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# Effect of Graphite Powder and Surfactant Mixed Dielectric in Electrical Discharge Machining of Nickel Alloy

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***Abstract***
The present work aims to analyze the influence of graphite powder and surfactant mixed dielectric during electrical discharge machining of Nickel Super Alloy. Material removal rate and surface roughness are chosen as performance measures. The experiments were conducted by varying graphite powder concentration, surfactant and combination of graphite powder and surfactant into the dielectric fluid at optimal process parametric condition for maximum material removal rate. It is observed from the results that Material Removal Rate (MRR) has been improved by 200 % with addition of combination of Surfactant (6 g/l) and graphite powder (14 g/l) in to the dielectric fluid. It is also noticed that the Surface Roughness (SR) is decreased by 5.49% and reduction in recast layer thickness (RLT) about three times when surfactant (6 g/l) alone added into the dielectric fluid.

***Keywords*:** Electrical discharge machining, MRR, SR, RLT

## 1. Introduction

The effect of additive powders (carbon, copper, iron and aluminium) mixed in to dielectric (kerosene) on EDM of steel-copper and brass-steel pair was studied and observed that machining rate increases with increase in powder quantity. The machining efficiency of the PMEDM process depends upon the type of additive powders, particle concentration, particle size, and their properties like thermal conductivity, electrical resistivity, density, melting point, specific heat, etc. [1]. It is also observed that unbalanced machining obtained at large concentration of powder due to possibility of short circuits [2]. The presence of additive powders in discharge gap significantly affects the factors like gap size, discharge transitivity, breakdown strength, and deionization of dielectric fluid [3]. Experiments were conducted on titanium alloy with various powders like iron, silicon carbide, graphite and chromium to explore the surface topography, MRR and electrochemical corrosion resistance of machined surfaces [4]. It was also noticed that increase in MRR when using graphite powder was mixed in dielectric fluid during PMEDM of Inconel 718 [5]. It was reported improved polishing performance of EDM when applied used with silicon powder added with the dielectric fluid. Favourable results were obtained in terms of reduced crater dimension, less white layer thickness and superior surface finish. [6]. Graphite powder and surfactant mixed dielectric medium effect on output parameters like WLT, MRR, SCD and SR during EDM of PH17-4 steel were studied [7]. The surfactant and graphite powder concentration into dielectric medium were optimized during Titanium alloy (Ti-6Al-4v) machining [8].

## 2. Experimentation

In the present work, experiments are conducted on RENE80 nickel super alloy using electrolyte copper of 14 mm diameter and 70 mm length as tool electrode. In this study, experiments were carried out in four stages. In first stage the experiment was conducted with dielectric fluid only. The second stage experiments were conducted by adding graphite powder into dielectric medium with varying its concentration. In third stage experimentation surfactant mixed into dielectric fluid and fourth stage experiments were conducted by varying graphite powder concentration into surfactant mixed dielectric fluid. Optimal combination of EDM input parameters such as pulse on time, peak current, and pulse off time values obtained for maximum metal removal rate were kept unchanged during experimentation. All the experiments were conducted on die sinking FORMATICS 50 EDM with controller ELECTRONICA PRS 20 and customized working medium circulating system has been intended for conducting experiments. The EDM oil grade SAE450 was used as dielectric medium for experimentation. The time of machining chosen for each experiment is 3minutes. Graphite powder and surfactant SPAN20 are chosen to add into the dielectric fluid.

The present work focused on to identify the consequences of the above powders and their concentrations on EDM features like MRR, SR. The experimental conditions are presented in the Table 1.

Table 1: Conditions for Experiments

| | |
|---|---|
| Work piece | 70mm X 35mm X4mm |
| Electrode | Electrolyte copper tool (ϕ14mm) |
| Dielectric Medium | Commercial EDM Oil grade SAE 450 |
| 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 |

Material removal rate is calculated by weight loss method. Further Talysurf roughness tester is used to measure surface roughness on machined surface. The machined samples were cut into perpendicular to the machined surface by wire cut EDM to find the Recast layer thickness (RLT) and polished. In order to expose the Recast layer structure and boundary line, etchant solution Kallings reagent (Hcl (100 ml) +ethanol (100 ml) + $Cucl_2$ (5ml)) is applied on the polished surface of specimen for a period of 1 minute. For the analysis the images of Recast layer was seen under scanning electron microscope (SEM) (Model Hitachi S3700N model). Further RLT has been found by taking the average values measured at 5 different points.

## 3. Results and Discussions

The values of Material Removal Rate and Surface Roughness values when graphite powder added into dielectric fluid by varying its concentration are shown in Table2. Table 3 represents the MRR, SR and RLT values when addition of graphite powder by varying its concentrations into surfactant mixed dielectric. Table4 presents the response values when surfactant (6 g/l) mixed into the dielectric fluid.

Table 2: Response Values with Varying Graphite Powder Concentration

| GPC(g/lt) | MRR($mm^3$/min) | SR(µm) | RLT(µm) |
|---|---|---|---|
| 0 | 25.47 | 3.69 | 44.63 |
| 4.5 | 45.61 | 5.36 | 28.79 |
| 9 | 75.08 | 5.80 | 41.37 |

| | | | |
|---|---|---|---|
| 14 | 59.77 | 5.03 | 42.39 |

Table 3: Response Values with Varying Graphite Powder Concentration and Surfactant

| SC(6g/l)+GPC(g/lt) | MRR($mm^3$/min) | SR(µm) | RLT(µm) |
|---|---|---|---|
| 4.5 | 46.21 | 5.78 | 29.56 |
| 9 | 53.48 | 5.91 | 33.82 |
| 14 | 76.53 | 6.07 | 40.79 |

Table4: Response Values when Surfactant added into dielectric fluid

| Dielectric | MRR($mm^3$/min) | SR(µm) | RLT(µm) |
|---|---|---|---|
| EDM oil+ SC 6g/lt | 27.17 | 3.49 | 14.43 |

### 3. 1. Effect of Graphite Powder Concentration and Surfactant on MRR

The variation of MRR is shown in Fig1. From this Fig1 it is clear that MRR increased to 45.61$mm^3$/min when graphite powder of 4.5g/l added into dielectric fluid. Then MRR further increased to 75.08 $mm^3$/min when graphite powder concentration increased from 4.5 g/l to 9 g/l and significant decrease in MRR (59.77 $mm^3$/min) is observed when graphite powder increased from 9 g/l to 14 g/l. From Table 8 it is also observed that the increase in MRR (27.17$mm^3$/min) when surfactant (6 g/l) is added into dielectric. Further when graphite powder mixed into the surfactant mixed dielectric fluid with varying its concentrations, it was observed that improvement in MRR with increasing in graphite powder concentration. From Figure 1 maximum MRR 76.53 $mm^3$/min is observed at graphite powder (14 g/l) added in to the surfactant mixed dielectric fluid and the improvement in Material Removal Rate (MRR) is about 200% when compared to normal EDM process. This may be due to the addition of surfactant (SPAN20) conductivity of EDM oil will increases, this cause for shorter bridging time that results shorter discharge relay time. This may be the reason for increase in the actual discharge time, which leads to increase in MRR. The addition of surfactant in the EDM oil causes to retard the agglomeration of fragments, carbon deposit and graphite powder particles because of electrostatic forces during machining. Homogeneous distribution of graphite powder particles achieved in the dielectric fluid and in electrode gap as well which minimizes the bridge effect that causes better circulation of discharge energy which results in overall increase in MRR

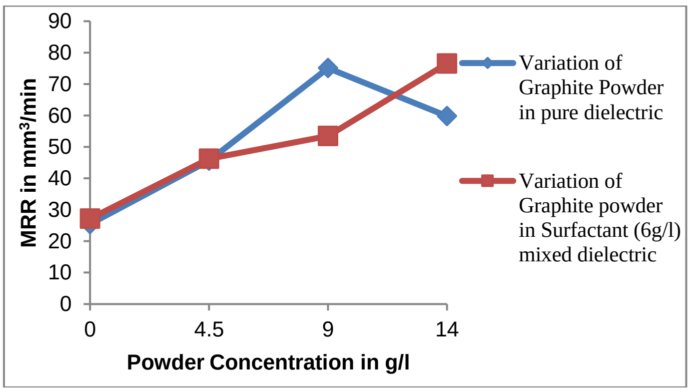


Fig.1: Variation of MRR for various dielectric combinations

### 3. 2. Effect of Graphite Powder Concentration and Surfactant on SR

The variation of SR with graphite powder concentration is shown in Fig2. From Fig2 it is observed that SR is 3.68 µm in normal EDM process. SR increases with increasing in addition of graphite powder into dielectric medium. Further minimum SR is 3.49 µm observed when surfactant (6g/l) is added into the dielectric fluid. It is also observed that increase in SR values with increasing in addition of graphite powder into surfactant mixed dielectric fluid. Due to the addition of surfactant into the dielectric causes wetting the powder, displacing the trapped air and disintegration of the particle clusters which prevent stagnation of the dispersed particle resulting into increased surface roughness and when graphite powder concentration increased the conductivity and impulsive forces drastically increases resulting in high electrical discharge energy density and high gas explosion. When gas explosion starts melting and evaporation take place and the plasma zone is extended which increases the surface roughness.

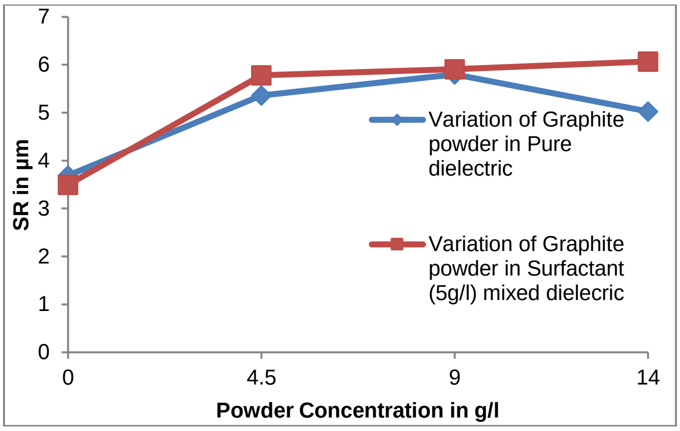


Fig.2: Variation of SR for various dielectric combinations

### 3.3. Effect of Graphite Powder Concentration and Surfactant on RLT

The scanning electronic microscope (SEM) images on machined samples over sectioned surfaces are shown in Figure 4. The variation of Recast Layer Thickness (RLT) with Aluminium powder concentration is shown in Figure 3. From the Figure 3 it is observed that minimum RLT (14.43 µm) is at Surfactant (6 g/l) added into dielectric fluid. When no surfactant added to dielectric medium, the recast layer thickness is extremely high. Significant increase in RLT was found with increase in Graphite powder concentration in to the dielectric fluid. Reduction in RLT was found when surfactant is mixed into dielectric fluid as compared to the normal EDM process. Further RLT is increased with increase in graphite powder concentration added into surfactant mixed dielectric fluid. This may be due to the addition of surfactant into the dielectric fluid increases thermal conductivity causes more heat rejection of spark energy into the dielectric fluid and reduction in energy available for single spark. This results into reduction in RLT.

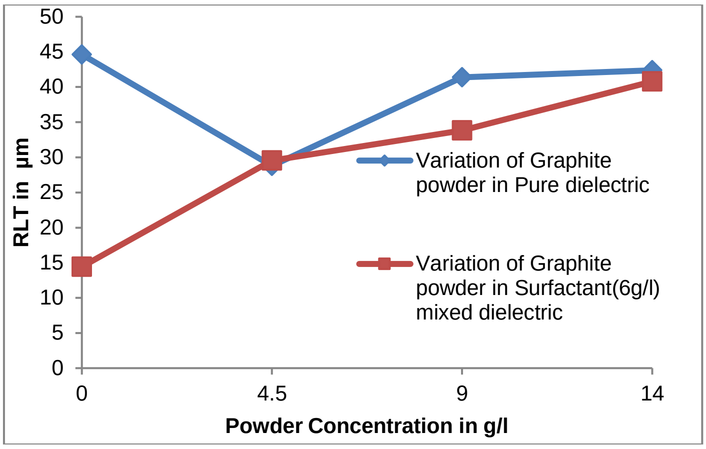


Fig 3: Variation of RLT for various dielectric combinations

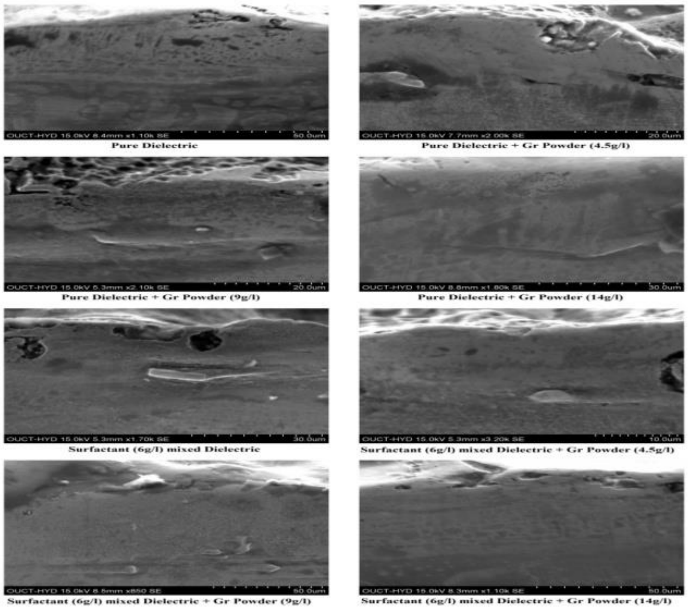


Fig 4: SEM images for RLT

## 4. Conclusions

The following conclusions were made after analyzing the results

1. The maximum MRR 76.53 $mm^3$/min is observed at graphite powder (14 g/l) added in to the surfactant mixed dielectric fluid.
2. The minimum SR is 3.49 µm observed when surfactant (6g/l) is added into the dielectric fluid.
3. The minimum RLT (14.43 µm) is observed at Surfactant (6 g/l) is added into dielectric fluid.

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