarity	Positive

Flushing	Side flushing with pressure 0.5 MPa
Gap voltage	70 V
Supply voltage	110 V
Pulse on time	65 µs
Peak current	20A
Pulse off time	48 µs
Machining time	3 minutes

For calculating MRR, 300 grams with a resolution of 0.1mg digital weighing balance was used to weigh the work piece before and after machining. Then MRR is calculated as follows.

$$MRR\left({mm^3}/{min}\right) = \frac{\Delta W}{\rho_w \times t} \quad \dots\dots\dots (1)$$

Where ΔW is the work piece weight difference between before and after machining (g), ρ_w is work material density (g/mm³) and t is time of machining in minutes. To measure surface roughness Talysurf was used on machined surface. Roughness measurements were conducted three times and average values are considered for calculation SR.

III. RESULTS AND DISCUSSION

Table VI presents average values of SR and MRR with varying aluminium powder concentration. Table VII shows response values with varying graphite powder concentration. Table VIII presents response values with varying combination of aluminium and graphite powder concentration (1:1ratio).

Table VI: Response values with varying Al powder concentration

Al powder concentration(g/lt)	MRR(mm^3/min)*	SR(µm)*
0	25.47	3.69
4.5	30.42	4.90
9	27.89	5.49
14	44.20	7.47

Table VII: Response values with varying Graphite powder concentration

Graphite powder concentration(g/l)	MRR(mm^3/min)*	SR(µm)*
0	25.47	3.69
4.5	45.61	5.36
9	75.08	5.80
14	59.77	5.03

Table VIII: Response values with varying combination of Al and Graphite powder (1:1 ratio) concentration

Al+ graphite powder concentration(g/l)	MRR(mm^3/min)*	SR(µm)*
0	25.47	3.69
4.5	71.90	4.44
9	68.61	5.66
14	64.43	5.49

*****Average of three values

A. Effect of Powders and their Concentrations on MRR

The variation of MRR with various powders and their concentrations is shown in Fig. 2. Comparison of MRR values with different powders and their concentrations is presented in Fig. 3. It was noticed from the Fig. 2 that MRR increases with mixing of powder particles into dielectric medium. Further MRR increases with increasing in graphite powder from 0 to 9 g/l, and then decreases with supplementary addition of graphite powder from 9 to 14 g/l. Whereas insignificant increase in MRR is noticed when increasing in Al powder from 0 to 4.5 g/l and then decreases with increasing in Al powder from 4.5 to 9 g/l and considerable increase in MRR is observed with increasing in Al powder substance from 9 to 14 g/l. However significant increase in MRR was observed with increasing in combination of Al and graphite powders (1:1 ratio) from 0 to 4.5g/l and then it decreases further increasing in combination of Al and graphite powders (1:1 ratio) from 4.5 to 14g/l.

When powders added into dielectric medium, powder particles gets charged due to voltage applied across the electrode and work piece. This causes the powders to move in a zigzag fashion in the medium. They form a series structure in the spark gap. This structure helps in bridge the gap between the work piece and the electrode. This causes to decrease in dielectric strength of medium and gap voltage which ensuing into series of discharges. This causes increase in sparking frequency with improved flushing conditions. This improves discharge transmissivity under the sparking area because thermal conductivity of dielectric fluid increases. Hence, MRR may increase due to the mixing of powder into dielectric medium.

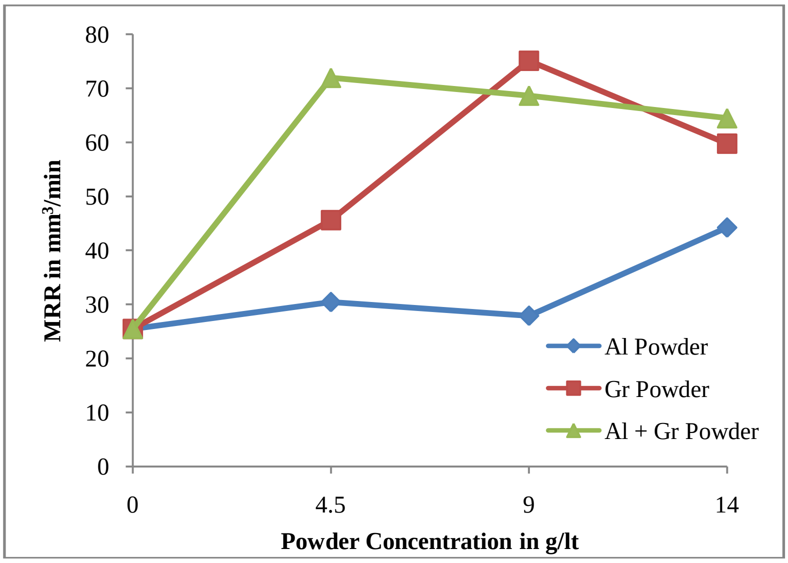
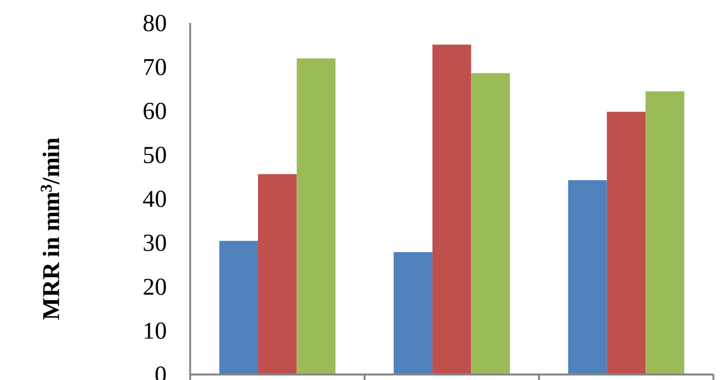


Fig. 2: Variation of MRR with powder concentration



	4.5	9	14
Al Powder	30.42	27.89	44.2
Gr Powder	45.61	75.08	59.77
Al + Gr Powder	71.9	68.61	64.43

Fig. 3: Comparison of MRR with powder concentration

It is also noticed from the Figure 3 that maximum MRR value obtained when graphite powder mixed into dielectric fluid at concentration of 9 g/l. This may be due to low density, high thermal conductivity and melting point of graphite powder when compare with the aluminium powder.

B. Effect of Powders and their Concentrations on SR

The variation of SR with various powders and their concentrations is shown in Fig. 4. Comparison of SR values at different powders and their concentrations is presented in Fig. 5. It was noticed from Fig. 4 that SR increases with powder particles added into dielectric medium. It is observed that SR increases with increasing in aluminium, graphite powders and also with combination of Al and graphite powders (1:1 ratio) from 0 to 9 g/l. it is also observed in decrease of SR with further increment of graphite powder concentration as well as combination of Al and graphite powders (1:1ratio) from 9 to 14 g/l. Whereas there is increase in SR is noticed when increasing in Al powder from 9 to 14 g/l.

The addition of powder substances into dielectric medium increases the discharge gap, the powder particles get energised and arrange themselves under the sparking area and gathered in clusters. The chain formation helps in bridging the gap between both the electrodes, which causes the early explosion. Faster sparking within discharge takes place causes faster erosion from the work piece surface. When graphite powder concentration in dielectric fluid increased the machining gap is reduced. It drastically increases the conductivity and impulsive forces, resulting in high electrical discharge energy and gas explosion makes expanded plasma zone resulting into increased surface roughness with large, deeper craters.

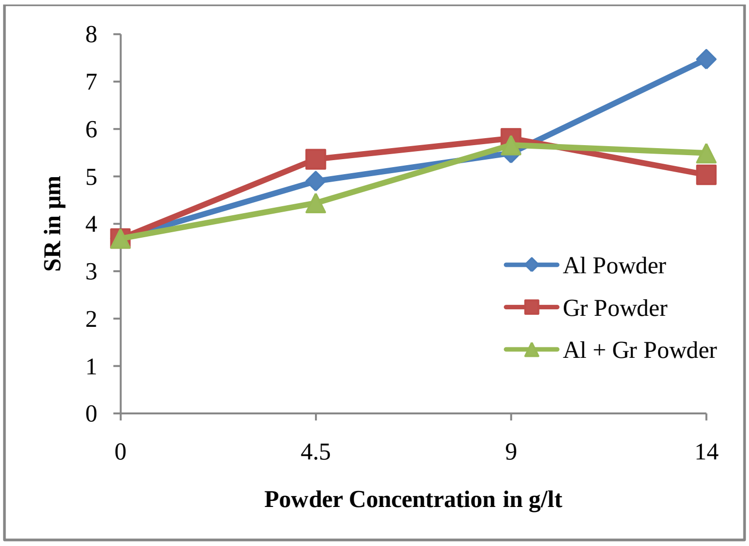


Fig. 4: Variation of SR with powder concentration

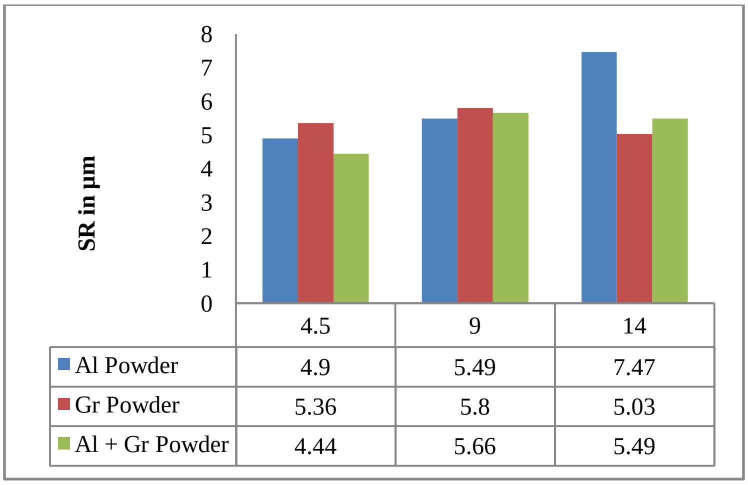


Fig. 5: Comparison of SR with powder concentration

It is noticed from the comparison of SR with powder concentration (Fig. 5) that minimum Surface Roughness is obtained at combination of Al and graphite powders(1:1 ratio) of 4.5 g/l.

IV. CONCLUSIONS

The following conclusions were made from this work:

1. The improvement in MRR and slight increase in SR were observed with mixing of powders into dielectric medium.
2. The trend of MRR and SR values were increased with increase in powder concentration into the dielectric fluid.

3. The maximum MRR (75.08 mm^3/min) achieved when the graphite powder of 9 g/l mixed in medium. The minimum SR (4.44 µm) is obtained at combination of aluminium and graphite powders (1:1 ratio) of 4.5g/l. However considering simultaneously better values for all two responses namely MRR (71.90 mm^3/min) and SR (4.44µm) are obtained with the combination of aluminium and graphite powders (1:1 ratio) of 4.5 g/l. Hence it is consider as the better condition.

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