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Experimental Investigations into the effects of Grain Size of Powder and Concentrations on Material Removal Rate in PMEDM of Inconel-718

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Abstract

EDM has been frequently used for providing blind holes and deep slots in low machinability materials and difficult to cut materials like super alloys which are used for manufacturing gas turbine blades. On the other hand, Low Material Removal Rate (MRR) is the main problems which are being faced in EDM of Inconel-718. There is need to investigate the effect of powder, powder concentration and powder particle size on MRR of Inconel-718. PMEDM of Inconel-718 indicate that pure Silicon (Si) powder mixed with dielectric gave encourage results. Si powder particle grain size and powder concentrations, these two input parameters have been taken and conducted detailed experimental study. From result it shows that out of all grain sizes chosen for experimentation the smallest grain size i.e. 15 µm and at powder concentration of 10 gm/ltr, gave maximum improvement in MRR when Inconel-718 machined by PMEDM (with suitable addition of pure Si Powder) instead of EDM.

Keywords:

Material removal rate;
Silicon powder;
Average grain sizes;
Powder concentration;
Inconel-718;
PMEDM.

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1. Introduction

The most important parameters of EDM are the Removal Rate, Electrode Wear, Accuracy and Surface Texture. The additives can increase MMR, decrease TWR, and improve the surface quality of work especially in mid-finish machining and finish machining [1]. There are several kinds of additive that can elevate the productivity of EDM when added to kerosene. Some conductive powders and lipophilic surface agents can lower the surface roughness and the tendency of cracks in middle-finish machining and finish machining, but the inorganic oxide additive does not have such effect.

The revised EDM process was developed by modifying the discharging circuit to minimize the discharging current and introducing a new driven mechanism with horizontal rotating electrode. By applying a thin copper diskette electrode, titanium alloy was machined using micro-slit EDM with various dielectric fluids. The dielectric fluids used kerosene, kerosene with aluminum powder, and kerosene with SiC powder. The effects of the various fluids used during the machining process were numerous. Such effects were more clearly accounted for by closely examining the material removal depth, the electrode wear rate, the slit expansion, the surface roughness, and the waveform of the discharging condition. The addition of both SiC and aluminum powder to the kerosene permit an extension of the gap between the electrode and the

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workpiece. The extended gap increased the debris removal rate and the material removal depth. Furthermore, a bridging effect was created by the added powder drifting within the kerosene and, in doing so, facilitates the dispersion of the discharge into several increments. Thus, several discharging trajectories were formed within a single input impulse and several discharging spots were created within a discharging impulse also. The effects due to the discrete discharging pulses are elucidated, these effects being the minimizing of the machined debris, which is easily removed, and the increasing of the material removal depth [2-3].

PMEDM machining can clearly improve machining efficiency at the same time surface roughness by selecting proper discharging parameters, and can provide reference accordingly for application of PMEDM machining technology in rough machining [4]. The aim of investigations was to find additives which led to modified discharge channels. The first investigation referred mainly to those groups of additives which can be found in commonly available spark erosion fluids, depending on the production process [5].

Performance in respect to MRR and electrode wear was compared for two graphite qualities. Correct electrode material is important for productivity and profitability of the manufacturing. Poco AF5 and PocoEDM3 were tested in a 23 factorial test. Two levels of discharge current and pulse duration were tested. The results showed that EDM3 graphite performs very well giving significantly higher MRR than AF5, but still with acceptable relative electrode wear. The AF5 gave significantly lower wear, but also lower MRR [6].

Machining parameters such as the dielectric type, peak current and pulse duration were changed to explore their effects on machining performance, including the material removal rate, electrode wear rate and surface roughness [6]. The additives with significantly different thermo physical properties, including aluminum (Al), chromium (Cr), copper (Cu), and silicon carbide (SiC) powders were studied. Experimental results showed that the particle size of additives in the dielectric oil affects the surface quality of EDMed work [8].

Response surface methodology has been used to plan and analyze the experiments. Pulse on time, duty cycle, peak current and concentration of the silicon powder added into the dielectric fluid of EDM were chosen as variables to study the process performance in terms of material removal rate and surface roughness. Experiments are performed on a newly designed experimental setup developed in the laboratory. The results identify the most important parameters to maximize material removal rate and minimize surface roughness. The recommended optimal process conditions have been verified by conducting confirmation experiments [9]. The research trends reviewed in EDM on ultrasonic vibration, dry EDM machining, EDM with powder additives, EDM in water and modeling technique in predicting EDM performances [10].

An axi-symmetric two-dimensional model developed for powder mixed electric discharge machining (PMEDM) has been using the finite element method (FEM). The model utilizes the several important aspects such as temperature sensitive material properties, shape and size of heat source (Gaussian heat distribution), percentage distribution of heat among tool, workpiece and dielectric fluid, pulse on/off time, material ejection efficiency and phase change (enthalpy) etc. to predict the thermal behavior and material removal mechanism in PMEDM process. The developed model first calculates the temperature distribution in the workpiece material using ANSYS (version 5.4) software and then material removal rate (MRR) is estimated from the temperature profiles. The effect of various process parameters on temperature distributions along the radius and depth of the workpiece has been reported. Finally, the model has been validated by comparing the theoretical MRR with the experimental one obtained from a newly designed experimental setup developed in the laboratory [11].

2. Experimental procedure

The electric discharge machine, model Sparkonix SEM model SN25 (die-sinking type) with servo-head was used to conduct the experiments. The Figure 1 shows the experimental set-up along with EDM machine. In order to prevent powder particles accumulation on horizontal plane surfaces, the dielectric tank has been designed conical. The flushing pipes have been designed to get the dielectric directly from the conical tank. A centrifugal pump was used for circulation of powder mixed dielectric fluid. The flushing pipes have been designed to get the dielectric directly from the conical tank. This design leads to reproducible and constant powder concentration in the dielectric fluid. Further, the pump having two outlets flow control valves. At one outlet flushing pipe is installed and another outlet one more pipe is mounted in order to set the desired flushing flow rate with the help valves. The end of the other outlet is immersed into the dielectric tank, it also perform the function to remove the powder particles which is settle on the top of the clamping vice. Commercial grade EDM oil (kerosene) was used as dielectric fluid. The conical dielectric tank has been designed and ensures the uniform or constant powder concentration of the powder particles in the dielectric fluid was ensured [13].

Figure 1. *View of Powder Mixed EDM (PMEDM) experimental set up*

There is no any accumulation of the powder particles on horizontal plane surfaces (i.e. bottom of dielectric tank). Flow rate of Powder mixed dielectric fluid and flushing system has been properly maintained. Figure 2 shows the close view of experimental set-up mounted on the T-slots of the machine table show the dielectric tank along with clamping system, electrode, tool holder, work piece and flushing nozzle. The Ni-based super-alloys (Inconel-718) and tungsten carbide has been used as work material and electrode material respectively in PMEDM. Two input parameters (Si powder grain sizes 15µm, 25µm and 40µm and concentration of powder) have been varied and rest of all the parameters (like peak current, pulse on time, off time, duty cycle etc) kept constant. Material Removal Rate (MRR) signifies the amount of material that has been removed from a specimen in a specified number of process cycles. It was estimated by calculating the difference between initial weight of the specimen and final weight of specimen after processing at specified set of condition by Powder mixed discharge machining (PMEDM) process. A precision electronic balance was used to measure the weight of the specimens.

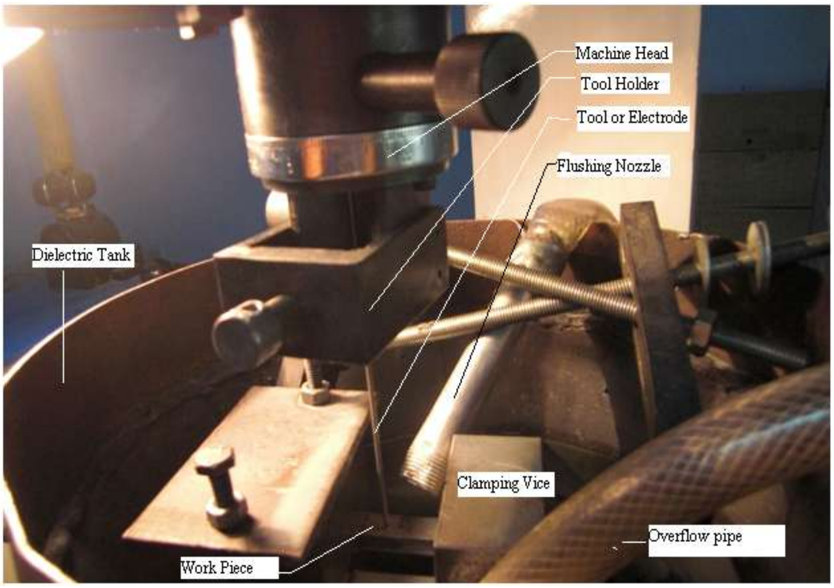

Figure 2. *Close view of experimental Set-up mounted on the T-slots of the machine table shows the dielectric tank along with clamping system, electrode, tool holder, work piece and flushing nozzle.*

3. Results & Discussion

From the results obtained by experimentation, the attempt has been made to study the effects of different powder particles Grain Sizes and their concentration on Material removal rate in PMEDM of Inconel-718 discuss in detail:

It reveals that, when the work piece machined by EDM (i.e. without powder addition) the material removal rate has not been improved as compared to PMEDMed i.e at zero powder concentration the molten metal gets re-solidify at very faster rate due to locally concentrated spark energy. The deposited the molten metal and debris reduces the material removal rate. At zero powder concentration (C=0), the MRR 11.3 mm^3/min was obtained, depicted in Table 1. On addition of Si powder it shows that the MRR increased significantly up to 23.3mm^3/min at powder concentration of 2gm/ltr. Further, by the use of Si powder particles, there was an evident increase the value of MRR and obtained maximum value of 38.7mm^3/min at powder concentration of 10gm/ltr. At this concentration the powder particles helps to extrude the debris easily, consequently increased the material removal rate. The additions of Si powder particles added in kerosene with proper proportion, widen the electrode and workpiece gap, this widen gap increased the debris removal rate.

However, when the silicon powder concentration is kept equal or more than that of 12gm/ltr, the material removal rate decreases drastically this is may be due to the re-solidification of molten metal along with powder particle, arcing and deposition of debris during machining process. So, from above discussion and experimental results, it is possible to conclude that the presence of silicon powder, with appropriate concentration, significantly enhance the material removal rate. The MRR data at various concentrations for Silicon Powder average Grain size of 15 µm depicted in Table 1.

Table 1: Concentration ‘C’ and MRR data for powder grain size of 15 µm

S.No	Concentration ‘C’ (gm/ltr)	MRR (mm^3/min)
1	0	11.3
2	2	23.3
3	4	25.2
4	6	29.0
5	8	36.3
6	10	38.7
7	12	34.8
8	14	31.2

The average powder particle grain size of 25µm, Table 2 shows the experimental values of MRR with respect to various powder concentrations. At concentration of 10gm/ltr gave maximum value of the MRR 30.2mm^3/min but it is less than that of 15µm grain size at 10gm/ltr concentration. On further addition of powder particles, the concentration becomes excess gave poor MRR which may be due to the arcing induced in between the tool used and the work piece which is not desirable. So the optimum concentration for 25µm particle size is 10gm/ltr.

Table 2: Concentration ‘C’ and MRR data for powder grain Size of 25 µm

S.No	Concentration ‘C’ (gm/ltr)	MRR (mm^3/min)
1	0	11.3
2	2	17.4
3	4	19.9
4	6	23.2
5	8	27.9
6	10	30.2
7	12	19.7
8	14	19.7

Further, by the use of powder particles of Grain size 40µm with different powder concentration shows the varying values of MRR as depicted in Table 3. At concentration of 8 gm/ltr gave maximum value 26.2mm^3/min of the MRR which was found less than that of 15µm and 25µm powder particle grain size. The larger size of the powder particle increases the gap between tool and workpiece which gave poor spark energy. On further addition of powder particles, the concentration becomes excess gave poor MRR. So, from above discussion and experimental results, it is possible to conclude that the not only powder particle grain size but also appropriate concentration improves the material removal rate significantly.

Table 3: Concentration 'C' and MRR data for powder grain Size of 40 µm

S.No	Concentration 'C' (gm/ltr)	MRR (mm^3/min)
1	0	11.3
2	2	15.1
3	4	17.4
4	6	22.9
5	8	26.2
6	10	23.0
7	12	21.3
8	14	21.3

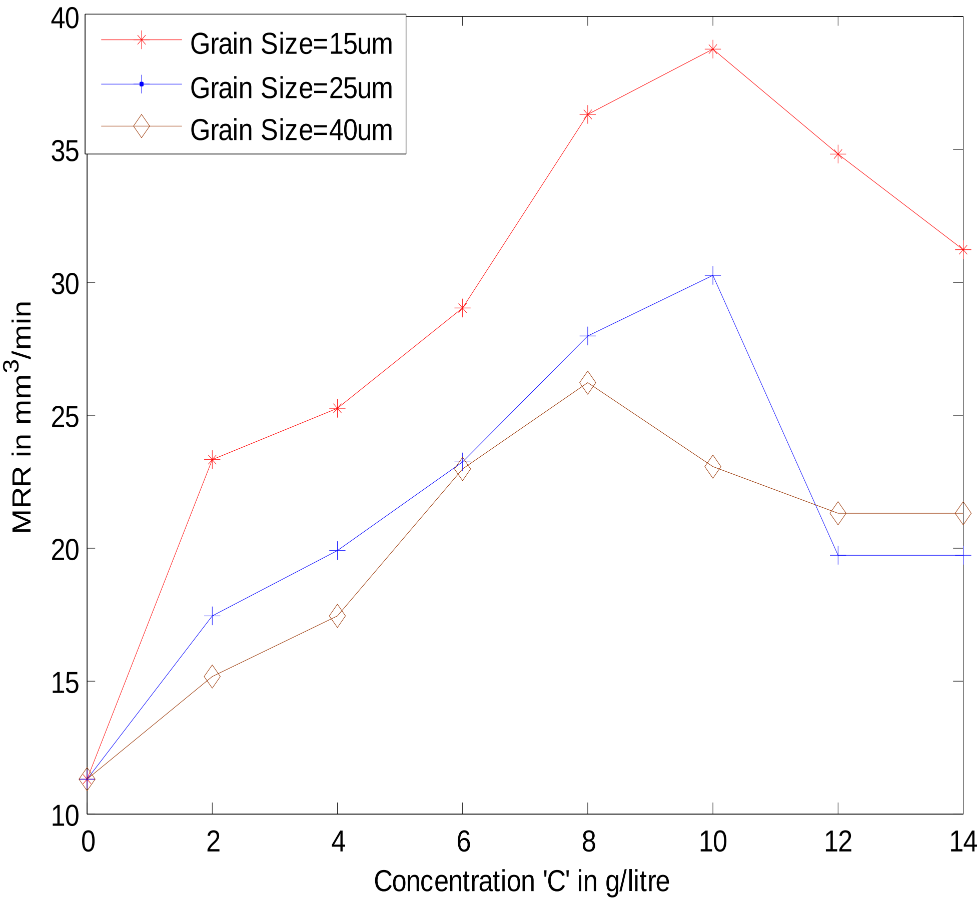

Figure 3: *MRR versus Concentration of powder at different grain sizes with current 3A; Pulse ON Time 6µs; Pulse OFF Time 5µs*

The calculated values of MRR at different powder concentrations and grain sizes are depicted in Table 1-3 and shown graphically in Figure 3. The results show that MRR was achieved maximum for grain size of 15µm as compare to all other grain sizes of powder particles used in this work at all powder concentrations. The MRR increases on successive increments in the powder concentration upto the optimum value, on further addition of powder (> 10g/ltr) the MRR decreases gradually. Further, it is also observed that MRR found maximum at powder concentrations of 10gm/ltr for grain sizes of 15µm and 25µm but at 8gm/ltr for grain size of 40µm. It has been observed that the MRR decreases as the particle average grain size increases. Smaller the powder particle grain size more will be the MRR as shown in Table 4.

Table 4: Powder Particle Grain Sizes vs maximum MRR at appropriate powder concentration

S.No	Powder Particle Grain Sizes (µm)	MRR (mm^3/min)	Powder Concentration (gm/ltr)
1	15	38.7	10
2	25	30.2	10
3	40	26.2	08

Larger particle size increases the spark gap causes the low spark intensity which subsequently gave low MRR. The Si powder particles uniformly distributed among the spark gap and the gap distance setup between tool and the work-piece increased from 15 to 40µm for chosen grain sizes.

4. Conclusion

In this experimental work, a powder-mixed electro discharge machining method is used to produce holes in a work piece of Inconel-718 and the effects of variation powder particles Grain Sizes and their concentration on Material removal rate in PMEDM of Inconel-718 is analyzed and the work completed is summarised as:

For the grain size of 15µm about 71% improvement, for 25µm about 62% improvement and for 40µm about 54% improvement in MRR has been observed when Inconel-718 was machined by PMEDM (with suitable addition of pure Si Powder) instead of EDM. Further, it is also observed that MRR found maximum at powder concentrations of 10gm/ltr for grain sizes of 15µm and 25µm but at 8gm/ltr for grain size of 40µm. MRR decreases on increasing the Grain size of powder particles. A larger size of the powder particles increases the gap but simultaneously decreases the material removal rate (MRR). Out of all chosen grain sizes, the 15µm particle size gave encourage results at optimum powder concentration of 10 gm/ltr. So it is reveals that not only the optimum silicon powder concentration but also the grain size affects the Material Removal rate of the PMEDMed process.

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