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A Review on Current Trends in PM-EDM using Commercial Kerosene as Di-Electric Fluid

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ABSTRACT
Powder Mixed Electrical discharge machining (EDM) process is one of the most commonly used nonconventional material removal processes. It is especially used for the manufacturing complex geometry and hard material parts that are extremely difficult-to-machine by using conventional machining processes. There are various types of products which can be produced using PMEDM. Parts of aerospace, automotive industry and surgical components can be finished by this process. In this paper, authors have reviewed the research work carried out in the development of PMEDM in the current scenario for the improvement of machining characteristics such as Material Removal Rate (MRR), Surface Roughness (SR) and Tool Wear Ratio (TWR) when the commercial kerosene is used as a dielectric fluid with different powder materials.

Introduction

Electrical Discharge Machining

EDM as a process was introduced over fifty years ago; improvements in technology have led to increases in both cutting speeds and component precision. Developing from initially tool making industry sectors of press tool and mould tools, the EDM process is now mainly found within production engineering, aerospace, motor sport, medical and scientific industries. Electrical Discharge Machining (EDM) is non-traditional, no physical cutting forces between the tool and the work piece, high precision metal removal process using thermal energy by generating a spark to erode the work piece. The work piece must be a conductive electricity material which is submerged into the dielectric fluid for better erosion. EDM machine has wide application in production of die cavity with large components, deep small diameter whole and various intricate holes and other precision part.

PM-EDM & Its Technology

In PMEDM process suitable material in the powder form will be mixed into the dielectric fluid in tank. Better circulation of the dielectric fluid can be done by stirring system. Constant reuse of powder in the dielectric fluid can be done by the special circulation system. Generally, various powders of particle that can be added into the dielectric fluid like Aluminum (Al) , graphite, copper (Cu) , chromium (Cr), Silicon carbide etc. spark gap provided by the additives particles. The powder particles of the material get energized & behave like a zigzag way manner. under the sparking zone, the particles of the material powder comes close to each other & arrange themselves in the form of chain like structure between the work piece surface & tool electrode. The interlocking between the different powder particles occurs in the direction of flow current. The chain formation helps in bridging the discharge gap between the electrodes. Because of bridging effect, the insulating strength of the dielectric fluid decreases resulting in easy short circuit. This causes early explosion in the gap and series discharge' starts under the electrode area. The faster sparking within a discharge causes faster erosion from the work piece surface and hence the material removal rate increases.

Major Component of Powder mixed Electrical discharge Machining

Power supply: It transforms the alternating current from the main utility supply into the pulse direct current required to produce the spark discharge at the machining gap.
Pulse Generator & Control Unit: This unit is responsible for supplying pulses at a certain voltage and current for specific amount of time. The power supply control the amount of energy consumed. The control unit is control the all function of the machining for example of Ton, Ip, duty cycle, putting the values and maintain the work piece the tool gap.
The servo system: The servo control unit is provided to maintain the pre-determined gap. It senses the gap voltage and compares it with the present value and the different in voltage is then used to control the movement of servo motor to adjust the gap.
Tool holder: The tool holder holds the tool during the process of machining.
Circulating Pump: This unit of the system is responsible for the circulation of powder mixed dielectric.
Electrode: The EDM electrode is the tool that determines the shape of the cavity to be produce
Permanent magnet: Magnetic forces are used to separate the debris from the dielectric fluid. For this purpose, two permanent magnets are placed at the bottom of machining tank
Machining Tank: The system consists of a transparent bath-like container, called the machining tank. It is placed in the work tank of the EDM, and the machining is performed in this container.

Principle of PMEDM

When voltage is applied the powder particles become energized and behave in a zigzag fashion. These charged particles are accelerated due to the electric field and act as conductors promoting breakdown in the gap. This increases the spark gap between tool and the work piece. Under the sparking area, these particles come close to each other and arrange themselves in the form of chain like structures. The interlocking between the powder particles occurs in the direction of flow of current. The chain formation helps in bridging the discharge gap between the electrodes. Because of bridging effect, the insulating strength of the dielectric fluid decreases resulting in easy short circuit. This causes early explosion in the gap and series discharge' starts under the electrode area. The faster sparking within a discharge causes faster erosion from the work piece surface and hence the material removal rate increases.

Functions of a Dielectric Fluid: The dielectric fluid in an EDM is used to

1. Act as a medium through which controlled electrical discharges occur.
2. Cool the section that was heated by the discharging effect
3. Flush the eroded particles from the machining gap
4. Provide insulation between the electrode and the work piece
5. Act as a medium used to carry away the solidified EDM debris from the discharge gap to the filter system.
6. Act as a heat transfer medium to absorb and carry away the heat generated by the discharges from both the electrode and the work piece

Major types of dielectric fluid

1. Mineral Oils
2. Kerosene
3. Transformer Oil
4. EDM Oils
5. Synthetic oil

Properties & Characteristics of Dielectric Fluid

1. Viscosity is the property that describes a fluids resistance to flow.
2. Flash Point-The flash point of a flammable liquid is the lowest temperature at which it can form an ignitable mixture in air.
3. Oxidation Stability is a measure of the dielectric fluids tendency to react with oxygen.
4. Volatility is a measure of the tendency of a dielectric fluid to vaporize
5. Acid Number is used to quantify the amount of acid present in a sample of dielectric oil.
6. Pour Point of oil is the temperature below which the oil no longer pours freely.

Literature

Sanjeev kumara et (1) were performed experiments on three die steel materials- OHNS die steel , D2 high-carbon high-chromium die steel, H13 hot die steel by electrical discharge machining using machining conditions favouring material transfer from tungsten powder suspended in the dielectric medium. They have concluded that surface modification is possible by the EDM method, The presence of tungsten carbide and increase in the percentage of carbon on the machined surface indicate that suspended powder particles can react with carbon (from the breakdown of the hydrocarbon dielectric) at high temperatures of the plasma channel to form carbides and The presence of tungsten carbide and increase in the percentage of carbon on the machined surface indicate that suspended powder particles can react with carbon (from the breakdown of the hydrocarbon dielectric) at high temperatures of the plasma channel to form carbides. They have also mentioned that Favourable machining conditions for material transfer by EDM is found to be low discharge current (less than 5 A), shorter pulse on-time (less than 10 _s), longer pulse off-time (more than 50 _s) and negative polarity of the tool electrode. Peak current is found to be the most significant factor for the phenomenon of surface modification. They have extended their remarks saying that Surface alloying with tungsten and carbon has a significant effect on its properties as observed from the increase in micro-hardness by more than 100% for all the three work materials. As surface hardness has a direct bearing on abrasion resistance, the life of dies and other press tools can be substantially improved by this method.

F.Q.Hua et (2) conducted experiments on surface properties of SiCp/Al with moderate fraction of Sic particle reinforced Al matrix composites in EDM and PMEDM using Environment scanning electron microscope. They have found that the surface properties are improved greatly in PMEDM than EDM as its surface roughness decreased about 31.5% and is better in corrosion resistance and wear resistance is twice of EDM. Finally they have also mentioned that the PMEDM is having promising applications in metal matrix composites machining field

Gangadharudu Talla et (3) have performed Modeling and multi-objective optimization of powder mixed electric discharge machining process of aluminum/alumina metal matrix composite and an attempt has been made to fabricate and machine aluminum/alumina MMC using EDM by adding aluminum powder in kerosene dielectric. Their results have shown an increase in MRR and decrease in surface roughness (Ra) compared to those for conventional EDM. They have prepared semi empirical models for MRR and Ra based on machining parameters and important thermo physical properties were established using a hybrid approach of dimensional and regression analysis. A multi response optimization was also performed using principal component analysis-based grey technique (Grey-PCA) to determine optimum settings of process parameters for maximum MRR and minimum Ra within the experimental range. They have concluded that the Machining the MMC by suspending conductive powder particle in the dielectric has shown improvement in productivity as well as surface quality. In their work, a combination of dimensional and non-linear regression analysis is used to model material removal rate (MRR) and surface roughness (Ra) by machining Al/Al2O3 MMC in aluminum suspended dielectric. In PMEDM process, using aluminum suspended kerosene dielectric for the machining of resulted in better MRR when compared to conventional EDM process. A significant decrease in Ra is observed. From the model equations, it was understandable that along with machining parameters, thermal conductivity, coefficient of thermal expansion and density of the material also significantly affect both MRR and Ra. PCA technique has been used to determine the weightages for responses while GRA has been used to combine the multiple objectives into single.

Kuldeep Ojha a et (4)have worked on material removal rate (MRR) and tool wear rate (TWR) study on the powder mixed electrical discharge machining (PMEDM) of EN-8 steel and using Response surface methodology (RSM) analysed the experiments. Peak current, pulse on time, diameter of electrode and concentration of chromium powder added into dielectric fluid of EDM were chosen as process parameters to study the PMEDM performance in terms of MRR and TWR. Experiments have been performed on newly designed experimental setup developed in laboratory. Most important parameters affecting selected performance measures have been identified and optimum process conditions have been found. Also recommended optimal conditions have been verified by conducting confirmation experiments. They have concluded that current, powder concentration and electrode diameter are significant factors affecting both MRR and TWR. Both the performance measures were observed an increasing trend with increase in current for any other settings of parameters. MRR shows increasing trend for increase in powder concentration. The trend shows that MRR will increase further with further increase in concentration. TWR increases with lower range of powder concentration and then decreases. The influence of duty cycle is insignificant on MRR for the range of parameters selected for experimentation. Maximum MRR is observed for a tool diameter of 12 mm. MRR shows decreasing trend both below and above 12 mm tool diameter range. Increase in tool diameter results in decreasing tool wear. The confirmation tests showed that the error between experimental and predicted values of MRR and SR are within permissible range. Empirical modelling of the process led to development of quadratic equations for both performance measures. Their research work adds valuable data regarding PMEDM process. They have ended by more work piece/ powder/ electrode materials/ experimental settings combinations are needed to be investigated further for much validation of the process.

M Prabu et (5) have done experimental investigation on effect of graphite powder suspended dielectric in electric in EDM of Al-TiB2 composites. The experiments were conducted on ELEKTRAPULS spark erosion machine. Their objective is to find the effect of parameters viz, current, pulse ON-time, flushing pressure and vibration As a result, the process becomes more stable thereby improving Material Removal Rate (MRR) and reducing Tool Wear Rate (TWR). The EDM set-up is used in their experimental study is M100 model die sinking EDM machine manufactured by Electronica Machine Tools. The Parameters and their settings are in L16 orthogonal array. It uses Kerosene as the dielectric fluid. The primary benefit of using kerosene is that it has very low viscosity and gets flushed away easily. The selected work piece material is Al-TiB2 composites. Each experiment was performed for fixed time period using brass as an electrode. Input process parameters are current, pulse on time and flushing pressure. The material removal rate and tool wear rate are evaluated by using an electronic balance machine. They have concluded that this work evaluates the feasibility of machining Al-TiB2MMC with graphite powder suspended dielectric fluid. MRR was found higher for larger Current. When comparing the MRR of with powder and without powder the MRR obtained for with powder is found higher. TWR slightly increases with increasing the Current. When comparing the TWR of with powder and without powder the TWR obtained for with powder is found higher. Increase in MRR was found on increasing Pulse ON-time. TWR increases with the increases in pulse ON-time.

Shriram Y. Kaldhone et (6) have studied the influence of operating parameters of tungsten carbide on the machining characteristics such as material removal rate. The effectiveness of PMEDM process with tungsten carbide, WC-Co is evaluated in terms of the material removal rate. They have observed that copper tungsten is most suitable for use as the tool electrode in EDM of WC-Co; better machining performance is obtained generally with the electrode as the negative and the work piece as positive. In their work, a study was carried out on the influence of the parameters such peak current, Duty factor, pulse on time , work piece material, powder type , powder concentration and flushing pressure. Taguchi methodology has been adopted to plan and analyze the experimental results. Experiments have been performed on newly designed experimental setup. In their study seven factors with three levels are investigated using Orthogonal Array (OA) L27.Material removal rate (MRR) in their experiment was calculated by using mathematical method. The result of their experiment then was collected and analyzed using MINITAB 16 software. The recommended best parametric settings have been verified by conducting confirmation experiments for MRR. From their experimental study it is found that addition of Silicon carbide powder enhances machining rate drastically with slightly increase in Tool wear rate. They have concluded that The MRR and TWR are mainly affected by the current and powder. With mixing of silicon carbide powder MRR can be increased by 90%. Current, Pulse on time, work piece material, Powder type and Flushing Pressure significantly affect MRR. The maximum MRR is produced at 8 g/l of SiC powder for Flushing pressure 1.5 Kg/cm2. Duty factor shows least effect on MRR. Finally, it was concluded that SiC powder and Current have impact to great extent on the MRR of Tungsten Carbide

M. A. Razak et (7) have done experiments on improving EDM efficiency with silicon carbide powder mixed dielectric fluid PMEDM works gradually at low pulse energy and distributes evenly the powder in machining area. 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 to conduct. Number of experiments were conducted is based on Taguchi orthogonal array with three level and two factors. The outcomes obtained were capable to increase MRR, improve surface finish, reduce TWR, reduce machining time and reduce machining cost. The objectives of their research work are: To investigate the influence of PMEDM in machining premium stainless mold steel material in terms of MRR, TWR and Ra. They have done the work to analyse the reduction machining time of EDM process with PMEDM and to define the optimal powder concentration and size of powder particles to achieve the highest efficiency of EDM process. They have concluded that EDM process plays a big role in mold manufacturing industries. Due to longer machining time, it machining cost is high. To increase EDM process efficiency, PMEDM was proposed. Their investigation is on SiC PMEDM powder concentration and powder particles size in cutting Stavax material. Their results have given information on: The influence of PMEDM in machining Stavax material in terms of MRR, TWR and Ra. The optimum powder concentration and size of powder particles to achieve the highest efficiency of EDM

G. Bharath Reddy et (8) presented the outcomes of an experimental analysis carried out to study the effect of micro-sized metal powders, when they are mixed to the dielectric fluid, during Electric Discharge Machining (EDM) of different steels. The work piece material, peak current, pulse on time, duty factor, gap voltage and mixing of fine metal powders(copper and aluminium) in dielectric fluid are taken as process input parameters. Material removal rate and Surface Roughness were taken as output parameters to measure the process efficiency. A newly designed experimental set up was used to perform the task. Taguchi design of experiments was used to conduct experiments. The achieved results of their work indicate that the addition of fine metal powders in dielectric increases the material removal rate and reduces the surface roughness. They have concluded that the Addition of micro-sized metal powders into the dielectric fluid is one of the modern progresses in EDM that confirms better material removal rates at chosen surface quality. From their current investigation, for the selected process parameters the following conclusions were made. Adding aluminium metal powder in dielectric fluid generates superior surface finish than that of the addition of copper metal powder and without the addition of metal powder. The material removal rate is mainly affected by Peak current and pulse on time, and type of metal powder as additive. At the higher value of peak current, greater is the MRR. Powder Mixed EDM makes discharge collapse easier, increases the discharge gaps and expands the discharge channel, and finally forms uniformly distributed large and shallow craters on the work piece. The Surface roughness of the HCH Cr steel is superior compared to EN-31 steel.

R.A.Prajapati et (9) experimented the effect of Silicon Dioxide (SiO_2) powder mixing into the dielectric fluid of EDM on machining characteristics of EN-8 with three input parameters Peak current, pulse on time and concentration of powder. Analysis was carried out for surface roughness. The result outcomes identified the important parameters and their effect on SR of En-8 in the presence of SiO_2 in a kerosene dielectric of EDM. Analysis was showed that the peak current and pulse on time have higher contribution toward surface roughness. The experimental result analysis showed EDM with zero concentration gives better surface finish rather than PMEDM. Better surface quality obtained at Peak current (9A), Powder concentration = 0 g/lit and 25 µs pulse on time. A series of tests were 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. Surface roughness measured for each experiment with setting process parameters. 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. They have concluded that PMEDM is not preferable. Peak current and pulse on time are the most influential parameters for reducing surface quality. The optimum levels of various process parameters obtained in their experimental work are: Peak current = 9 A, Powder concentration = 0 g/lit and 25 µs pulse on time for better surface quality

Ved Parkash et (10) have conducted the experiments on the effect of powder mixed dielectric on tool wear rate (TWR) in EDM has been observed. Experiments were designed using Taguchi method and appropriate Orthogonal Array and experiments have been performed as per the set of experiments designed in the orthogonal array. Signal to Noise ratios are also calculated to analyze the effect of PMEDM more accurately. They have concluded that the PMEDM (Powder Mixed Electric Discharge Machining) has significant effect on the tool wear rate. The Tool Wear Rate is higher with Copper as an additive and less when Graphite is used in dielectric. As current is directly proportional to discharge energy and pulse on-time. With increase in current and pulse on-time, tool wear rate also increases. The TWR is 3.685gms/µsec. When no additive is mixed in kerosene dielectric medium and this TWR decreases to 3.315gms/µsec. When Copper powder is mixed with dielectric medium and it again decreased to 2.5185gms/µsec. When Graphite powder is mixed with the dielectric medium. As it is known that lesser the TWR means higher the Tool Life, so it is clear that Tool life increases with the addition of Graphite powder in the dielectric medium.

Gurule N. B. et (11) experimented the effect of tool rotation on mrr during powder mixed EDM of die steel They have concluded that Current, on time, tool material, tool rpm and powder concentration significantly affect MRR. The suspension of Al powder into dielectric enhances MRR. The maximum MRR is produced at 4 g/l of Al powder, 900 tool rpm with Cu tool. Flushing shows least effect on MRR. Finally, it was concluded that Al powder and rotary tool have impact to great extent on the MRR of die steel. Their study shows future scope and potential for the improvements in the EDM field.

Abhishek Abrol et (12) studied the effect of chromium powder mixed dielectric fluid on machining characteristics of AISI D2 die steel has been studied. Peak current, pulse on time, pulse off time, concentration of powder are the process parameters. The process performance is measured in terms of material removal rate (MRR), tool wear rate (TWR) and surface roughness (SR). The research outcome will identify the important process parameters that maximize MRR, minimize TWR and SR. The design of experiment was undertaken using Taguchi method. ANOVA analysis was used to investigate the percentage contribution of each process parameter for optimizing the performance. Their study indicates that all the selected parameters except pulse off time have a significant effect on MRR. Current is found to be the most significant factor for MRR and TWR. With increase in current, TWR increases. Also, surface roughness increases with increase in pulse off time. They have concluded that MRR is mainly affected by current, pulse-on time and powder concentration. With the increase in current and pulse-on time, MRR increases. But it is also observed that with the increased concentration of chromium powder, MRR tends to decrease. TWR is mainly affected by current. With the increase in current, TWR increases. Also, TWR tends to decrease with the increase in chromium powder concentration. Current is the most dominant factor affecting both MRR and TWR. Both the performance data show an increasing pattern with increase in current for any other parameter. Surface roughness is mainly affected by the pulse-off time as per the main effects plot for SR. Surface Roughness is higher with the increase in pulse-off time.

Nimo Singh Khundrakpam et (13) have studied the effect of polarity on Different EDM (EDM, Dry-EDM and Powder Mixed EDM) has been studied in different polarity and dielectric mediums. It was observed experimentally that increase in tool hole diameter increase Material Removal Rate (MRR) and Tool Wear Rate (TWR). Dry-EDM has negligible TWR. In reverse polarity MRR is very low except Dry-EDM. They have concluded that increase in tool hole diameter increase both MRR &TWR. The dry EDM gives negligible tool wear rate. Tool Hole Diameter has more effective on dry EDM in both the polarity. Their Experiment is more suggested to study different powder mixed to dielectric medium for better MRR and TWR.

Mahendra G. Rathi et (14) experimented the 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, Aluminium oxide, Graphite powder used. Machining characteristics measured in terms of Material removal rate, tool wear rate. To obtain the optimal process parameter combination, optimization is carried out by the Signal-to-Noise (S/N) ratio analysis of Taguchi method using L18 Orthogonal Array. An analysis of variance (ANOVA) is used to present the influence of process parameters on material removal rate, tool wear rate. Results obtained by Taguchi method and by ANOVA method, are compared and found that they match closely with each other. As the MRR is depends mostly on current. Current carrying capacity of any material depends on it electric conductivity. Here Graphite is having highest electric conductivity than Aluminium oxide and Silicon carbide and therefore MRR is higher in case of Graphite powder. As well as TWR is less. They have concluded that The Maximum MRR is obtained at a high peak current of 18 A, a 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.

Marek Rozenek et (15) The EDM characteristics obtained using hydrocarbon dielectric (kerosene) and mixture deionized water with abrasive powder have been compared. The relationship between surface roughness parameters, material removal rate and operating parameters of EDM have been determined for different kind of powder and its concentration in kerosene/water. The investigation results were showed that there are chances for replacing the conventional dielectric with water and that would imply considerable economic and ecology advantages. A copper cylinder of 20 mm in diameter has been used as a tool electrode; the hole has been made in the cylinder in order to pump dielectric into to area of machining. The tool steel NC6, in compliance with Polish Standard, was used as a workpiece. To determine of basic EDM relationships between input parameters such as pulse current, on-time, duty factor, and output parameters namely material removal rate (MRR) and surface roughness (Ra, Rz), factorial design and multiple regression analysis have been used. First series of experiments were carried out using kerosene and kerosene/powder mixture as dielectric and second series with using deionized water and deionized water/powder mixture. During machining negative and positive polarity of tool electrode was used for investigation of polarity effect, it is an especially important when water-based dielectric is used. They have concluded that application of powder in the dielectric lead to reduce surface roughness. The investigation results were showed that there are chances for replacing the conventional dielectric with powder suspended deionized water and that would imply considerable economic and ecology advantages.

B Govindharajan et (16) focused on performance of nickel mixed with kerosene as dielectric medium in electrical discharge machining of Monel 400TM. The optimum range of nickel powder, Graphite powder 6g mixes with the dielectric medium of kerosene servotherm (75:25) were developed experimentally. It was reported slightly more material removal rate, very low tool wear rate, better dimensional accuracy and good surface finsh in Monel 400TM. They have concluded that the experimentally observed performance of kerosene-servotherm of different proportion of nickel powder found that better machining output in EDM of Monel 400TM. The surface smoothness and diameteral accuracy reported by kerosene servotherm of 8g nickel mixed dielectric medium gives better result. After than drawn all graphs which shows the optimum proportion mixture of nickel powder influences the MRR, TWR and OC.8, 6g of nickel and graphite powders are mixed with kerosene-servotherm (75:25) gives better results of MRR, TWR and OC.

Kuldeep Ojha et (17) have presented parametric optimization for material removal rate (MRR) and tool wear rate (TWR) study on the powder mixed electrical discharge machining (PMEDM) of EN-8 steel has been carried out. Response surface methodology (RSM) has been used to plan and analyse the experiments. Average current, duty cycle, angle of electrode and concentration of chromium powder added into dielectric fluid of EDM were chosen as process parameters to study the PMEDM performance in terms of MRR and TWR. Experiments have been performed on newly designed experimental

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setup developed in laboratory. Most important parameters affecting selected performance measures have been identified and effects of their variations have been observed. They have concluded that the quantitative analysis of machinability of EN-8 steel in PMEDM process has been carried out. Chromium powder particles are mixed in EDM dielectric fluid. RSM has been applied for analysis. Optimum results have been found as suggested by software.

Nimo Singh KhundrakpamÂ et (18) presented a Central Composite Design (CCD) for combination of variables and Response Surface Method (RSM) have been used to explore the influence of process parameter such as; peak current, powder concentration and tool diameter on the Material Removal Rate (MRR) on EN-8 steel. Analysis Of Variance (ANOVA) at 95% level of significance was performed to obtain the significant coefficients. Significant process parameters have been identified and optimum process conditions have been obtained. A confirmation experiments has been conducted and verified optimal conditions. Percentage errors are predicted and an actual value for developed models was found within 5%. They have concluded that the powder concentration have more significant effect on MRR. The adequacy of the developed models was checked by performing confirmation runs. The variation in prediction errors for MRR was found within ±5.5%. It was concluded that the model is valid to predict the machining responses within the experimental region.

Table:

S.No.	Year	Authors	Inputs	Powder used
1	2012	Sanjeev Kumara et	Peak current, pulse on-time and pulse off-time	tungsten carbide (WC and W2C) powder
2	2013	F.Q. Hua et	Current; pulse duration; pulse interval time; gap voltage	Al powder concentration: 35 g/L Al particle sizes <2 m
3	2015	Gangadharudu Talla et	powder concentration, peak current, pulse on time and duty cycle	Powders of aluminum and alumina of sizes about 15 mm and 90mm
4	2011	Kuldeep Ojha a et	Current, duty cycle, powder concentration and electrode diameter	chromium powder 45-55 µm
5	2015	M Prabu et	current, pulse ON-time, flushing pressure	graphite powder
6	2014	Shriram Y. Kaldhone et	current, Pulse on time ,Duty factor, Work Piece material, Powder type , Powder Concentration, Flushing Pressure	Silicon carbide
7	2015	M. A. Razak et	Powder concentration, Powder particles size	silicon carbide (SiC)
8	2015	G. Bharath Reddy et	The work piece material, peak current, pulse on time, duty factor, gap voltage	copper and aluminium
9	2015	R.A.Prajapati et	Peak current, pulse on time and concentration of powder.	Silicon Dioxide (SiO2) powder
10	2013	Ved Parkash et	peak current, pulse on-time, pulse off-time and polarity	copper and graphite
11	2012	Gurule N. B et	Current, off time, on time, tool material, powder concen, tool rpm & flushing pressure	Aluminium
12	2015	Abhishek Abrol et	Peak current, pulse on time, pulse off time, concentration of powder	chromium
13	2014	Nimo Singh Khundrakpam et	pulse on time, Discharge Current, Duty Factor, Gap Voltage, Gas flow Pressure	Graphite
14	2014	Mahendra G. Rathi et	Powder media (Graphite, Al2O3 ,SiC), Current, Pulse on time, Duty cycle	Graphite powder
15	2014	Marek Rozenek et	Current, grain size, pulse on time, grade,	silicon carbide SiC , Al2O3, Al
16	2014	B.Govindharajan et	Machine voltage, Gap voltage, current, work piece diameter, thickness, tool diameter, tool length	nickel powder, Graphite powder
17	2011	Kuldeep Ojha et	Average current, duty cycle, angle of electrode and concentration of chromium powder	chromium powder
18	2014	Nimo Singh KhundrakpamÂ et	peak current, powder concentration and tool diameter	Silicon Powder

Conclusion: PMEDM is very useful type of EDM which gives better results in terms of MRR, SR & TWR and others even in comparison with conventional EDM. Out of all the di-electric fluids used in PMEDM, commercial kerosene is the best in view of viscosity because of which it flushes very well. Various powders i.e. silicon powder, chromium powder, nickel powder, graphite powder, Aluminium powder etc were used in PMEDM while kerosene as considered as a dielectric fluid.

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