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INFLUENCE OF POWDER SUSPENDED DIELECTRIC ON MRR & SURFACE ROUGHNESS IN EDM

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ABSTRACT

EDM is a non traditional machining process used to machine complex shape electrically material irrespective to its hardness by removing material through electrically discharges in the presence of dielectric fluid. Powder mixed EDM is modified process which is used to improve surface roughness in addition to improvement in machining efficiency of the process .This process can be applied to fine finishing machining which eliminate post production surface treatment Powder mixed EDM has a different mechanism from the conventional EDM which can improve the surface roughness and higher resistance to corrosion because of the diffusion of electrode (tool) and/or powder into the machined surface. Various powders materials like Aluminium (Al), chromium (Cr), copper (Cu) & sililicon carbide (SCi) has its different effects on material removal rate and surface finish. An intensive study is carried on the investigation done by the different researchers in the field of Powder mixed EDM. This paper presents the different effects of various powders & their characteristics on the efficiency of EDM when used as suspended particles in dielectric fluid.. The mechanism of EDM in Powder suspended dielectric fluid is also discussed. This paper mainly focused on the effect of powder concentration, the particle size, the particle density, and the particle receptivity, thermal conductivity of powder along with other machining parameters on MRR and surface roughness are discussed. Highest surface finish & MRR can be achieved by selection of proper powder characteristics & optimum parameters.

Keywords Powder mixed dielectric EDM, MRR, Surface Roughness. Powder characteristics

1. INTRODUCTION

From several decades Electro-Discharge Machining has been an important manufacturing process for the Mold & die manufacturing because of its versatile quality to machine hard materials which are extremely difficult to machine by using conventional machining processes.[24**]**. EDM is non-conventional machining method in which material is removed from the work-piece by series of repeated electric discharge between the electrode (tool) and work-piece in the presence of dielectric fluid. This process has wide application in industries because to ability to machine geometrically complex shapes of any material irrespective of its hardness. The process is widely used in machining of tool, dies and mold of harden tool steel Industries. But due to its low machining efficiency and poor surface finish it is restricted to further applications and requires lot of research to improve its performance [25]. Since 1940 a considerable research effort has been made to have deep understanding, prediction and control of the electro-discharge machining process [4**]**. Several researchers had studied several approaches to increase the surface quality and machining efficiency namely electrode rotary movement, the electrode composition and discharge processes modification, hybrid process of joining of EDM with other non conventional machining method like ultrasonic machining, electrochemical, electro-grinding etc.

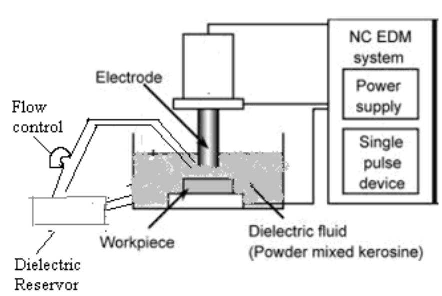

Fig. 1 Schematic diagram of EDM Process

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In normal EDM process low current finishing operations are characterized by long machining time, low discharge, high tool wear & uncertainty in the final surface finish **[16**} After Electro discharge machining mechanical polishing is must to achieve surface finish, which requires enormous time, reduced manufacturing efficiency. Powder Suspended dielectric EDM is developed to achieve fine surface finish at relatively high machining rate.[16,20**]** Recent study have to carried out to generate Near mirror of mirror like surface finish by using powder suspended dielectric in Electro-discharge machining. In spark erosion machining of the EDM process, the discharge point temperature is estimated to exceed several thousand degrees Celsius [12**]**. Metallic electrodes usually work best for Electr5o-discharge machining materials that have low melting points such as aluminum, copper and brass. As for steel and its alloys, graphite is preferred. The general rule is: metallic electrodes for low temperature alloys: graphite electrodes for high temperature alloys. The locally generated high-temperature sparks causes the surrounding dielectric fluid to evaporate and volume to expand. The high pressure generated by this inertial enclosure effect quickly removes molten metals from the surface of machined material. In EDM controlled discrete electrical discharges between the tool and the work electrode would degenerate into arcing. i.e. spark concentration when too much debris exists in the spark gap because of failure to evacuate debris. Actually, the low discharge energy and the small electrode-work-piece distance lead to difficulties in gap cleaning, to the capacitive effect enhancement and to discharge igniting delay. **[17,18**]. Most promising one is modified process of EDM is used in which machining is achieved in presence of conductive and semi conductive micro powder suspended in the dielectric fluid [10,14,16]**.** Addition of powder particles in the dielectric results increase of discharge gap accompanied by reduction of capacitive effect influence and the abnormal discharge occurrence.

In 1981, Jeswani studied the effects graphite powder mixed dielectric in EDM and noted that MRR is increased [5]. Several researchers have studies the effect of different powder suspended dielectric on MRR & Ra. Wong.et.al. (1998) reported to achieve near mirror finish surface by using semi conductive Si and C powder mixed dielectric by lowering the breakdown strength of the insulating dielectric fliud and increasing the discharge probably [23]. Powder additive can cause higher material removal rate [5,14,23]**.** Firstly the effect of impurities of various materials like Cu, Al, in dielectric fluid of EDM was studied.[2]**.** Further various studies have been carried out by Mohr et. Al in which he investigated effect of silicon powder on MRR and SR in EDM [13,14,15].

Like other machining methods EDM machining is also divided into two phases, rough machining & finish machining. The finish machining phase requires high surface quality, while rough surface machining phase requires high machining efficiency with certain quality. Numerous research results show that powder mixed EDM (PMEDM) machining can distinctly improve the surface roughness & surface quality in the in the finish machining phase & obtain nearly mirror surface finish [14]

2. MECHANISM OF POWDER MIXED EDM

Papers, In conventional EDM, Electric field is formed by dielectric fluid & it contributes in initiating discharge breakdown as shown in fig 2.

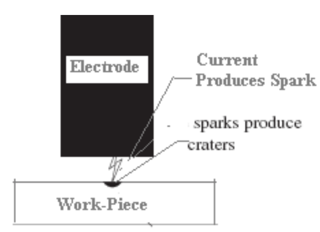

Fig 2 Mechanisum of EDM

But in powder mixed EDM, changes in the discharge gap produced due to the current conducting micro-powder. Addition of powder like Silicon, graphite, or Aluminium to the dielectric fluid result, excellent surface finish. This process is also known as diffused Discharge machining. In this process the electric discharges from the electrode do not directly strike to the work-piece like conventional EDM, but strike the suspended micro-particles in the fluid & generate micro-discharges .as shown in fig 3. This micro-electrical discharges result in craters to small that they produce a mirror finish. .

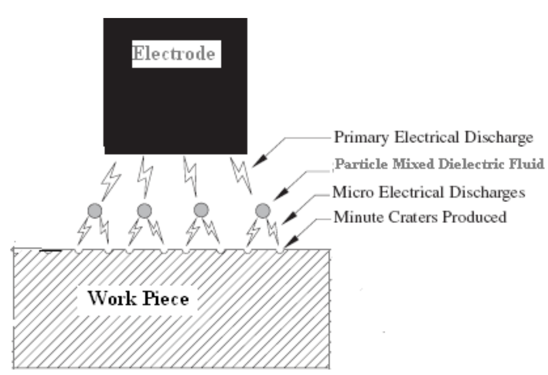

Fig 3 Mechanism of powder mixed EDM

2.1 Discharge Gap

Without powder mixed EDM, the insulated property of the dielectric fluid form even density electric field, and contribute little in initiating of discharge breakdown and hence small discharge gaps. Where as in powder mixed EDM, lot of current conducting micro powders produces changes in the discharge gap**.[25]** The debris in the spark gap usually consists of metal & carbon particles results in insulating fluid drastically lowers the breakdown strength of dielectric. Gap debris facilitates the ignition process & increase the gap size [10]. Under the pressure of gap voltage, lots of positive and negative charges gather at the top and bottom of the powders. The nearer to the top or bottom points, the higher is the electric charge density. Then between these two powders particles, where electric field density is the highest, discharge breakdown will firstly occur when the electric field density exceed the break down-resistant capacity. Discharge breakdown then causes a short circuit between the two powder particles and redistribution of electric charges. More electric charges then gather at those points which lead to further discharge between these two powder and other powders, resulting in series of discharges and finally discharge breakdown between the electrode and the work-piece. As the distances between powders become smaller than the discharge gaps and more electric charges gather at the extremities of the powder than at other points, series of discharges occur easily and this series of discharges will cause discharge through the whole discharge gap. In the process of powder mixed EDM, electric discharge can easily occur due to enlarged discharge gaps. This enlarge gap improves the flushing & results in much more stable cut. The current is evenly distributed & greater surface area can be machined & higher spark energy can be used, this results in finer finish. This improves the flushing & results in much more stable cut. The current is evenly distributed & greater surface area can be machined, & higher spark energy can be used & this results in finer finish.

2.2 Discharge Passage

At electric discharging, current carriers (ions and electrodes) are accelerated towards the anode and the cathode and accumulate energy while moving and collide with medium molecules and powder particles this causing them to gather energy and release more carriers, thus multiplying current carriers in the passage and then the widening of the passage occurs. As the discharge gap is widened in this machining, its discharge passages are wider than those of without powder mixed EDM

2.3. Distribution of Powder Particles

The widening of discharge gaps and even distribution of powder particles in the discharge gaps reduce the initializing action of the etched scraps on electric discharge and effectively prevent intensive discharge, resulting in even discharge and even distribution of etched cavities on the machined surface. This widened discharge passage enlarges the discharge heat influenced area and reduces the discharge density to form large and shallow etched cavities on the machined surface. This improves the surface finishing with the same setting of machining parameters.

Thus PM EDM process with a low discharge current, low discharge time and an electrode negative polarity enables a small surface roughness on large arrear with proper setting of process variables.

Different researchers reported that gap debris have significant influence on discharge transitivity, gap size, breakdown strength & deionization [5, 10**]**. Theoretically the effect of debris controlled to some extent by the characteristics of suspended powder particles. Role of powder characteristics include particle size, particle concentration, particle density, etc in PMEDM so far unclear. Once a sufficient understanding of their influence is established, the optimum selection of these particles (Additives) will be the key to success in precision EDM

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3. POWDER CHARACTERISTICS

Type or print your Various characteristics of powder like particle size, particle concentration, particle density, electrical resistivity, thermal conductivity, micro-hardness, melting point, evaporation point, latent heat, density of striking particle have been studies on different type of powder material mixed in dielectric fluid. Overall effects of these properties at various setting of machining parameters on final Material removal rate and surface roughness have been carried. The beginning of this hybrid process started with finding the effect of impurities (aluminum copper, carbon, and iron) in dielectric fluid of EDM by Erden and Bilgin [2]. Jeswani investigated the effect of graphite powder in Kerosene oil as dielectric and reported improvement of MRR and reduction of Tool wear rate .Mohri et al. investigated the effect of silicon powder mixed machining and reported of better performance on MRR and SR under controlled machining conditions [13, 14, 15]. Wong et al.. (1998) studied the effects of different powder graphite, Silicon, Aluminum crushed glass silicon carbide and molybdenum sulphide on tool steels (SKD-11, SKD-16,SKH-51, SKH-54 and AISI-01) [23]

. It is reported of Al powder able to produce mirror like finish surfaces on SKH-51 and have no effect on SKH-54, whereas graphite powder appears to have better properties conducive to the generation of fine surfaces. Carbon properties are not seems to be conducive for generation of fine surfaces. Molybdenum disulphide and Silicon powder suspensions also give fine surfaces but at some lower efficiency than graphite powder.

Tzeng and Lee (2001) investigated the effects of various powder suspensions (Al, Cr, Cu and SiC) in Kerosene dielectric on machining of SKD11 material on EDM [21]. Increase of largest gap with Al than any other powder and reported of variation of MRR with size of particle size and thus proper size of powder particle enhance the machining efficiency and increase of powder size led to reduction of MRR. Further best MRR can be achieved at optimum combination of powder concentration and power on time any variation in these optimum value of concentration lead to reduction of MRR. MRR vary with type of powder .out of these Cr produced the greatest MRR and SiC produces least MRR at optimum level of concentration.

Uno and Cetin (2001) has investigated the effects of various type of powder suspension on machined surface and using Nickle powder mixed fluid and reported of formation of new layer of low surface roughness on surface possessing new properties as per powder composition used [22]. Thus hard layer with small surface roughness values can be obtained with mixing of carbon powder. The surface has higher corrosion resistance because of the diffusion of electrode and /or powder material into the machined surface [8, 11].

Zhao et al (2002) studied the application of powder mixed EDM in rough machining by using aluminum powder suspension in special working fluid from Mobil and reported of better machining efficiency owing to easier discharge break down and discharge breakdown can occur with small pulse width, and reducing pulse width caused more discharges per unit time [25]. Similar result have been produced by Pecaus and Henriques (2007) using silicon powder mixed dielectric fluid for machining of AISI H13 and reported of generation of mirror like surfaces. [19].

3.1 Effect of Powder Concentration on MRR and SR

Wong Y.S. et al. (1998) reported that in PMEDM with copper, Al, iron & graphite powder, the machining rate generally is proportional to the concentration of the powder **[**23]. MRR is influenced by the concentration of Al powders of size less than 100µs Higher MRR is achieved at 0.5cm^3 /l at discharge current 4.0A with power on time 25µs.At higher or lower than this concentration value give lower MRR**.** [19,21]. Concentration of Silicon powder also influence morphology, with rise of powder concentration from 0 g/l to 20g/l with constant dielectric flow rate of 1l/min, Ra_{max} values increase with the silicon concentration and with 10 to 20g/l. Without silicon powder in the dielectric, open circuit abnormal discharges and small incidence of short circuiting occurs. It means this concentration range maximizes the process efficiency. For higher concentration rates it is observed that the abnormal discharges occurrence directly depend on the powder concentration. Additionally the occurred abnormal discharge is purely due to short circuit type & can be explained by an excess of powder particles in the gap promoting the formation of particles bridges between the electrode and the work-piece. [19].

Jeswani (1981) investigated the EDM process using finishing discharge energy levels and graphite powder suspended in the dielectric, & reported that the powder concentration has an important influence on the discharge process, resulting in increasing both the gap distance and the discharging rate. Under this author achieved best results for particular conditions for powder concentration **of 4 g/l** within a range of 0.25 to 6 g/l., and also reported at low concentration the gap increasing is not enough to promote the discharge stability and for higher concentrations the higher gap distance generates discharge inefficiency [5]**.** Mohri et al. and Narumiya et al. used powder concentration of silicon, aluminum and graphite with a range of 2 to 40 gm/l and reported that the powder concentration leads to increase the gap distance and is larger for the aluminum powder but there is no direct relation between the surface roughness the gap distance [14,15,16]. In fact**,** the best results achieved the surface roughness using low concentration of silicon & graphite powders.

Wong et al.(1998) investigate & confirms the results achieved by previous researcher [23**]** that the best surface finish is obtained with low powder concentration (2g/l) using silicon & graphite powder mixed dielectric. The use of silicon powder concentration in the range of 1 to 3 g/l promotes the formation of slightly smoother craters resulting in the reduction of the surface roughness.

3.2 Electrical Conductivity of Powder

The level of electrical conductivity must have a significant effect in powder mixed EDM process, but not too high since the increasing of the gap distance beyond a certain limit deteriorates the discharge process**.**

3.3 Particle Size

Particle size of powder have an significant effect on MRR and SR. Powder concentration and the grain size are critical for the process performance, ranging typically between 1 to 20 g/l and 1 to 15 µm respectively**.** It is observed that the proper addition of micro particles helps to stabilizing the electric discharge and enhance the machining efficiency. The improvement in process stability resulted from a reasonably large gap size that reduces the arcing frequency through lower debris concentration and a more even debris distribution in the interspaces. But increase in particle size led to a reduction in the improvement of the MRR [21]. This can be attributed to both lower electrical power density and higher possibility of abnormal discharge. With increase in the particle size machining efficiency decreases. The MRR results for the largest particle size (100 µm) at various concentrations were low. The large spark gap is mainly responsible for reduction of MRR. This was due to the combined influences of low electrical power density, fewer particles striking, non uniform particle distribution and poor a improvement in the discharge transitivity. Under the same particle concentration the smallest suspended particle size led to the greater MRR. It is also evident that gap size increases with an increase in particle size resulting in better surface finish [21].

3.4 Particle Properties

The From the previous work it is reported that silicon and graphite are the two powder materials that allow a clear increase of the discharge stability and a consistent improvement of the surface roughness Experimental results of effects of additive (Al, C, Cr, and SiC) mixed EDM have reported Cr produced highest MRR and SiC lowest MRR when the powder addition was less than 1.0 cm3 l-1 and the applied current was 4.0 A. When the current was as low as 1.5 A, the difference in MRR became very small owing to the low energy input. This result due to spark gap for Cr is smaller than that for Al and slightly higher electrical power density and gas explosion pressure for Cr. Further the density of Cr is twice that of Al, resulting in a stronger particle impact. Also thermal conductivity of Al is nearly three times larger than that of Cr. which indicate that more energy is removed by the aluminum suspended dielectric fluid. Thus Cr produced largest MRR. For SiC particles, its electrical resistivity of SiC is much greater than those of Cr and Al and increase in spark gap size is the smallest. Accordingly its power density and gas explosion pressure would be higher owing to small spark gap; the large amount of SiC particles in the spark gap still tends to cause arcing instead of sparking. Therefore SiC has the least improvement in MRR. The effect of Cu powder does not improve machining efficiency of EDM. Due to its high density, all most all the Cu powder fall to the bottom of the dielectric fluid. Hence the spark gap was not increased to improve MRR.

Table 1. Properties of Powder Particles.

Powder	Density (g cm□3)	Thermal Conductivity (W cm□1 deg□1)	Electrical Resistively (mVcm)	Melting point (□C)	V Specific heat(cal g□1 deg□1)
Al	2.70	2.38	2.45	660	0.215
Cr	7.16	0.67	2.60	1875	0.11
Cu	8.96	4.16	1.59	1083	0.092
SiC	3.21	1.0–5.0	1 □□109	2987	0.18

4. Other Related Parameters

4.1 Spark Gap

Presence of powder particles in dielectric has significant effect on spark gap during electric discharge machining. Which directly influence the surface finish. Spark gap distances observed for normal & PMD-EDM for the range of machining conditions are shown in table 2. Presence of powder increases the spark gap distance which causes gap width. Results in reduction of back pressure which would other wise hinder the flow of the dielectric. .An increase in spark gap distance also useful in effective removal of debris from the gap [3,5,6]. Powder suspended dielectric early breakdown, increased gap distances reduces the electrostatic capacity, results in the discharge of micro-current at each potential discharge and due to this small craters are produced on the work-piece which results fine surface finish [16].

Table 2 Spark Gap under Different Powder Suspension Conditions

Powder	Mesh	Size µm	Degree of Purity %	Spark Gap µm
Al	325	42- 48	99.5	120-160
Si	325	42- 48	99.5	26 - 35
SiC	08	2.3 – 2.4		80 - 90

* Without powder spark gap distance is 10-15 µm

4.2 Polarity

In powder EDM polarity also affects the surface finish. With positive polarity the region of the discharge craters consists of a number of small craters surrounding a deep centered crater increases the degree of overlap of the craters which results to dull appearance to the machined surface. With a negative electrode polarity, flat craters are generated and these overlap to extend of giving a smooth surface.

4. CONCLUSION

From the above various studies on the effects of powder mixing in dielectric fluid on the Surface finish and material removal rate of Electro- Discharge Machining process, following conclusion can be drawn.

1. Powder characteristics like particle size, particle concentration, particle density, thermal conductivity and electrical resistivity have significant effect on the performance of EDM
2. Silicon and graphite are the two powder materials that allow a clear increase of the discharge stability and a consistent improvement of the surface roughness
3. SiC has the least improvement in MRR. The effect of Cu powder does not improve machining efficiency of EDM
4. Gap distance increase with the optimum powder concentration and is larger for the aluminum powder
5. Proper size of minute particles helps to enhance the machining efficiency. The results also revealed that an increase in particle size led to a reduction in the improvement of the MRR
6. Hard layer with small surface roughness values can be obtained with mixing of carbon powder. With this process of new layer of low surface roughness can be formed on surface possessing new properties as per powder properties used in the dielectric.
7. Appropriate amount of powder present in the dielectric results in increase in the spark gap.

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