Influence of Different Powder-Suspended Dielectric on The EDM Characteristics of Inconel 825

Soni Kumari, Goutam Nandi, Pradip Kumar Pal

***Abstract:** The present work aims to study the influence of various powder-suspended dielectrics viz. aluminium (Al), graphite (C), and silicon (Si) on several EDM performance characteristics namely material removal rate (MRR), surface roughness (Ra), and radial overcut (ROC) of Inconel 825. Results indicate that the powder properties like thermal conductivity, electrical conductivity, density, and hardness have a major impact on the machining performance and the quality of the machined surface. It has been observed that the aluminium powder particles dispersed in EDM oil yield highest material removal rate as compared to the other powders whereas the silicon powder particles provide a better surface finish and least radial overcut.*

***Index Terms:** EDM, Inconel 825, Machining, Powder suspended dielectrics.*

I. INTRODUCTION

Powder-mixed electric discharge machining (PMEDM) is one of the novel furtherances in the domain of EDM. In it, nano-sized abrasive powder particles are dispersed in the dielectric with the purpose of increasing electrical and thermal conductivities of the working medium. These dispersed particles reduce the overall electrical resistivity of the dielectric and permit the spark generation from an enlarged gap. Hence, ameliorated spark frequency and controlled flushing mode with multitudinous sparks lead to enhance both MRR and surface quality. Therefore, it became necessary to examine the impact of powder suspended particles during the EDM.

Jahan et al. (2000) executed micro-EDM of cemented WC–Co and scrutinized various surface characteristics namely roughness average (R_a), surface topography, peak-to-valley roughness (R_{max}), and crater dimension. It has been noticed that the dielectric dispersed with graphite powder particles enhances the material removal rate, increases the surface finish, and decreases the electrode wear ratio. Kumar and Batra (2012) assessed the surface characteristics during tungsten–PMEDM of different die steels. The study concluded that adequate transference of carbon and tungsten at the work surface enhances the microhardness. Bhattacharya et al. (2012) performed PMEDM on HCHCr, EN31, H11 die steel materials and examined the favorable parametric combination. It has been noticed that the combination of copper tool and dielectric dispersed with aluminium powder particles enhance the MRR. However, graphite-PMEDM yield low MRR but better surface finish. Singh and Yeh (2012) executed abrasive powder-mixed electro-discharge machining (APM-EDM) on aluminium MMCs and optimized the multi-response characteristics by means of grey relation analysis. Bai et al. (2013) performed powder-mixed near dry (PMND)-EDM and established a connection between the machining parameters and MRR. It has been noticed from the study that the MRR increases when the pulse duration peak discharge current, air pressure, and flow rate, increase. However, when the tool rotational speed and pulse-off time increase, the MRR decreases. Prihandana et al. (2014) executed micro-EDM on Inconel 718 and studied the effect of dielectric dispersed with MoS2 powder particles in suitable size and concentration to enhance the quality microholes. Kolli and Kumar (2014) achieved improved material removal rate, better surface finish and lower tool rate during B4C dispersed PMEDM of Ti–6Al–4 V alloy. Singh et al. (2015) utilized a graphite tool electrode to perform PMEDM on Co 605 superalloy and attained improved microhardness and surface finish. Razak et al. (2015) performed PMEDM and studied the impact of particle size and concentration of silicon carbide on various performance characteristics namely surface finish, material removal rate, machining time, tool wear rate, and cost. Kuriachen and Mathew (2016) utilized a tungsten carbide electrode for machining Ti–6Al–4V and assessed the impact of dielectric dispersed with SiC powder particles. Baseri and Sadeghian (2016) examined the influence of various parameters namely surface roughness, energy input, tool wear rate, tool rotational speed on MRR, and the TiO_2 powder concentration.

However, it has been depicted from the literature that lesser work had been carried out to study the machinability aspects of Inconel 825 during the PMEDM. Therefore, the present work highlights the relative study between the conventional EDM (where no powder particles have been dispersed in the dielectric) and PMEDM (where graphite, aluminum, and silicon powder particles have been dispersed in the dielectric) to examine the machinability of Inconel 825 alloy.

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II. EXPERIMENTATION

A special experimental setup, as shown in Fig. 1, has been prepared by placing a self-fabricated tank on an existing die sinking spark erosion machine (Model: Sparkonoix S-50 manual+ ZNC made by Sparkonix India Pvt. Ltd., India).

Fig. 1 An experimental setup for the EDM process

Three different powder particles i.e. graphite, silicon, and aluminium have been used in the experimentation. Two crucial properties of the powder particles namely thermal conductivity and electrical resistivity, listed in Table 1, significantly affect the process of EDM.

TABLE I

Thermal conductivity and electrical resistivity of powder particles

Properties/Powders	Thermal conductivity ($Wm^{-1} K^{-1}$)	Electrical resistivity ($\mu\Omega$-cm)
Graphite (C)	3000	103
Silicon (Si)	168	2325
Aluminium (Al)	236	2.89

Rectangular shaped (40 mm x 40 mm x 5 mm) Inconel 825 has been used as the workpiece material with positive polarity throughout the experimental trails. Table 2 lists the chemical configuration (percentage by weight) of the workpiece. A cylindrical shaped copper bar having a diameter of 8 mm has been chosen as a tool electrode.

TABLE II

Inconel 825 configuration (percentage by weight)

Element	Content
(C)	0.03
(Si)	0.35
(P)	0.01
(Ni)	39.01
(Mn)	0.12
(S)	0.02
(Cr)	22.70
(Mo)	2.78
(Cu)	2.78
(Ti)	0.65
(Co)	0.034
(Al)	0.05
(V)	0.06
(W)	0.4
(Fe)	30.99

The selection of process parameter plays a crucial role in obtaining the desired output. In this context, the following process parameters (Table 3) have been selected. These parametric values have been fixed throughout the experimentation.

TABLE III

Process parameters with their respective values

Parameter	Value
Gap Voltage (V)	230
Current (A)	5
Pulse on time (μs)	200
Pulse off time (μs)	100
Flushing pressure (kg/cm^2)	0.5
The gap between the tool electrode and workpiece (mm)	0.5

Total twelve experimental trails have been taken on the workpiece. Initially, three experimental trails have been taken with pure EDM oil where no powder particles have been dispersed in the machining oil. The remaining nine trails, three for each powered particles, have been taken with varying percentage of 2g/ltr, 4g/ltr, and 6g/ltr by weight. A weight measurement of the powder particles and the workpiece before and after machining have been done using an electronic digital precision balance checker (Model: CWS series; Make: Scaletec Mechatronics Pvt. Ltd., India; Accuracy: 0.001g) as shown in Fig. 2.

Fig. 2 Weight measurement of the powder particles

The surface roughness (R_a) of the machined samples has been evaluated by means of a Talysurf surface roughness tester manufactured by Taylor Hobson. A toolmakers microscope has been employed to measure the diameter of the machined samples as shown in Fig. 3, whereas the diameter the tool electrode has been measured using a digital Vernier caliper. By means of these measurements, the radial overcut (ROC) for all the trails has been calculated.

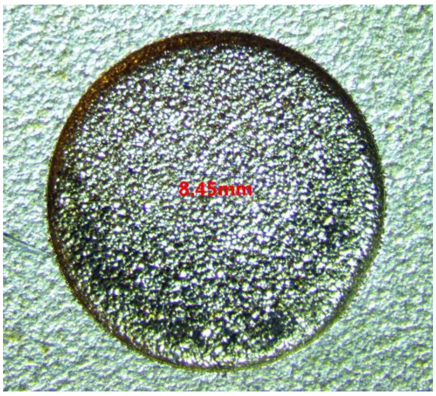

Fig. 3 Measurement of machined surface diameter

III. PROCEDURE FOR PAPER SUBMISSION

Material removal rate, surface roughness, and radial overcut have been measured for Inconel 825 with respect to the dielectric dispersed with various powder particles.

A. Material removal rate

Amelioration in the material removal rate has been witnessed for all the three powders due to their uniform dispersion in the dielectric. The attribute behind such amelioration in MRR goes to the abatement in breakdown strength of the dielectric due to the insertion of conductive particles. In a conventional EDM process, the gap between the two electrodes is quite low but here, in case of a powder dispersed EDM, it expands tremendously and due to this, the discharge passages gets stretched. However, these powder particles attempt to bridge this opening between the electrodes. Therefore, the powder particles, which has to be dispersed in an increasing percentage, increases the sparking frequency leading to an amelioration in the MRR. The influence of powder particles and the process parameters on MRR has been depicted in Fig. 4.

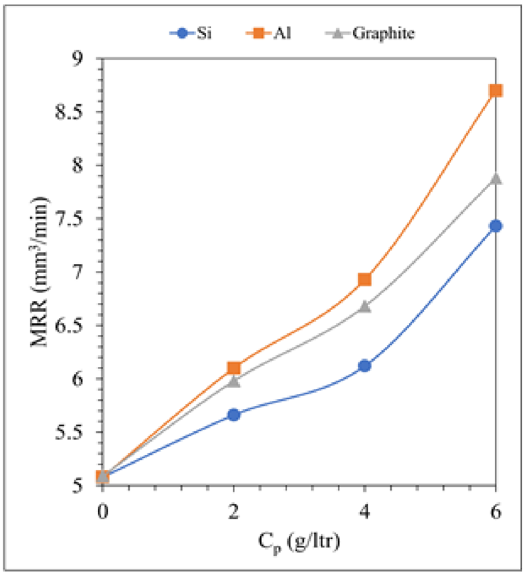

Fig. 4 Effect of powder particles on MRR

Out of these three powder particles, it has been found that aluminum powder particles produce the highest MRR. It is because of the low electrical resistivity of aluminium powder particles as compared to the graphite and silicon powder particles (Refer to Table 1). Low electrical resistivity of aluminium powder particles enables the spark generation from a longer distance as compared to the other particles, which in turn increases the sparking frequency. Additionally, the remains after machining have been cleansed away effortlessly and instantly due to the better spark gap. Therefore, better MRR has been attained from the aluminum powder in a concentration range of 6 g/ltr. With increasing concentrations, accumulation of aluminium begins. These accumulated particles stuck to the workpiece and produce short circuit and short arc. On the other side, graphite powder particles, which are less dense as compared to the other powder particles, readily mix with the dielectric and attain highest MRR at the concentration of 6 g/ltr. Among all these powder particles, silicon possesses the lowest electrical and thermal conductivity. Therefore, it does not affect the MRR as much as other particles do. MRR increases when the peak current increases. An amelioration in MRR occurs because of an increment in discharge energy.

B. Surface roughness

The insertion of these powder particles reduces the surface roughness significantly. All these powder particles are subjected to the plasma channel and the gas babble where they get pressed heavily. Due to these situations, the entrapment of gas in the cavities decreases considerably. Consequently, smooth, uniform and the less concave surface has been obtained. The influence of powder particles and the process parameters on R_a has been depicted in Fig. 5.

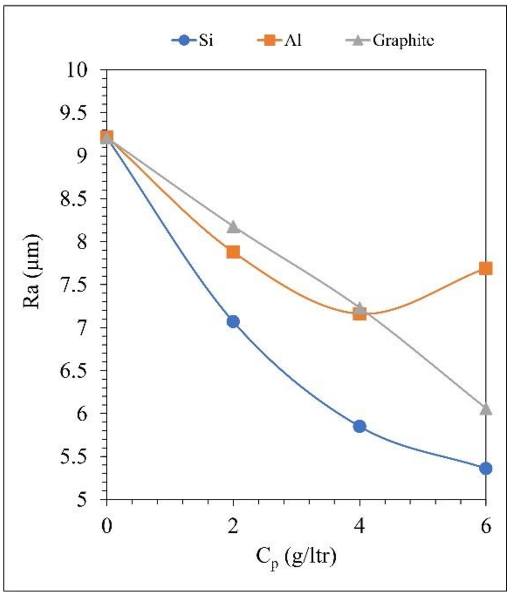

Fig. 5 Effect of powder particles on Ra

As the silicon particles possess low thermal and electrical conductivity, their insertion into dielectric result in minimal surface roughness accompanied by aluminum and graphite powder particles. At a specific time, several silicon powder particles enter into the electrode gap due to their smaller size. Consequently, the overall discharge energy gets dispersed uniformly in a bigger region.

Amid a single discharge, several craters, in small sizes, get formed. As a result, small sized silicon particles yield higher surface quality as compared to the large sized particles of aluminum and graphite. The sharp-edged silicon particles increase the abrasive action on the crater edges. Therefore, shallow craters have been witnessed with dielectric dispersed with silicon particles. Even though the aluminium powder particles possess high electrical conductivity than graphite powder, they yield high surface roughness as compared to the graphite powders. There may be a number of causes behind this conduct. First, the density of aluminium powder particles is higher than that of graphite powder particles. Due to this, the aluminium powders do not mix homogeneously with the dielectric. Hence, discharge energies have been dispersed uniformly among the powder particles, specifically, in the case of graphite powder particles, which make them appropriate for the production of small and shallow craters. Besides this, the aluminium powder particles have a propensity to accumulate due to the Vander-walls force or electrostatic force when added to the dielectric. The surface roughness of the samples reduces when the concentration of powders increase. However, when the powder concentration gets high, the surface roughness decreases. It occurs because of a bigger discharge heat area, which in turn, reduces the discharge density to form large diameter and shallow craters on the surface. The availability of too much powder particles in the dielectric results in short-circuiting which in turn increases the surface roughness.

C. Radial overcut

The breakdown strength of the dielectric radically decreases due to insertion of conductive powder particles in it. The weak breakdown strength enables the spark generation from a longer distance. As a result, radial overcut increases. The influence of powder particles and the process parameters on ROC has been depicted in Fig. 6.

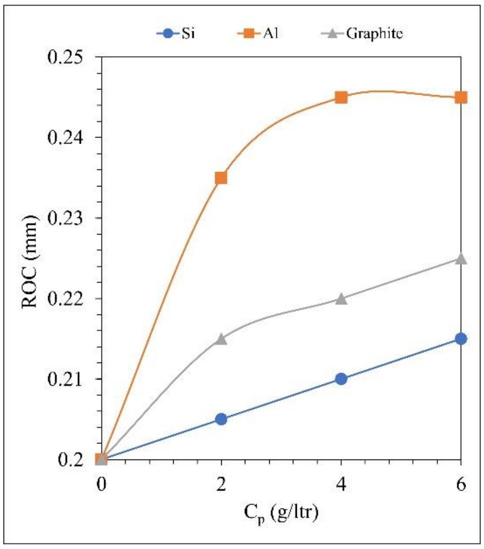

Fig. 6 Effect of powder particles on radial overcut

The properties of powder particles affect the ROC remarkably. The silicon powder particles have an insignificant effect on the ROC due to their thermal and physical properties. The density and the electrical resistivity and of silicon particles are highest among all the particles. Hence, they are less homogeneous and possess the highest insulating strength. Due to these two actualities, silicon powder particles dispersed dielectric yields in low ROC. As the electrical conductivity of aluminium particles is highest, the dielectric dispersed with aluminium powder particles yields in high ROC. When the concentration of the powder particles increases, the ROC also increases. The breakdown strength of the dielectric profoundly decreases due to the occupancy of conductive or semi-conductive powder particles in the gap leading to a bigger spark gap.

IV. CONCLUSION

The study reveals that the powder-mixed EDM has a significant influence on MRR, surface roughness, and radial overcut. The influence of different powder particles has been recapitulated as follows:

- Aluminium powder particles yield best MRR followed by graphite and silicon powder particles for the powder concentration range of 6 g/litre. The MRR produced by the aluminium powder particles increases with increasing powder concentration.
- With increasing concentration of powder particles, silicon powder particles yield better surface finish accompanied by graphite and aluminium powder particles. However, at lower concentration (up to 4 g/litre) of powder particles, aluminium gives a better surface finish than the graphite.
- The silicon powder particles produce the least radial overcut accompanied by graphite and aluminium powder particles.

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