A Review on Effect of Various Powders Mixed in EDM on Response Variables of Various Materials

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Abstract - *In this paper various powders mixing into the dielectric fluid of EDM on machining characteristic of various materials has been studied. Various process parameters namely peak current, pulse-on time, pulse-off time, powder concentration, powder grain size and nozzle flushing, duty factor, etc. have been considered. The process performance is measured in terms of Response variables like Material Removal Rate (MRR), Surface Finish (SR), Tool Wear Rate (TWR) etc. Various types of dielectric fluids are used. Optimization Methods used are Taguchi Method, Response Surface Methodology, ANOVA etc. This paper reviews the research work carried out from the inception to the development of Powder Mixed Dielectric electric Discharge Machining within the past decade & also briefly describing the Current Researches conducted & optimization technique used in the various Powder mix in Electric Discharge Machining (PMEDM) field.*

***Key Words*: EDM, PMEDM, MRR, SR, TWR, Taguchi method, ANOVA, RSM.**

1. INTRODUCTION

Electric discharge machining (EDM) is non conventional machining process. It was first invented in the late 1940s. It is used for machining hard and difficult to machine materials such as heat treated tool steel, super alloys and carbides etc. It is commonly used in mould, die making industry and in manufacturing of automotive, aerospace, surgical components. EDM is a non-traditional machining process where material is removed by melting and vaporizing from small area of the workpiece surface. Arc is established between electrode and workpiece. There is no physical contact between tool and workpiece. Pulsed arc discharges occur in the gap filled with an insulating medium between tool electrode and work piece. It's unique feature of using thermal energy to machine electrically conductive parts regardless of hardness has been its distinctive advantage. Some of the problems associated with EDM are low machining efficiency, tool wear rate and poor surface finish. To overcome these limitations powder mixed EDM (PMEDM) has emerged as one of the advanced technique. The working principle of PMEDM is shown in Figure 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 required voltage is applied to both the electrodes, an electric field is created. The spark gap is filled up with powder particles, and the gap distance between electrode and the workpiece increases from 20 µm to 50 µm. The powder particles get energized and behave in a zig-zag fashion. The grains come close to each other under the sparking area and gather in clusters. Under the influence of electric forces, the powder particles arrange themselves in the form of chains at different places under the sparking area (refer to Figure 1). 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 start under the electrode area. Due to the increase discharge frequency more number of sparks generate within the discharge region, resulting more material to be removed from work surface. They also find that added particles not only enlarge the plasma channel but also widen it, due to this more number of sparks generated and electric energy uniformly distributed among the sparks thus creating uniform erosion from the workpiece producing shallow craters and hence improves surface finish.

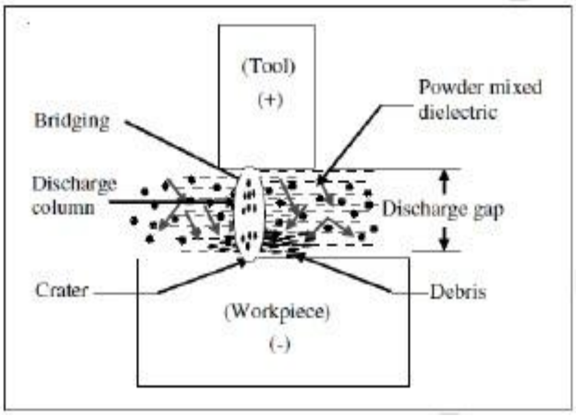

Fig -1: Principle of PMEDM Process

2. LITERATURE REVIEW

It is observed during the review of literature that most of the researches for PMEDM moves around how to increase MRR, reduce tool wear and to increase surface finish. Material removal rate and surface roughness shows opposite behavior i.e. if one increases other decreases due to the reason that higher MRR can be achieved when with high peak current small electrode gap and more pulse on time resulting affect on surface roughness. Kansal et al. [1] established optimum process conditions for powder mixed EDM in the rough machining phase using the response surface methodology with silicon powder and found that, addition of an appropriate amount of the silicon powder into the dielectric fluid caused improvement in MRR and high surface finish has been achieved. Kansal et al. [2] studied the effect of silicon powder mixing into dielectric fluid of EDM on machining characteristics of AISI D2 die steel. It was reported that this innovative development gives better machining rates with desired surface quality, peak current and concentration of silicon powder are the most influential parameters for causing material removal. Norliana et al.[3] reported that number of researchers worked in this area and investigated on various types of powder with different concentration of grain size but aluminium powder suspension attracts many researchers since it contributes well for improving MRR as well as the surface finish. Singh et al.[4] found that aluminium powder mixed in dielectric medium in EDM significantly affect the machining performance, minimum surface roughness is obtained with copper electrode. Singh et al.[5] designed a separate tank for better circulation of the powder mixed dielectric in which a stirring system is employed. The machining tests were conducted on ASTM A681 D3 die steel workpiece using copper electrodes with Al_2O_3 and TiC mixed EDM oil. It was reported that MRR is higher with TiC powder in dielectric fluid to 6 g/liter concentration level and TWR is higher with Al_2O_3as an additive. Hussain et al.[6] have done experimental investigation on addition of aluminium metal powder to dielectric fluid in EDM. The process performance was measured in term of MRR, TWR, SR and WLT. It was found that high MRR, good surface finish and minimum white layer thickness achieved. Gurule et al.[7] investigated the potential of PMEDM for enhancing material removal rate (MRR) of AISI D2 die steel with rotary tool. The maximum MRR is reported at 4 g/l of Al powder, 900 tool revolutions per minute with Cu tool. Rajurkar et al.[8] studied the recent advancement in EDM and reported that uses of powder mixed EDM gives higher MMR. Rajurkar has indicated some future trends activities in EDM like machining advanced materials, mirror surface finish using powder additives, ultrasonic assisted EDM automation. Rathi et al.[9] studied the effect of graphite powder mixed into kerosene during EDM of Inconel 718 workpiece. It was found that the maximum MRR is obtained at high peak current of 18A, low TWR is achieved during machining. YooKim et al. [10] studied effect of graphite powder additive in dielectric fluid on SR, EWR and MRR. It was reported that the graphite powder decrease the TWR, SR and gives high MRR using pure kerosene as dielectric fluid. Amit Kumar et al.[11] studied investigation of powder mixed EDM process parameter for machining inconel alloy using response surface methodology and found out that MRR increases rapidly with increasing peak current and pulse on time, graphane nano powder work satisfactorily for machining Inconel825 in nano PMEDM.

2.1 CURRENT REASEARCH PROGRESS IN PMEDM

Current research of Powder Mixed EDM is focused & tabulated in below Table -1.

Table -1: Latest Research in Powder Mixed EDM

Author/ Year	**Process Parame t- -ers**	**Powde r Type**	**Tool Electrod e and Workpie ce**	**Optimiza - -tion Techniq ue Used**	**Research finding**
H. K. Kansal, Sehijpal Singh, P. Kumar [2005]	Peak current, pulse on time, duty cycle, powder concent ration	Si	Tool- Copper Workpiec e- EN-31 (AISI521 00) Die steel	ANOVA , RSM	MRR increases with the increase the concentrati on of the silicon powder.
H. K. Kansal, Sehijpal Singh, P. Kumar [2007]	Peak current, pulse on time, powder concent ration	Si	Tool- Copper Workpiec e- AISI D2 die steel	ANOVA for MRR S.N. Data	Peak current and concentrati on of silicon powder are the most influential parameters for causing MRR.
Paramjit Singh, Anil Kumar, Naveen Beri, Vijay Kumar [2010]	Polarity, powder concent ration, Powder grain size.	Al	Tool- Copper Workpiec e- Hastelloy Steel	ANOVA, regressio n analysis	Too low and too high concentrati on of aluminium powder in EDM oil reduces MRR of Hastelloy.
S. Singh, H.Singh, J. Singh, R.Bhatia [2011]	Peak current, pulse on time, pulse off time, electrod e lift time	Al_2O_3 and TiC	Tool- Copper Workpiec e- ASTM A681 D3 die steel	ANOVA, Graphical ly	TiC gives better results in terms of Material removal rate and tool wear rate Al2O3 powder.
K. Hussain, Palaniyan di [2012]	Peak current, Pulse on time, polarity,	Al	Tool- Copper Workpiec e- W300	Taguchi Method ANOVA for EWR,MR	Maximum MRR is obtained at a high peak current of

	powder concentration			R	12 A, a moderate Ton of 180 μs, and a low Conc. of powder 1g/L in positive polarity.
N.B.Gurule, K.N. Nandurkar [2012]	Peak current, pulse on, pulse off time	Al	Tool-Copper,Brass Workpiece-AISI D2 die steel	Taguchi method, ANOVA	The maximum MRR is produced at 4 g/l of Al powder, 900 tool rpm with Cu tool.
M. G.Rathi, D. V. Mane [2014]	Peak current, pulse on time, duty cycle powder concentration.	Graphite and Si	Tool-Copper Workpiece-Inconel -718	ANOVA	Low TWR is achieved at a current of 12 A, a moderate Ton of 20 μs, duty cycle 90% and SiC as powder media.
Y. S. Kim, N. C. Chong [2018]	Polarity, powder concentration, Powder grain size.	Graphite	Tool-WC-CO Workpiece-STS304	RSM	Graphite powder decrease the tool wear rate, gives high MRR with using pure kerosene as dielectric fluid.
A. Kumar, S. Kumar [2018]	Peak current, pulse on time, duty cycle powder concentration.	Graphene	Tool-Copper Workpiece-Inconel-825	RSM	Graphane nano powder work satisfactorily for machining Inconel825 with high MRR.

3. DISCUSSION

Study of machining on different metals shows varying nature of material removal rate, surface roughness with respect to process parameters, indicating machining nature of all metals are not same. Many researchers studied and concluded that PMEDM gives better MRR and surface finish than EDM. However there is no consistency in the amount of improvement in results. These variations can be attributed to selection of parameter and different types of materials. The variation in the results carried out by researchers can be investigated further on different types of steel materials which is mostly use in various sectors. In view of Kansal et al.[1] more development in MRR is expected at higher concentration level of silicon powder during machining with PMEDM, however this has not been supported with valid experimental results. Experiments have been carried out either by using aluminium or silicon powder in isolation. An attempt of using both the powders on the same material may help in comparing outcomes of Al and Si powder.

4. CONCLUSION

This paper present a brief summary of important published research work based on experimental investigation on PMEDM using powder particle of different materials in dielectric fluid with different combinations of tool electrode and workpiece. Further researchers get success to achieve mirror like surface finish and improved MRR by using different powders but the effect of different size and concentration of different powders on various parameters like material removal rate, surface finish and tool wear rate is still a mystery. Very little or no work has been done to find the effect of grain size and concentration of powder on machining parameters like surface finish ,material removal rate and tool wear rate as per the best knowledge of authors.

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