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Review Article

POWDER MIXED EDM FOR IMPROVEMENT OF MRR AND SURFACE FINISH: A REVIEW

Jignesh B Patel*., Raghavendra. S. Darji and Mukeshkumar Dalai

Department of Mechanical Engineering, Babaria Institute of Technology, Varnama, Vadodara, Gujarat, 391240

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ABSTRACT

EDM is very unique process because of its ability to machine almost every material for which conventional machining is not possible along with surface finish (SF). Electrical discharge machining is used for manufacturing of the components where excellent surface finish is required. But the major limitation of the process is that the Material Removal Rate (MRR) is very low. To increase the MRR Powder Mixed EDM (PMEDM) is one of the recent advancements in EDM process where the ceramic powder particles added to the dielectric fluid. The material removal rate (MRR) needs to be increased along maintaining the surface finish (SF) as higher productivity levels are demanded, which is today's need in industrial area. For this we are going to add different ceramic powder particles in the die electric fluid after the optimization of conventional EDM parameters. This work will be carried out on Inconel 718 which is Nickel alloy which gives very wide temperature range for the application.

INTRODUCTION

Electrical Discharge Machining (EDM) is a thermoelectric process in which workpiece material is removed by high frequency-controlled pulses generated in the dielectric medium between the tool and workpiece electrodes separated by a small gap. The disadvantages of the EDM are poor surface finish and less material removal rate. A plasma channel is formed due to the continuous bombardment of ions and electrons generating temperature in the range of 8000 °C–12000 °C in the discharge gap which causes vaporization and removal of the material. Powder mixed electro-discharge machining (PMEDM) is a promising technique which reduces the limitations and improves the machining performance of EDM. Mixing of fine metallic powder to the dielectric fluid decreases its insulating strength and consequently increases the inter-electrode space causing an easy removal of the debris. On application of a voltage of 80–315 V, an electric field in the range of 105– 107 V/m is applied, giving rise to positive and negative charges on the powdered particles. The powdered particles start moving in zig zag path on getting energized, thus forming clusters in the sparking area. The bridging effect takes place below the sparking area causing multiple discharges in a single pulse leading to quicker sparking and erosion from the workpiece surface. This easy short circuit improves the machining rate of the process. The plasma channel gets enlarged, producing consistent sparks forming shallow craters on the workpiece surface with superior surface quality. Material removal occurs from both the electrode surfaces and under suitable machining conditions, the removed material combined with the powder particles get settled on the surface of the workpiece, modifying and improving the properties resulting in breakdown of the dielectric fluid. As the sparking trend changes in the presence of metallic powders, lots of alteration in the surface properties occurs.[1]

Machining mechanism of PMEDM

Fine powder is mixed with dielectric solution by means of stirrer and a circulation pump are installed for reuse of powder. Gap distance between tool and work-piece is kept at 25μm to 50μm.Gap voltage- 80 to 320 V. Electric field crated due to gap voltage- 105 to107 V/m. Powder particles between tool and work-piece get energized and behave in a zigzag fashion. Also, they arrange themselves in chain form. These Chains help in 'Bridging Effect'. Due to 'Bridging Effect' gap voltage and insulating strength of the dielectric fluid decreases. This causes short-circuit and early explosion in the gap. Due to this series discharge and faster sparking in the interelectrode gap, MRR becomes higher. Added powder makes the plasma channel wider and enlarged. Electric density decreases, and sparking is

Corresponding author:* **Jignesh B Patel
Department of Mechanical Engineering, Babaria Institute of Technology, Varnama, Vadodara, Gujarat, 391240

uniformly distributed among the powder particles.Due to the uniform discharges, uniform erosion takes place andimproves the Surface Finish. [1]

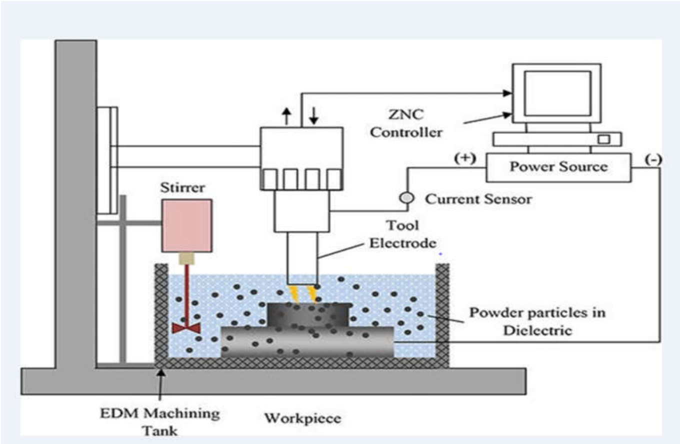

Figure 1 Diagram of PMEDM

Current understanding of the PMEDM is presented here as the process is yet to be fully established. In PMEDM, fine powder particles are suspended in the dielectric oil. An electric field is created in the inter-electrode gap (IEG) when sufficient voltage (about 80 to 320V) is applied between them. Ionization of dielectric takes place as in the case of conventional EDM. Under the applied electric field, positive and negative charges accumulate at the top and bottom of the powder particles respectively (Workpiece positive and tool negative case). The capacitive effect of the electrodes leads to the formation of chains of powder particles. First discharge breakdown occurs where the electric field density is the highest (between 'a' and 'b' in Figure). This breakdown may be between two powder particles or a powder particle and an electrode (Tool or workpiece). Redistribution of electric charges takes place after the first discharge and electric charges gather at point 'c' and 'd'. Further discharge happens between these powder particles and the other particles where electric field density is highest[2,3].

Enlargement of discharge gap: Size of the discharge gap largely depends on the electrical and physical properties of the powder particles. Under high-temperature machining conditions, the free electrons present in electrically conductive powder particles reduce the overall resistance of the dielectric. The improved conductivity helps the spark to be generated from a longer distance and thus enlarges the discharge gap.[4,5]

Widening of discharge passage: After the first discharge, powder particles in IEG get energized and move rapidly along with ions and electrons. These energized powder particles colloid with dielectric molecules and generate more ions and electrons [2]. Thus, more electric charges are produced in PMEDM compared to conventional EDM. Also increased discharge gap aids in the reduction of hydrostatic pressure acting on the plasma channel. These two phenomena ensure the widening of the discharge passage. The enlarged and wide discharge column decreases the intensity of discharge energy leading to the formation of large shallow cavities on the workpiece surface.

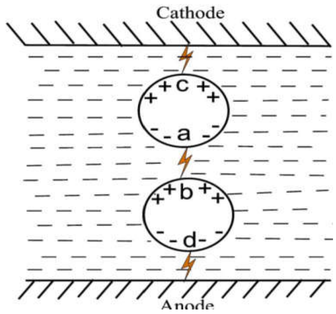

Figure 2 Series discharging in PMEDM [6]

Multiple discharges: Multiple discharge paths are observed in PMEDM due to the rapid zigzag movement of the suspended powder particles ensuring uniform distribution of energy and formation of multiple craters in single pulse duration. Unlike conventional EDM, the discharge waveform in the case of PMEDM is significantly different from the input pulse. Voltage fluctuates rapidly within single pulse duration due to multiple discharges.[7,8]

Influence of powder characteristics

Jahan *et al.* [9] presented a comprehensive analytical modelling of PMEDM process. Fig. shows the schematic representation of different forces acting on a powder particle present in the inter-electrode gap. In Figure, F_l, F_c, F_d, Fe and 'f' are lift, columbic, drag, electric, friction (direction only) forces respectively. W denotes the self-weight of the particle. The derived formula for breakdown energy of powder-mixed dialectic is provided in Eq. 1.1.

$$E_{br}^2 = E_i^2 - 2\sigma T \frac{1}{\varepsilon_1}\left(\frac{\varepsilon_p + 2\varepsilon_1}{\varepsilon_p - \varepsilon_1}\right)\left[\frac{1}{r^3}\left(\ln\frac{N_f}{N_i}\right)\right]$$ .....Equation 1.1

where E_i = Initial voltage for concentration N_i, E_{br} = Breakdown voltage for final concentration N_f, σ = Boltzmann constant, T = Temperature, ε_1 = Permittivity of dielectric, ε_p= Permittivity of powder particle and r = Radius of powder particle.

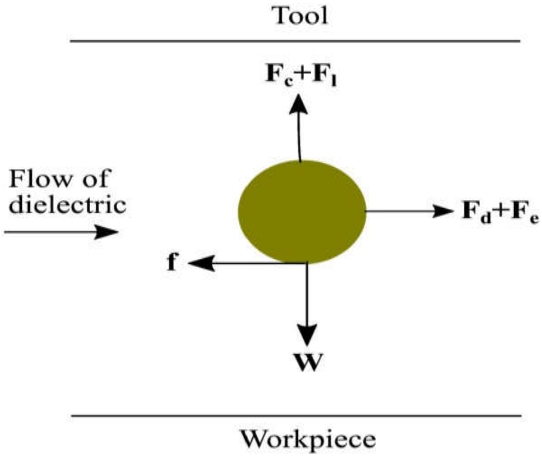

Figure 3 Different forces acting on a powder particle

From $E_q$it is evident that E_{br} depends on particle radius and change in concentration 'N', permittivity of the particles and dielectric. For no addition of powder particles or unchanged concentration ($N_f = N_i$), the value of E_{br} = Ei, which means no change in breakdown strength. The derived expression for spark gap during PMEDM is given in Eq. (1.2)

$$d_2 = \alpha d_1 \left(1 + \frac{r + h_p}{g_d}\right)$$ …..Equation 1.2

where α = Field enhancement factor for small protrusion, d g = Distance between bottom of the particle and micro-peak, p h = Height of the protrusion. d_1= Spark gap without powder suspension. From Eq. (1.2), it is clear that spark gap during PMEDM (d_2) is higher than that of conventional EDM process (d_1). Density, size, electrical and thermal conductivities are some of the critical characteristics of the powder particles that significantly affect PMEDM process. Increase in electrical conductivity of the dielectric, and resulting extension of discharge gap in PMEDM, as discussed earlier, enhance spark frequency and facilitate easy removal of debris from the machining zone [9,10]. High thermal conductivity of powder particles removes a large amount of heat from the discharge gap leading to reduction in discharge density. Therefore, only shallow craters are formed on the workpiece surface[11,12]. Number of surface cracks developed on the machined surface are also reduced along with their width and depth, as the intensity of discharge energy is less in PMEDM compared to conventional EDM process[13,14].

Process parameters

***Current or peak current (Ip)**:* During each pulse-on time, current rises until it attains a certain predetermined level that is termed as discharge current or peak current. It is governed by the surface area of cut. Higher currents produce high MRR, but at the cost of surface finish and tool wear. Accuracy of the machining also depends on peak current, as it directly influences the tool wear.[1]

***Discharge voltage (V)**:* Open circuit voltage between the two electrodes builds up before any current starts flowing between them. Once the current flow starts through plasma channel, open circuit voltage drops and stabilizes the electrode gap. A preset voltage determines the working gap between the two electrodes. It is a vital factor that influences the spark energy, which is responsible for the higher MRR, higher tool wear rate and rough surfaces.[1]

***Pulse-on time or pulse duration (T_{on})**:* It is the duration of time (µs), the current is allowed to flow per cycle. Dielectric ionizes and sparking takes place during this period. It is the productive regime of the spark cycle during which current flows and machining is performed. The amount of material removal is directly proportional to the amount of energy applied during this on-time. Though MRR increases with Ton, rough surfaces are produced due to high spark energy.[1]

***Pulse-off time or pulse interval (T_{off})**:* It is the duration of time between two consecutive pulse-on times. The supply voltage is cut off during pulse-off time. Dielectric de-ionizes and regains its strength in this period. This time allows the molten material to solidify and to be washed out of the arc gap. Pulse-off time should be minimized as no machining takes place during this period. However, too short Toff leads to process instability.[1]

***Duty cycle (τ)**:* It is a percentage of the on-time relative to the total cycle time. This parameter is calculated by dividing the on-time by the total cycle time (on-time and off time), which is shown in Equation. At higher τ, the spark energy is supplied for longer duration of the pulse period resulting in higher machining efficiency. [1]

$$\tau = \frac{T_{on}}{T_{on} + T_{off}} \times 100$$

***Polarity**:* Polarity refers to the potential of the workpiece with respect to the tool. In straight or positive polarity, the workpiece is positive, whereas in reverse polarity workpiece is negative. In straight polarity, quick reaction of electrons produces more energy at anode (workpiece) resulting in significant material removal. However, high tool wear takes place with long pulse durations and positive polarity, due to higher mass of ions. In general, selection of polarity is experimentally determined depending on the combination of workpiece material, tool material, current density and pulse duration.[1]

Dielectric Fluid: Dielectric fluid carries out three important tasks in EDM. The first function of the dielectric fluid is to insulate the inter electrode gap and after breaking down at the appropriate applied voltage, conducting the flow of current. The second function is to flush away the debris from the machined area, and lastly, the dielectric acts as a cool ant to assist in heat transfer from the electrodes. Most commonly used dielectric fluids are hydrocarbon compounds, like light transformer oil and kerosene. [1]

Electrode gap: The inter electrode gap is a vital factor for spark stability and proper flushing. The most important requirements for good performance are gap stability and the reaction speed of the system; the presence of backlash is particularly undesirable. The reaction speed must be high in order to respond to short circuits or open gap conditions. Gap width is not measurable directly but can be inferred from the average gap voltage. The tool servo mechanism is responsible for maintaining working gap at a set value. Mostly electro mechanical (DC or stepper motors) and electro hydraulic systems are used and are normally designed to respond to average gap voltage.[1]

Tool work time (T_w) and tool lift time (T_{up}): During the working time Tw, multiple sparks occur with a pulse on duration Ton and pulse off time Toff. Then, the quill lifts up for T_{up} duration when impulse flushing is done. The impulse flushing is an intermittent flushing through side jet and is done through a solenoid valve is synchronized with the lifting of tool. The dielectric is directed towards the IEG to accomplish removal of the debris.[1]

Flushing Pressure and Type of Flushing: is an important factor in EDM because debris must be removed for efficient cutting. Moreover, it brings fresh dielectric into the inter electrode gap. Flushing is difficult if the cavity is deeper and inefficient flushing may initiate arcing that may create unwanted cavities which are detrimental for surface quality and dimensional accuracy. There are several methods generally adopted to flush the EDM gap: jet or side flushing, pressure flushing, vacuum flushing and pulse flushing. In jet flushing, hoses or fixtures are used and directed at the inter electrode gap to wash away the debris. In pressure and vacuum flushing, dielectric flows through the drilled holes in the electrode, workpiece or fixtures. In pulse flushing, the movement of electrode in up and down, orbital or rotary motion creates a pumping action to draw the fresh dielectric. The usual range of pressure used is between 0.1 and 0.4 kgf/cm^2.[1]

Applications of PMEDM

EDM has been used in manufacturing of aerospace components such as fuel system, engine, impeller and landing gear components where high temperature and high-stress conditions prevail. However, the safety and life of the components were questionable due to poor surface integrity. Application of PMEDM process in place of conventional EDM adequately addressed the problem arising due to poor surface integrity. Some of the specific applications of PMEDM in automobile industry include the manufacturing of engine blocks, cylinder liners, piston heads and carburettors. With the increased precision, accuracy and the capability to be used under micro machining domain, PMEDM is also used to produce medical implants and surgical equipment. Some of the specific devices include surgical blades, dental instruments, orthopaedic, spinal, ear, nose, and throat implants. Surface modification in the form of electro discharge coating is also realized by PMEDM technique. Therefore, light metallic alloys can be surface treated for wear resistance applications typically in automobile and aerospace industries.

LITERATURE REVIEW

[15]Sagar Patel *et al* In PMEDM Aluminum oxide (Al_2O_3) powder with a particle concentration of 0.5–1.5 gm/l was added into the dielectric to study improved machining performance. Inconel 718 was machined using copper–tungsten electrode with tool rotation about 300 rpm. Experiments were designed using Taguchi’s three-level L18 orthogonal array. Amathematical model is developed to correlate the influences of these variables such as Peak current (I_p), Sparking gap (V), Pulse on time, (T_{on}), duty cycle and slurry concentration on MRR.A mean effect plots are generated to develop correlation between the influences of these variables such as Material Removal Rate, Tool Wear Rate, Surface Roughness and Heat affected zone. They conclude that the powder concentration does not have a significant effect on the response parameters, machining parameters play a vital role in improving machining efficiency.

[16]Gurpreet Singha *et al* In this study, High-carbon(HCHCr) Hot Die Steel (H13) and EN31 and two electrode materials graphite (more than 99% purity) and Tungsten-Copper (79.36% W, 19.462% Cu, 0.121% Ni, 0.047% Z, 0.014% Ti) of diameter 20mmhas been used. Before the start of experimentation, the chemical composition of work piece and electrode material was measured on an Optical Emission Spectrometer DV-6. The dimension of each workpiece 100×50×10mm has been selected. Each work piece has been grinded on surface grinding machine to level the machining surface. They conclude that the effects of various parameters study, found that increase in input current crater size on machined surface has been increased. The uniform particle distribution a less micro cracks on the surface has been observed when surface has been machined with copper powder in the dielectric fluid. While machining material from the electrode and powder has been transferred to the surface which further enhanced the surface properties.

[17]Mahendra G. Rathi *et al* In this paper is to Study on Effect of Powder Mixed dielectric in EDM of Inconel 718. The effect of various powder mixed in dielectric is studied input parameters like Duty cycles, current, pulse on time and powder media in that Silicon carbide, Aluminum oxide, Graphite powder used. Machining characteristics measured in terms of Material removal rate, tool wear rate. They conclude that Maximum MRR is obtained at a high peak current, moderate Ton of 5µs, duty cycle 85% and Graphite as powder media. Low TWR is achieved at a current of 12 A, a moderate Ton of 20 µs, duty cycle 90% and Sic as powder media.

[18]Khalid Hussain Syed *et al*, In this paper, an attempt has been made to study the effect of aluminum powder when mixed in the distilled water dielectric fluid. The work and tool electrode materials used are W300 die steel and electrolytic copper respectively. Pulse peak current, pulse on-time and concentration of aluminum powder are taken as the process parameters. They conclude that with increase in the concentration of the aluminum powder, the WLT tends to decrease for any value of peak current. Higher concentration of aluminum powder in the distilled water produces thin white-layer consisting more cracks and voids on the machined surface.

[19]Anil Kumar *et al* Additive mixed electric discharge machining (AEDM) is a recent innovation for enhancing the capabilities of electrical discharge machining process. The objective of present research work is to study the influence of operating process input parameters on machining characteristics of nickel-based super alloy (Inconel 718) in aluminum AEDM with copper electrode. The effectiveness of AEDM process on Inconel is evaluated in terms of material removal rate (MRR), surface roughness (SR), and wear ratio (WR) using one variable at a time (OVAT) approach. They conclude that the Highest spark gap is obtained with medium size (mesh size 325) particles.9. Six g/l of aluminum medium size additive powder in dielectric produces maximum MRR, minimum SR, and 4 g/l produces minimum WR.

[20]Gunawan S. Prihandana *et al.* This study investigates the influence of molybdenum disulfide (MoS2) powder suspended in dielectric fluid on the performance of micro-EDM of Inconel 718 with focus in obtaining quality micro holes. It was observed that MoS_2 powder suspension with 50 nm of size and 5 g/l of concentration can produce better quality micro holes in Inconel 718. Moreover, it was also found that 50 nm MoS2 powder was the best powder size to achieve the highest material removal rate. They conclude that as for the effect of powder concentration on material removal rate, the highest material removal rate mostly can be achieved at a concentration level of 10 g/l. 5 g/l provides the highest MRR.50 nm powder suspended in dielectric fluid provides the highest material removal rate compared to the other sizes (2 µm and 10 nm).

[21]Tien-Long Banh *et al* four quality characteristics of the electrical discharge are simultaneously presented and optimized using titanium powder mixed electric discharge machining. The Taguchi method and the grey relational analysis are applied to the processing parameters to investigate the following: workpiece material, tool material, polarity, pulse-on time, current, pulse-off time, and powder concentration. The combination of the Taguchi method and grey relational analysis

is applied to optimize simultaneously four quality characteristics of powder mixed electric discharge machining, including material removal rate, tool wear rate, surface roughness, and microhardness surface. Research has shown that titanium powder mixed into the dielectric fluid in the Improved the productivity and surface quality of fine EDM. after using PMEDM with the titanium powder in the optimal conditions through the GRA were of good quality, where the topographies had a good shape, the number and size of cracks was reduced, and the white layer was of uniform thickness.

[22]Pallavi Chaudhary *et al*, in this paper, a study was carried out on the influence of the parameters such peak current, powder type, powder concentration on EN-19 work piece. Taguchi methodology has been adopted to plan and analyze the experimental results. In this study seven factors with three levels are investigated using Orthogonal Array (OA) L9. They conclude that the Larger MRR has been achieved, the effect of powder concentration was most significant, TWR firstly increases and then decreases with increase in pulse on time & Current.

[23]SachinMohala *et al* in this study investigates the feasibility of machining Al-Si_p metal matrix composite by multiwalled carbon nanotube (MWCNT) mixed electric discharge machining (EDM). Experiments were conducted on indigenously developed Nano-powder mixed electric discharge machining (NPMEDM) setup. Material removal rate (MRR) and surface roughness (SR) were considered as the performance measures. They conclude that the material removal rate increases with addition of the MWCNT and its concentration due to increased dielectric strength and more uniform and increased spark frequency. The surface roughness decreases with CNT concentration CNT concentration increases further, the surface roughness tends to increase again.

[24]Shih-Fu Ou *et al* This study focuses on machining orthopedic-implant materials based on titanium and titanium–tantalum alloys using bioactive hydroxyapatite (HA)-powder suspension as the dielectric. The influence of the powder particles and the work-piece composition on the machining performance was investigated. Employing a suspension dielectric with 5 g/L HA caused a smoother surface (Ra 2.1 μm) with a thinner recast layer (~9 μm) as compared to using water to machine titanium which has surface roughness of Ra 2.4 μm with a recast layer close to 10 μm. In addition, the MRR of titanium machined in the HA-powder-suspension dielectric (6.4x10-4 gmin-1) was greatly lower than that in water (28.6x10-4 gmin-1).The MRR, EWR, and the surface roughness of titanium and titanium–tantalum alloys under PMEDM exhibited an inverse relation with respect to the melting temperature and thermal conductivity of the alloy. They conclude that the MRR, EWR, surface roughness, and thickness of the recast layer showed a strong initial decrease after which they gradually increased with the concentration of HA in the dielectric. Increasing the discharge current increased the MRR, EWR, surface roughness, and the recast-layer thickness; however, the amounts of HA in the recast layer were lower.

[25]Fred L. Amorim *et al* in this literature, there are technological gaps in the use of molybdenum as an additive powder in PMEDM process. The influences of different sizes of fine Mo powder particles (5 and 15 μm) suspended in dielectric fluid in several EDM finishing regimes and machining times were investigated regarding AISI H13 tool steel surface modification. They conclude that Hardness increase of about four times fold in comparison with the matrix material. In terms of solidified layer formation, free of microcracks and pores.

[26]Saeed Daneshmand *et al* In this study, the effect of input parameters of EDM such as voltage, pulse current, pulse on time and pulse o®-time on output parameters like material removal rate, tool wear rate and surface roughness in both conditions of the rotary tool with powder mixed dielectric EDM and the stationary tool excluding powder mixed dielectric were investigated. They conclude that pulse on-time were the most significant parameters affecting MRR, TWR.

[27]Nipun D. Gosai *et al* in EDM, dielectric plays important role in machining operation. In present paper silicon powder suspended plus kerosene is used as dielectric to explore the effect of these dielectrics on the execution criteria such as material removal rate (MRR) and roughness (Ra) in the midst of machining of titanium combination (Ti-6Al-4V). Peak current, pulse on time, pulse off time and powder included into dielectric liquid of EDM were picked as methodology parameters to think about the PMEDM execution with respect to MRR and Ra. They conclude that the blend of high peak current and high concentration yields more MRR and littler SR.

[28]L. Li *et al* This paper introduces a machining method of Sic abrasive mixed EDM with magnetic stirring. Structural features and chemical composition were analyzed by scanning electron microscope (SEM) and X-ray diffraction (XRD). Micro-hardness distribution on the cross section was measured with FM800 micro hardness tester. The influence of pulse width and pulse peak current on the formation of the surface hardening layer is analyzed. The results show that a continuous strengthened layer was formed during Sic abrasive mixed EDM process. The hardness of the formed layer was significantly improved because of the formation of Tic and $TiSi_2$ phases on the machined surface. They conclude that the surface processed by mixed-abrasive EDM is smooth, the quality of reinforced layer becomes better. The hardness of mixed powder mixed EDM surface increases to more than two times of hardness of the bulk material.

[29]Chander Prakash *et al* In this study is to fabricate sub micro and Nano scale topography by PMEDM process to enhance the biocompatibility without affecting machining efficiency. The effect of Si powder concentration along with pulse-current and duration on the surface and machining characteristics has been investigated. A significant decrease in surface crack density on the machined surface with 4 g/l Si powder concentration was observed. The silicon as powder additive in dielectric fluid of EDM (PMEDM) significantly improved the surface quality by reducing surface defects like micro-cracks, craters/pit size, recast layer thickness. PMEDM can be considered as potential technique to improve the surface characteristics and chemistry without sacrificing machining efficiency.

[30]S. Tripathy *et al* In the present work application of Taguchi method in combination with Technique for order of preference by similarity to ideal solution(TOPSIS) and Grey Relational Analysis (GRA) have been adopted to evaluate the

effectiveness of optimizing multiple performance characteristics for PMEDM of H-11 die steel using copper electrode. The effect of process variables such as powder concentration (C_p), peak current (Ip), pulse on time (Ton), duty cycle (DC) and gap voltage (Vg) on response parameters such as Material Removal Rate (MRR), Tool Wear Rate (TWR), Electrode Wear Ratio (EWR) and Surface Roughness (SR) have been investigated using chromium powder mixed to the dielectric fluid. They conclude that Conductive powder to the dielectric fluid improves the surface topography with less defects, cracks and surface roughness, which is directly related to the size of the crater formed and the distribution of recast layer on the surface.

[31]BhikshaGugulothu *et al* In the present investigation, the effect of graphite powder concentration into the dielectric fluid as drinking water on electric discharge machining of Ti-6Al-4V alloy is studied. Taguchi parameter design approach was used to get an optimal parametric setting of EDM process parameters namely, peak current, pulse on time, pulse off time and graphite powder concentration that give up optimal process performance characteristics such as material removal rate and surface roughness. Also, individual effect of process Parameters on performance characteristics was studied. They conclude that Machining characteristics namely MRR, SR increase with increase of peak current. MRR decreases less significantly with increase of powder concentration.

[32]Nihal Ekmekci *et al*in this paper Hydroxyapatite (HA) powder suspension in deionized water was used as a dielectric liquid during Electrical Discharge Machining of Ti6Al4V work material. The machined surfaces were evaluated by scanning electron microscopy, energy dispersive spectroscopy, and optical microscopy. The powder particles in the dielectric liquid extensively migrated and formed an HA rich layer on the work material surface under specific machining conditions. They conclude that Using high pulse current over distinct levels and reduced pulse time result in a build-up of a decomposed layer due to high temperatures attained during the process.

[33]M. A. Razak *et al* PMEDM may lead to improve machined part surface finish, improve material removal rate (MRR) and reduce tool wear rate (TWR). Further investigations on powder concentration and powder particles size for silicon carbide (Sic) PMEDM are proposed.

Number of experiments to be conducted is based on Taguchi orthogonal array with three level and two factors. The outcomes are expected capable to increase MRR, improve surface finish, reduce TWR, reduce machining time and reduce machining cost. They conclude that the reduction machining time of EDM process with PMEDM. The optimum powder concentration and size of powder particles to achieve the highest efficiency of EDM process.

[34]MurahariKolli *et al* in this paper, Taguchi method was employed to optimize the surfactant and graphite powder concentration in dielectric fluid for the machining of Ti-6Al-4V using Electrical Discharge Machining (EDM). The process parameters such as discharge current, surfactant concentration and powder concentration were changed to explore their effects on Material Removal Rate (MRR), Surface Roughness (SR), Tool wear rate(TWR) and Recast Layer Thickness (RLT). They conclude that optimum condition improves the material removal rate, reduces surface roughness and less recast layer of Titanium alloy.MRR increased with increase in the discharge current and graphite powder concentration.

[35]B. Kuriachen *et al* in the present work, an experimental investigation has been performed in order to study the effect of Sic micro particle suspended dielectric on machining Ti-6Al-4V with tungsten carbide electrode. The effect of major electric discharge milling process parameters; voltage, capacitance and powder concentration in dielectric on responses viz., MRR and TWR were studied. It is observed that maximum MRR were obtained at low levels of powder concentrations and middle levels of capacitance and voltages. Minimum TWR were observed at low levels of powder concentration and it increased with capacitance and voltage.

[36]Anderson Molinetti *et al* This work investigated the influence of silicon and manganese powders with fine particle sizes, using two different concentrations, suspended in the dielectric when EDM machining AISI H13 tool steel. It evaluated the surface roughness, hardness, and the chemical composition and micro-structure of the recast layer; using X-ray diffraction (XRD), scanning electron microscopy (SEM), and energy dispersive spectroscopy (EDS) techniques. They conclude that the addition of Si and Mn to the dielectric fluid promoted a more uniform solidified layer when compared to EDM process without the use of powder suspended in the dielectric. Surface roughness of the workpieces improved significantly when PMEDM with silicon and manganese powders. Si powder improved the average surface roughness.

[37]Chander Prakash *et al* Herein, a b-Ti-based implant was subjected to powder mixed electric discharge machining (PMEDM) for surface modification to produce a novel biomimetic nonporous bio ceramic surface. The microstructure, surface topography, and phase composition of the non-machined and machined (PMEDM) surfaces were investigated using field-emission scanning electron microscopy, energy-dispersive x-ray spectroscopy, and x-ray diffraction. They conclude that the potential of PMEDM treatment for tailoring Nano-scaled and micro scaled surface features to promote biomechanical anchorage. Furthermore, this research work provides an insight into the surface modification of dental implants.

[38]Balbir Singha *et al* This paper presents the experimental investigation on tool wear rate (TWR) in power mixed electrical discharge machining (PMEDM) of aluminum 6061 alloy reinforced with 10% silicon carbide particles (AA6061/10%SiCp Composite). Composite material is fabricated by mechanical stir casting process and further characterized by SEM and EDS. Tungsten powder with concentration of 4gm/liter is mixed in the dielectric fluid.They conclude that TWR increases significantly with rise in current whereas higher pulse on time yields a moderate reduction in tool wear rate. pulse on time, pulse off time and gap voltage. Comparing to the basic EDM process, the tool wear rate reduces by 51.12%, by using PMEDM approach.

[39]Harmesh Kumar *et al* This paper reports the results of an experimental study to develop mirror-like surface finish on the surface of AISI-D2 die steel by electric discharge machining (EDM)using carbon nanotubes (CNTs). The CNTs will be

mixed into the dielectric fluid of EDM in defined proportion to develop and analyze the surface characteristics of AISI-D2 die steel. The newly developed proposed technology is called Nano powder mixed electric discharge machining (NPMEDM). This research presents the influence of various processing parameters namely concentration of CNTs, peak current, and pulse duration on surface topography of workpiece machined by NPMEDM. They conclude that the CNT's concentration has a strong interaction with peak current in MRR results. The pulse duration has a significant effect on both MRR and SR.

[40]Balbir Singh *et al* in this study, machining of AA6061/10%SiC composite fabricated by mechanical stir casting process has been experimentally investigated using electro discharge machining (EDM) process with tungsten-powder-mixed dielectric fluid (PMEDM). Peak current, pulse on-time, pulse off-time, and gap voltage are selected as machining parameters. They conclude that the surface roughness of EDM surface can be reduced using PMEDM approach.

[41]Zakaria Mohd Zain *et al* the objective of this investigation is to determine the ability of tantalum carbide (Tac) powder-mixed dielectric fluid to enhance the surface properties of stainless steel material during EDM. The properties investigated are the micro-hardness and corrosion characteristics of the EDM surface. Machining was conducted with 25.0 g/L concentration of Tac powder in kerosene dielectric fluid. They conclude that the PMEDM of Tac powder in kerosene dielectric fluid can enhance the corrosion resistance of the stainless-steel material.

SUMMARY OF LITERATURE

- From the literature review, we can understand that the optimization of input parameters of PMEDM like Pulse on Time, Pulse Off Time, Servo Voltage, Peak Current, Slurry concentration, Flushing pressure can improve the characteristics.
- In PMEDM change in input parameters Pulse on Time, Pulse Off Time, Servo Voltage, Peak Current, Powder concentration, Flushing pressure its directly or indirectly affected to the MRR and SR.
- MRR increased with increase in the discharge current and powder concentration with optimum values.
- The MRR & surface roughness and thickness of the recast layer showed a strong initial decrease & increased with the powder concentration.
- Maximum MRR is obtained at 5A of peak current and minimum SR is obtained at 2A.
- Using MoS_2 powder concentration on material removal rate, the highest material removal rate mostly can be achieved at a concentration level of 10 gm/l.
- Less micro cracks on the surface has been observed when using copper powder.
- With Titanium powder the number and size of cracks was reduced, and the white layer was of uniform thickness.
- Conductive powder (Chromium) to the dielectric fluid improves the surface topography with less defects, cracks and surface roughness.

CONCLUSION

- In powder mixed electric discharge machining (PMEDM) Chromium and tungsten powder were not used as powder additive in dielectric fluid during the machining of Inconel 718.
- According to literature review, selection criteria for the powder material was not mentioned in detail.
- No literature co-relates characteristics of powder and response parameters.

References

1. Izhar Khan1, Bilal Shaikh2, Bilal Khan3, Abdullah Khan4, Irshad Shaikh, A Study on Effect of Powder on EDM (PMEDM), *International Journal on Recent Technologies in Mechanical and Electrical Engineering* (IJRMEE) ISSN: 2349-7947 Volume: 3 Issue: 4 11 – 15.
2. W.S. Zhao, Q.G. Meng, Z.L. Wang, The application of research on powder mixed EDM in rough machining, *J. Mater. Process. Technol.* 129 (2002) 30–33.
3. Z.Z. Lu, F.L. Zhao, Y.Y. Yang, Research on dielectric breakdown and discharge channel in powder-mixed EDM, Dalian LigongDaxueXuebao/*Journal Dalian Univ. Technol.* 48 (2008) 373–377.
4. G.S. Prihandana, M. Mahardika, M. Hamdi, Y.S. Wong, K. Mitsui, Accuracy improvement in nanographite powder-suspended dielectric fluid for micro-electrical discharge machining processes, *Int. J. Adv. Manuf. Technol.* 56 (2011) 143–149.
5. F.L. Zhao, Z.Z. Lu, H. Wang, Z.Q. Qian, Research on effecting mechanism of particles in powder-mixed EDM, Dalian LigongDaxueXuebao/*Journal Dalian Univ. Technol.* 45 (2005) 668–671.
6. M. Kunieda, M. Yoshida, N. Taniguchi, Electrical Discharge Machining in Gas, CIRP Ann. - Manuf. Technol. 46 (1997) 143–146.
7. H.M. Chow, L.D. Yang, C.T. Lin, Y.F. Chen, The use of SiC powder in water as dielectric for micro-slit EDM machining, J. Mater. Process. Technol. 195 (2008) 160–170.
8. K.Y. Kung, J.T. Horng, K.T. Chiang, Material removal rate and electrode wear ratio study on the powder mixed electrical discharge machining of cobalt-bonded tungsten carbide, *Int. J. Adv. Manuf. Technol*. 40 (2009) 95–104.
9. M.P. Jahan, M. Rahman, Y.S. Wong, Modelling and experimental investigation on the effect of nanopowder-mixed dielectric in micro-electrodischarge machining of tungsten carbide, Proc. Inst. Mech. Eng. Part B *J. Eng. Manuf.* 224 (2010) 1725–1739.
10. A. Bhattacharya, A. Batish, N. Kumar, Surface characterization and material migration during surface modification of die steels with silicon, graphite and tungsten powder in EDM process, *J. Mech. Sci. Technol.* 27 (2013) 133–140.
11. T.Y. Fong, F.C. Chen, Investigation into some surface characteristics of electrical discharge machined SKD-11 using powder-suspension dielectric oil, J. *Mater. Process. Technol.* 170 (2005) 385–391.

12. B. Jabbaripour, M.H. Sadeghi, M.R. Shabgard, H. Faraji, Investigating surface roughness, material removal rate and corrosion resistance in PMEDM of r-TiAl intermetallic, *J. Manuf. Process*. 15 (2013) 158–166.
13. F.Q. Hu, F.Y. Cao, B.Y. Song, P.J. Hou, Y. Zhang, K. Chen, *et al*., Surface properties of SiCp/Al composite by powder-mixed EDM, in: Procedia CIRP-The Seventeenth CIRP Conf. Electro Phys. Chem. Mach., 2013: pp. 101–106.
14. Q.Y. Ming, L.Y. He, Powder-suspension dielectric fluid for EDM, *J. Mater. Process. Technol*. 52 (1995) 44–54.
15. Sagar Patel, DigneshThesiya & AvadhootRajurkar, "Aluminum powder mixed rotary electric discharge machining (PMEDM) on Inconel 718", *Australian Journal of Mechanical Engineering*, DOI: 10.1080/14484846.2017.1294230.
16. Gurpreet Singh, Gurmail Singh, Kamaljit Singh, Amit Singlad, "Experimental studies on material removal rate, tool wear rate and surface properties of machined surface by powder mixed electric discharge machining", Materials Today: Proceedings 4 (2017) 1065–1073.
17. Mahendra G. Rathi, Deepak V. Mane, "Study on Effect of Powder Mixed dielectric in EDM of Inconel 718", *International Journal of Scientific and Research Publications*, Volume 4, Issue 11, November 2014 ISSN 2250-3153.
18. Khalid Hussain Syed, P. Kuppan, "Studies on Recast-layer in EDM using Aluminium Powder Mixed Distilled Water Dielectric Fluid", *International Journal of Engineering and Technology* (IJET).
19. Anil Kumar, Sachin Maheshwari, Chitra Sharma, and Naveen Beri, "Analysis of Machining Characteristics in Additive Mixed Electric Discharge Machining of Nickel-Based Super Alloy Inconel 718", Materials and Manufacturing Processes, 26: 1011–1018, 2011.
20. Gunawan S. Prihandana & TutikSriani& Muslim Mahardika & M. Hamdi & Norihisa Miki & Y. S. Wong & Kimiyuki Mitsui, "Application of powder suspended in dielectric fluid for fine finish micro-EDM of Inconel 718", *Int J Adv Manuf Techno* 10.1007/s00170-014-6145-4.
21. Tien-Long Banh, Huu-Phan Nguyen, Cuong Ngo and Duc-Toan Nguyen, "Characteristics optimization of powder mixed electric discharge machining using titanium powder for die steel materials", sagepub.co.uk/journals Permissions. *nav* DOI: 10.1177/0954408917693661.
22. Pallavi Chaudhury, SikataSamantaray, SibakantaSahu, "Multi Response Optimization of Powder Additive Mixed Electrical Discharge Machining by Taguchi Analysis", Materials Today: Proceedings 4 (2017) 2231–2241.
23. SachinMohal, Harmesh Kumar, "Study on the Multiwalled Carbon Nano tube Mixed EDM of Al-SiCp Metal Matrix Composite", Materials Today: Proceedings 4 (2017) 3987–3993.
24. Shih-Fu Ou, Cong-Yu, Wang, "Effects of bio ceramic particles in dielectric of powder-mixed electrical discharge machining on machining and surface characteristics of titanium alloys". PII: S0924-0136(17)30071-7
25. Fred L. Amorim & Vitor A. Dalcin & Paulo Soares & Luciano A. Mendes, Surface modification of tool steel by electrical discharge machining with molybdenum powder mixed in dielectric fluid", *Int J Adv Manuf Technol* DOI 10.1007/s00170-016-9678-x.
26. Saeed Daneshmand, Behnam Masoudi And Vahid Monfared, "Electrical Discharge Machining of Al/7.5% Al2O3 MMCs Using Rotary Tool And Al2O3 Powder", *Surface Review and Letters*, Vol. 24, No. 2 (2017) 1750018.
27. Nipun D. Gosai and Anand Y. Joshi, "Experimental Investigation and Optimization of Process Parameters Used in the Silicon Powder Mixed Electro Discharge Machining of Ti-6Al-4V Alloy Using Response Surface Methodology", *J. Manuf. Sci. Prod*. 2016; 16(1): 21–32.
28. L. Li, L. Zhao, Z. Y. Li, L. Feng & X. Bai (2016), "Surface Characteristics of Ti-6Al-4V by Sic Abrasive Mixed EDM with Magnetic Stirring, *Materials and Manufacturing Processes*", DOI: 10.1080/10426914.2016.1151043
29. Chander Prakash, H. K. Kansal, B. S. Pabla& Sanjeev Puri (2016): "Experimental Investigations in Powder Mixed Electric Discharge Machining of Ti-35Nb-7Ta-5Zr β-Titanium Alloy", *Materials and Manufacturing* Processes.
30. S. Tripathy, D.K. Tripathy, "Multi-attribute optimization of machining process parameters in powder mixed electro-discharge machining using TOPSIS and grey relational analysis", *Engineering Science and Technology, an International Journal* (2015).
31. BhikshaGugulothu, D. Hanumantha Rao and G. Krishna Mohana Rao, "Optimization of Edm Process Parameters And Graphite Powder Concentration on Electrical Discharge Machining of Ti-6al-4v Alloy Using Taguchi Method", 2394-6210, VOLUME-1, ISSUE-5,2015.
32. Nihal Ekmekci & BülentEkmekci (2015), "Electrical Discharge Machining of Ti6Al4V in Hydroxyapatite Powder Mixed Dielectric Liquid, Materials and Manufacturing Processes", DOI: 10.1080/10426914.2015.1090591.
33. M. A. Razak, A. M. Abdul-Rani, and A. M. Nanimina, "Improving EDM Efficiency with Silicon Carbide Powder-Mixed Dielectric Fluid", *International Journal of Materials, Mechanics and Manufacturing*, Vol. 3.
34. MurahariKolli, Adepu Kumar, "Effect of dielectric fluid with surfactant and graphite powder on Electrical Discharge Machining of titanium alloy using Taguchi method", *Engineering Science and Technology, an International Journal* xxx (2015) 1e12.
35. B. Kuriachen& J. Mathew (2015)' "Effect of Powder Mixed Dielectric on Material Removal and Surface Modification in Micro Electric Discharge Machining of Ti-6Al-4V", *Materials and Manufacturing Processes*, DOI: 10.1080/10426914.2015.1004705.
36. Anderson Molinetti& Fred L. Amorim1 & Paulo César Soares Jr. & Tiago Czelusniak, "Surface modification of AISI H13 tool steel with silicon or manganese powders mixed to the dielectric in electrical discharge machining process", *Int J Adv Manuf Technol* DOI 10.1007/s00170-015-7613-1.

37. Chander Prakash, H.K. Kansal, B.S. Pabla, and Sanjeev Puri, "Processing and Characterization of Novel Biomimetic Nanoporous Bio ceramic Surface on b-Ti Implant by Powder Mixed Electric Discharge Machining", *JMEPEG* DOI: 10.1007/s11665-015-1619-6.
38. Balbir Singh, Jatinder Kumar & Sudhir Kumar (2015), "Investigation of the Tool Wear Rate in Tungsten Powder Mixed Electric Discharge Machining of AA6061/10%SiCp Composite", *Materials and Manufacturing Processes*, DOI:10.1080/10426914.2015.1025965.
39. Harmesh Kumar, "Development of mirror like surface characteristics using Nano powder mixed electric discharge machining (NPMEDM)", *Int J Adv Manuf Technol* DOI 10.1007/s00170-014-5965-6.
40. Sarabjeet Singh Sidhu, Ajay Batish & Sanjeev Kumar (2014), "Study of Surface Properties in Particulate-Reinforced Metal Matrix Composites (MMCs) Using Powder-Mixed Electrical Discharge Machining (EDM)", *Materials and Manufacturing Processes*, 29:1, 46-52, DOI: 10.1080/10426914.2013.852211.
41. Zakaria Mohd Zain, Mohammed Baba Ndaliman, Ahsan Ali Khan and Mohammad Yeakub Ali, "Improving micro-hardness of stainless steel through powder-mixed electrical discharge machining", DOI: 10.1177/0954406214530872.

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