Scientific Journal of Impact Factor(SJIF): 3.134
e-ISSN(O): 2348-4470
p-ISSN(P): 2348-6406

International Journal of Advance Engineering and Research Development

Volume 1, Issue 12, December -2014

Experimental Investigation of Powder mix EDM using Silicon Dioxide as a Powder additive for Material Removal Rate

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Abstract: *Powder mixed EDM (PMEDM) has emerged as one of the advanced techniques in the direction of the enhancement of the capabilities of EDM. Its use is particularly intense when very complex shapes on hard and brittle material with high geometrical and dimensional accuracy are required with increase of machining rate. In this work, the effect of Silicon Dioxide (SiO2) powder mixing into the dielectric fluid of EDM on machining characteristics of EN-8 has been studied with three input parameters Peak current, pulse on time and concentration of powder. The process performance is measured in terms of Material Removal Rate (MRR) on weigh basis. The result outcome will identify the important parameters and their effect on MRR and SR of En-8 in the presence of SiO2 in a kerosene dielectric of EDM. Analysis shows that the percentage contribution of peak current peak current and pulse on time have higher percentage contribution toward MRR. The experimental result analysis shows that the setting of peak current at high level (17 A), pulse on time at medium level (50 µs) and powder concentration at 6 g/lit produced highest MRR.*

Keywords*-EDM, PMEDM, Peak current, Pulse on time, Concentration , MRR*

I. INTRODUCTION

There has been a rapid growth in the development of harder and difficult to machine metals and alloys during the last two decades. Conventional edged tool machining is uneconomical for such materials and the degree of accuracy and surface finish attainable is poor. In view of seriousness of this problem, it was emphasized the need for the development of newer concepts in metal machining. The newer machining that developed is often called 'modern machining processes or 'non-traditional machining process.' In unconventional machining methods, there is no direct contact between the tool and work piece; hence the tool need not to be harder than work piece. Further, in spite of the recent technical advancement, the conventional machining processes are inadequate to produce complex geometries shapes in hard and temperature resistant alloy and die steels. Keeping these requirements into mind, a number of non-conventional methods have been developed.

WORKING OF POWDER MIXED EDM (PMEDM)

Powder mixed EDM (PMEDM) has emerged as one of the advanced techniques in the direction of the enhancement of the capabilities of EDM. In this process, a suitable material in fine powder form (aluminum, chromium, graphite, copper, or silicon carbide, etc.) is mixed into the dielectric fluid of EDM. The spark gap is filled up with additive particles. The added powder significantly affects the performance of EDM process. The electrically conductive powder reduces the insulating strength of the dielectric fluid and increases the spark gap distance between the tool electrode and work piece. As a result, the process becomes more stable, thereby improving machining rate (MR) and surface finish.
The principle of PMEDM is shown in Figure 1.1. In this process, the material in powder form is mixed into the dielectric fluid either in the same tank or in a separate tank. When a voltage of 80-320 V is applied to both the electrodes, an electric field in the range 105 to 107 V/m is created. The spark gap is filled up with additive particles, and the gap distance between tool and the work piece increases from 25 µm to 50 µm to many times larger. The powder particles get energized and behave in a zigzag fashion. The grains come close to each other under the parking area and gather in clusters. Under the influence of electric forces, the powder particles

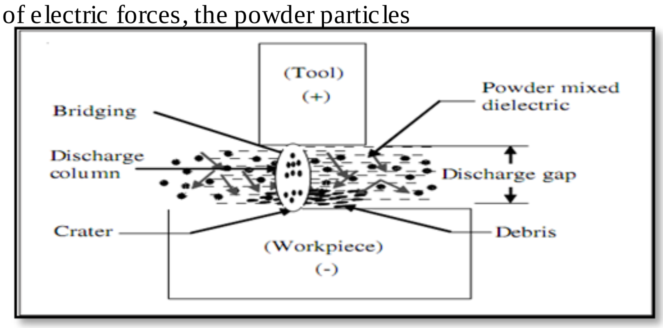


Figure 1.1 Principle of PMEDM process

arrange themselves in the form of chains at different places under the sparking area. The chain formation helps in bridging the gap between both the electrodes. Due to the bridging effect, the gap voltage and insulating strength of the dielectric fluid decreases. The easy short-circuit takes place, which causes early explosion in the gap. As a result, the 'series discharge' starts under the electrode area. Due to the increase in the frequency of discharging, the faster sparking within a discharge takes place, which causes faster erosion from the work piece surface. At the same time, the added powder modifies the plasma channel. The plasma channel gets enlarged. The electric density decreases; hence, sparking is uniformly distributed among the powder particles. As a result, even and more uniform distribution of the discharge takes place, which causes uniform erosion (shallow craters) on the work piece. This results in improvement in surface finish. [4][7]

II. LITERATURE REVIEW

Katshushi Furtutani, Akinori Saneto, Hideki Takezawa, Naotake Mohri, Hidetaka Miyake, have been studied about a surface modification method by electrical discharge machining with a green compact electrode to make tick TiC or WC layer. Titanium alloy powder or tungsten powder was suspended from the green compact electrode and adheres on a workpiece by the heat caused by discharge. Research found that TiC layer can be accreted by using a thin electrode to keep the powder concentration high. [1] Zhao W. S., Meng Q. G., Wang Z. L.; have performed experimental research on the machining efficiency and surface roughness of PMEDM in rough machining. Also compared machining efficiency and surface roughness between PM (Powder mix)-EDM and conventional EDM. The result showed that PMEDM machining can clearly improve machining efficiency at the same time surface roughness. Increasing peak current and decreasing pulse width improved the machining efficiency with an increasing rate of 70% without much deterioration of surface finishing. [2] Puertas I, Luis C. J., studied on the machining parameters optimization of electric discharge machining. Peak current, pulse on time and pulse off time are considered as variable input parameters [3] Bansal H.K., Sehijpal Singh, Kumar P. used response surface methodology for the parameters optimization of powder mixed EDM. To avoid the wastage of kerosene oil, a small dielectric circulating system designed and stirring system incorporated to avoid the particle setting. When suitable voltage is applied, the powder particles get energized and behave in zigzag fashion. They have concluded that the silicon powder suspended in the dielectric fluid of EDM affects both MRR and SR. the slope of the curve on the graph indicates that the MRR increases with the increase in the concentration of the silicon powder. The ANOVA suggests that the peak current and concentration are the most important parameters on MRR and SR.[4] Tzeng Yih-fong, Chen Fu-chen, focused on the surface characteristics of electrical discharge machined SKD-11 using powder-suspension dielectric oil. addition of powder leads to an increase in the gap size that subsequently resulted in a reduction in electrical discharge power density and in gas explosive pressure for a single power pulse. It is observed that the effects of particle concentrations on surface are less influential than the discharge current. [5] Biing Hwa Yan, Hsien Chung Tsai, Fuang Yuan Huang investigated the influence of the machining characteristics on pure titanium metals using an electric discharge machining (EDM) with addition of urea into distilled water. The effects of the urea addition on surface modification are also discussed. Input parameters as the dielectric type, peak current and pulse duration to explore their effects on machining performance. Machining performance is measured based on three output parameters including material removal rate, electrode wear and surface roughness. Elemental distribution of nitrogen on the machined surface was qualitatively determined to access the effects on surface modification. The experimental results indicated that the nitrogen elements decomposed from the dielectric that contained urea, migrated to work piece, forming a TiN hard layer and resulting in good wear resistance of the machined surface after EDM.[6] Bansal H.K., Sehipal Singh, Praddep Kumar; have studied the effect of silicon powder mixing into the dielectric fluid of DM on machining characteristics of EDM of AISI D2 die steel. Process parameters taken were peak current, pulse on time, pulse off time, concentration of powder, gain and nozzle flushing where as the process performance was measured in terms of machining rate. Analysis indicated that the percentage contribution of peak current and powder concentration toward MR was maximum among the all the parameters.[7] Norliana Mohd Abbas, Daius G. Solomon, Md. Fuad Bahari, have discussed the research trends in EDM on ultrasonic vibration, dry EDM machining, EDM with powder additives techniques and EDM in water in predicting EDM performances. higher efficiency gained by the employment of ultrasonic vibration is mainly attributed to the improvement in dielectric circulation which facilitates the debris removal. 8] Ranjit K. Roy has given the concept of Design of Experiments to improve quality through product and process improvement. DOE is a technique of defining and investigating all possible combination in an experiment involving multiple factors and to identify the best combination. In this different factors and their levels are identified. In design of experiment the results are also analyzed to establish the best or the optimum condition for a product or a process. The Analysis of Variance (ANOVA) is the statistical treatment most commonly applied to the results of the experiments to determine the percent contribution of each factors.[9]

III. EXPERIMENTAL SET-UP

Design of Experiment (DOE) is a powerful technique used for exploring new processes, gaining increased knowledge of existing process and optimizing these processes for achieving world class performance. DOE is an experimental strategy in which effects of multiple factors are studied simultaneously by running tests at various levels of the factors. Here, Experiments were conducted on a Z 50 JM-322 die-sinking EDM machine manufactured by JOEMARS. The existing dielectric circulation system of Z 50 JM-322 EDM machine needs about 200 liters of kerosene in circulation. The dielectric fluid was circulated by pumping system. Fixture is designed to hold the work piece. The machine tank is field up with dielectric fluid i.e. kerosene. EN-8 material is selected as a workpiece material because of it's industrial needs that it is widely used in metal forming; forging, squeeze casting and pressure die casting.. Copper electrodes with diameter 15 mm have been selected as a tool. The machining is performed in commercially available kerosene oil. Silicon dioxide powder with 40 µm particle size was added into the kerosene oil.

A series of tests will be conducted in order to compare EDM conventional process performance with powder mixed dielectric EDM performance on widely used industrial material EN-8. Based on literature survey three parameters are considered as critical input parameters (1) Peak current (2) Pulse on-time (3) Concentration of powder. The response out come is MRR.

Figure .1.2 Electro Discharge Machine used for performing experiments

45 work piece of EN 8 of size 50 mm X 30 mm X 6 mm are being produced for experimental work with copper electrode. Chemical composition of EN 8 is given in table 1.1 whereas physical property is in table 1.2. Factors levels with their range selected as per table 1.3

Table 1.1 Chemical composition of EN-8

Composition in %	C	Si	Mn	P	S
	0.390	0.240	0.690	0.027	0.029

Table 1.2 Physical property of EN-8

	Yield strength	Ultimate strength
EN-8	450.79 MPa	694.84 MPa

Table 1.3 Factors with levels value

Factors	Level 1	Level 2	Level 3	Level 4	Level 5
Concentration of powder i.e. SiO_2 (g/lit.)	0	2	4	6	8
Peak current (A)	9	13	17	--	--
Pulse on-time (µs)	25	50	75	--	--

The MRR is estimated by calculating the difference between the initial weight and the final weight of the work piece after processing at a specified set of conditions by EDM and PMEM as[7][9]:

(A) Effect of MRR V/S peak current at different pulse on time at different concentration

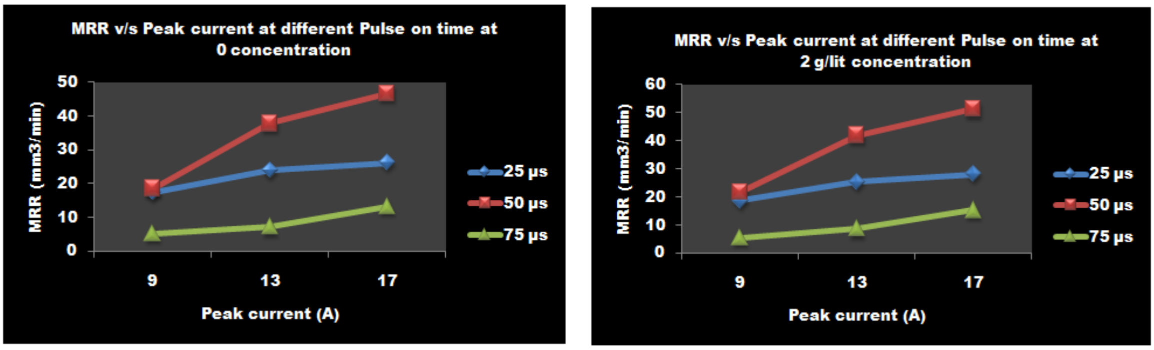


Figure 1.3 MRR v/s Peak current at different Pulse on time at 0 & 2 g/lit Concentration

The graphs of MRR v/s peak current at different pulse on time at zero concentration shown in figure 1.3. It is observed that as the current increases the material removal rate is increases in both EDM and powder mixed EDM (PMEDM). This is because peak current has large impact on input energy. With increase in current ions and electrons are accelerated towards their respective electrodes more strongly. The suspended particles get energized and act as a carriers, which on further collision with ions and electrons gather more energy and release more carriers, resulting in avalanche of ions and electrons. This cause more discharge per unit time on work piece surface. The fatser sparking takes place within a discharge, the faster the erosion from the work piece surface, and hence higher MRR. The maximum MRR obtained at zero g/lit concentration of additive powder is 46.67 mm3/min which is at 17 A and 50 µs. It is observed that the MRR increases with increment of concentration in powder mixed EDM. The maximum MRR at 2 g/lit concentration is 51.27 mm3/min at 9 A peak current and 50 µs pulse on time.

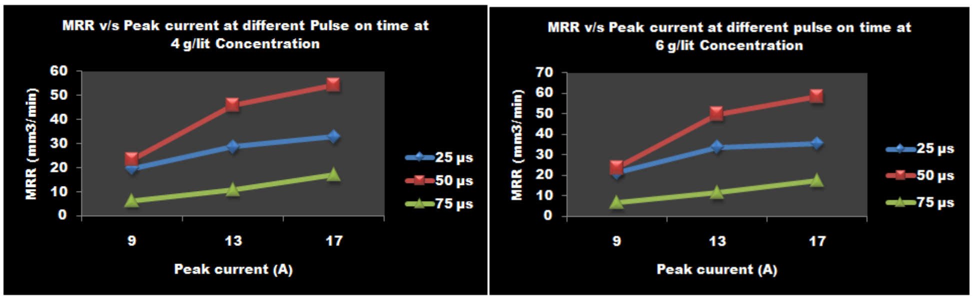


Figure 1.4 MRR v/s Peak current at different Pulse on time at 4, 6 & 8 g/lit Concentration

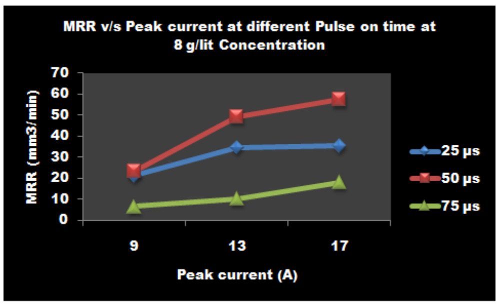


Figure 1.5 MRR v/s Peak current at different Pulse on time at 4, 6 & 8 g/lit Concentration

The graphs MRR v/s peak current at different pulse on time at concentration level 4, 6 and 8 g/lit is shown in figure 1.3,1.4. Here also the same trend of MRR we can observe which shows enhancement of MRR as levels of peak current increases. The maximum material removal rate obtained at various level of concentration of silicon dioxide powder is 58.32 mm3/min at 17 A peak current when concetration is 6 g/lit and lower MRR atainable is 5.13 mm3/min at 9 A when electro discharge machine works as conventional EDM.

(B) Effect of MRR V/S Concentration at different peak current and different pulse on time in PMEDM

Table 1.4 Experimental results for MRR at different peak current and different pulse on time in PMEDM

parameter	2 g/l	4g/l	6 g/l	8 g/l	
9 A	18.57	19.71	21.22	21.26	25 µs
	21.48	23.28	23.58	23.38	50 µs
	5.51	6.16	6.6	6.44	75 µs
13 A	25.26	28.6	33.62	34.5	25 µs
	41.86	45.86	49.79	49.17	50 µs
	8.54	10.9	11.45	10.21	75 µs
17 A	28.05	32.71	35.47	35.3	25 µs
	51.27	54.23	58.32	57.3	50 µs
	15.18	16.88	17.57	17.97	75 µs

Experiments carried by varying different peak current and different pulse on time. During experiments it is observed that MRR varies with broad range.

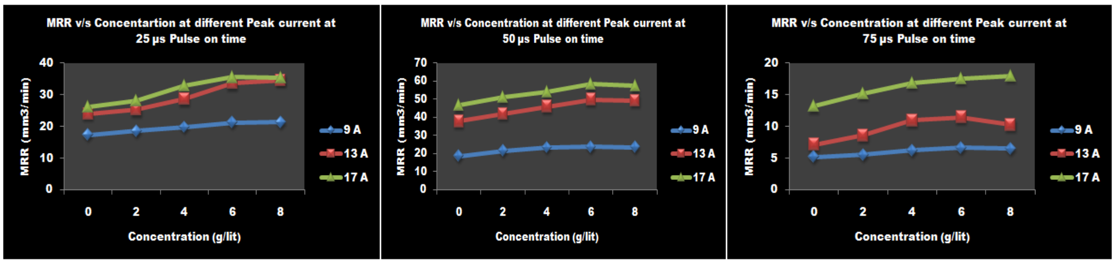
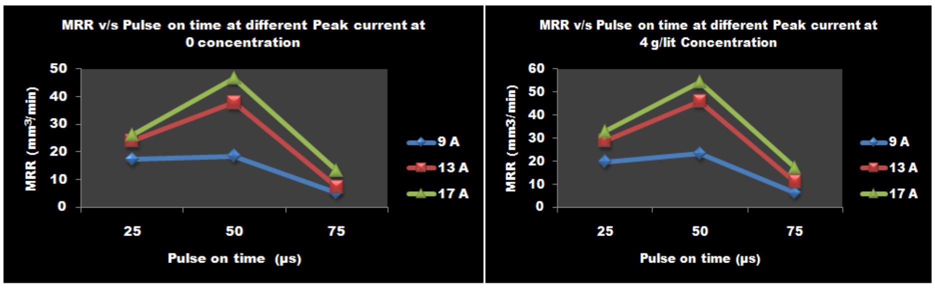


Figure 1.6 MRR v/s Concentration at different Peak current at different Pulse on time

Figure 1.6 which shows graph about MRR v/s concentration at different peak current at different pulse on time, when silicon dioxide powder is suspended into the dielectric fluid of EDM, there is an increase in MRR. This trend also highlights the comparison of MRR in EDM and PMEDM, as level 1 indicates the case of Conventional EDM, while levels 2 to 8 represent powder – mixed EDM. This observation suggests that appropriate amount of powder into the dielectric fluid of EDM causes grater erosion of the material. The reason for the enhancement of MRR is mainly attributed to the lower breakdown strength of the dielectric fluid when conductive powder particles are added to it. The spark gap distance is increased over normal EDM. This facilitates in rising up the discharging frequency and hence enhances the MRR. The maximum MRR produced at 6 g/lit concentration of silicon dioxide powder. Up to 6 g/lit concentration of SiO2 powder MRR is rising but after it MRR becomes almost stable in all cases. MRR at 8 g/lit concentration is almost equal to that at 6 g/lit concentration of additive powder in dielectric fluid of EDM.

(c) Effect of MRR v/s Pulse ON Time at different peak current and concentration



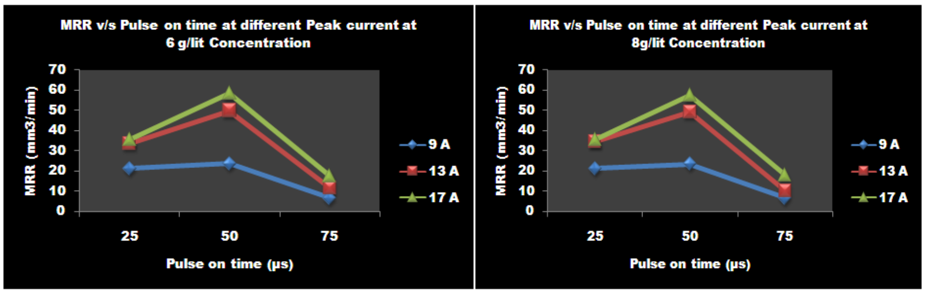


Figure 1.7: MRR v/s Pulse on time at different Peak current at zero, 2, 4, 6, 8 g/lit Concentration

The pulse on time is another factor which in figure 1.7 shows the variation in MRR . Above graphs indicates the relationship between MRR and Pulse on time under different peak current for conventional EDM and 2 g/lit, 4 g/lit Concentration also. At zero concentration of powder in dielectric fluid of EDM with increase in pulse on time, MRR first increases and then decreases. This can attributed from the fact that very short pulse duration causes less vaporization on the work piece surface, whereas larger pulse duration makes machining process unstable due to the increased probability of short circuiting. The highest MRR obtained in conventional EDM is 46.67 mm3/min which is under 17 A peak current and at 50 µs pulse on time. Where as in powder mixed EDM MRR is obtained up to 58.32 mm^3/min. It is observed that MRR obtained at 50 µs pulse on time is highest at each and every level of and peak current in conventional EDM and Powder Mixed EDM also. The graphs in figure 6.7 and 6.8 indicates that highest MRR are 51.27 mm3/min, 54.23 mm3/min, 58.32 mm^3/min and 57.3mm^3/min under 2 g/lit, 4 g/lit, 6 g/lit and 8 g/lit concentration of silicon dioxide powder at 50 µs pulse on time. The difference between MRR obtained at different concentration and under varying peak current is lower when pulse on time is 25 µs and 75 µs as compare to that at 50 µs pulse on time.

IV. CONCLUSION

Electric discharge machining has been found to be a promising machining technique for obtaining desired dimensional accuracy and intricacy from hard and tough die steels. Powder mixing into dielectric fluid of EDM is one of the innovative developments that ensure better machining rates. The result of present work helps to understand the behavior of process parameters for MRR. The experimental investigation helps to obtain machining conditions in the presence of silicon dioxide powder in the dielectric fluid to get maximum machining rate from EN-8.

- Peak current, concentration of the silicon dioxide powder and pulse on time significantly affects the MRR.
- The optimum levels of various process parameters obtained in this experimental work are:
    - Peak current = 17 A, Powder concentration = 6 g/lit and 50 µs pulse on time for highest material removal rate.

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