



RESEARCH ARTICLE

POWDER MIXED ELECTRIC DISCHARGE MACHINING - A REVIEW PAPER

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ABSTRACT

The main objective of this paper is focused, to study the previous investigations of various researchers. Some recently invented advance materials like, Titanium, Titanium carbide etc. are not easily machined by conventional machining processes. So that, powder mixed electric discharge machining will be preferred for these materials. Because it gives better output responses like better material removal rate, lower tool wear rate and extensively smooth machined surface. These output responses are highly used in industrial applications. This review paper will be helpful for the young researches to understand the mechanism of powder mixed electric discharge machining and brief the previous research investigation in this field.

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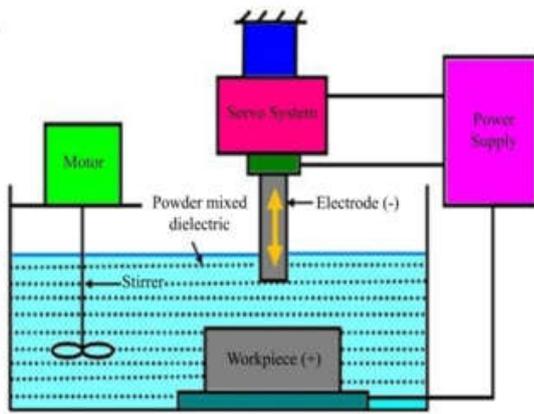
INTRODUCTION

Electrical discharge machining (EDM) is one of the most extensively used non-conventional material removal processes (Naveen Kumar, 2001). Its unique feature of using thermal energy to machine electrically conductive parts regardless of hardness has been a distinctive advantage in the manufacture of mould, die, automotive, aerospace and surgical components which are difficult to manufacture by conventional machining (Kanwal Jeet Singh, 2017). In mechanism of EDM, unwanted parts of work-piece is removed by the high temperature spark and many defects such as cracks, porosity, residual stress, improper recast layer are found due to high temperature variation (Naveen Kumar, 2001). Hence an innovative technique known as powder mixed EDM has been performed in the presence of foreign particles suspended in dielectric medium to overcome some of the limitations of conventional EDM (Varundeep, 2013). The mechanism of PMEDM is totally different from the conventional EDM (Kanwal Jeet Singh, 2017). A suitable material in powder form is mixed into the dielectric fluid of EDM. When a suitable voltage is applied, the spark gap filled up with additive particles and the gap distance setup between tool and the work-piece increased from 25-50 to 50-150 mm (Varundeep, 2013).

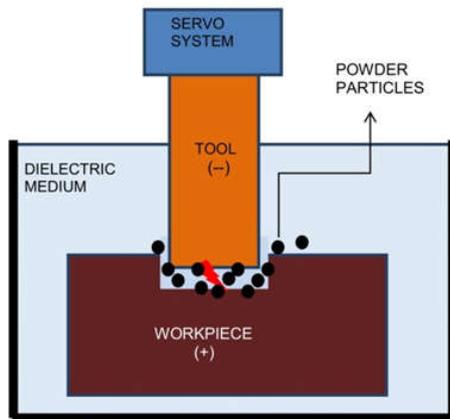
The powder particles get energized and behave in the zig-zag fashion. These charged particles are accelerated by the electric field and act as conductors. The powder particles arrange themselves under the sparking area and gather in clusters. The chain formation helps in the bridging the gap between both the electrodes, which causes the early explosion. Faster sparking within discharge takes place causes faster erosion from the work-piece surface (Haron *et al.*, 2001). The input process parameters used in PMEDM are electrical parameters, non-electrical parameters and powder parameters. Electrical parameters are discharge current, pulse on-time, pulse off-time, peak current, average current, gap voltage, electrode polarity, pulse frequency, spark gap, duty factor etc.

Non-Electrical parameters are electrode material, dielectric fluid, and work-piece material. Powder parameters are powder concentration, type of powder and abrasive size. The performance measures of PMEDM are tool wear rate, material removal rate, surface quality, wear ratio, surface roughness, recast layer thickness, over cut and heat affected zone. The major components and the mechanism of material removal process of powder mixed electric discharge machining are shown in figure below: The major components of powder mixed electric discharge machining are servo system, electrode and the work-piece, power supply, motor and stirrer arrangement, tank filled with dielectric fluid, pump and reservoir which are shown in figure (a).

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(a) Major components of PMEDM (Naveen Kumar, 2001)



(b) Mechanism of Material removal (Naveen Kumar, 2001)

In PMEDM, a suitable material in powder form is mixed into the dielectric fluid in a tank when a voltage is applied between electrodes, an electric field in the range is created. The powder particles get energized and behave in Zig Zag fashion. Under the influence of electric forces, the powder particles arrange themselves in the form of chains at different places under the sparking area as shown in figure (b) under the sparking area. The chain formation helps in bridging the discharge gap between both the electrodes. Due to bridging effect, the easy short circuit takes place which causes early explosion in the gap. As a result, a series discharge starts under the electrode area. The faster sparking within a discharge takes place causing faster erosion from work-piece surface and hence the material removal rate (MRR) increases. The sparking is uniformly distributed among the powder particles, hence electric density of spark decreases. Hence even and more uniform distribution of the discharge takes place which causes uniform erosion on work-piece. This results in improvement in the surface finish.

LITERATURE

Che Haron et al. (2001) investigated possible correlation between the EDM parameter and the machine ability factors. The observation was made that it gives the highest material removal rate and the lowest wear rate. The material removal rate and the electrode wear rate are not only dependent on the diameter of electrode, but also had close relation with the supply of current.

Vinod Yadav et al. (2002) investigated high temperature gradients generated at the gap during EDM results in large localized thermal stresses in a small heat-affected zone. A finite element model has been developed to estimate the temperature field and thermal stresses. It was observed that, after one spark, substantial compressive and tensile stresses develop in a thin layer around spark location. **Jianfeng Zhao et al. (2003)** investigated selective laser sintering (SLS) is a suitable process to manufacture an EDM metal prototype directly. A parametric experiment has been applied, achieving substantial improvements in electrode quality and machining quality. The electrode made by SLS can be used as an EDM electrode. The preferable surface finish of cavity can be obtained using rough or semi-finish machining parameters with this kind of electrode. This is sufficient, and shows the potential of machining using an electrode made by SLS.

Shankar Singh et al. (2004) investigated the effects of machining parameters such as pulsed current on material removal rate, diametric overcut, electrode wear and surface roughness in electric discharge machining of En-31 tool steel. The investigation indicate that the output parameters of EDM increase with the increase in pulsed current and the best machining rates are achieved with copper and aluminum electrodes. **Casas et al. (2005)** investigated that flexural strength of WC-Co cemented carbides (hard metals), under both monotonic and cyclic loading, is strongly affected by EDM. An analysis of the results using a linear-elastic fracture mechanics approach allows establishing a clear connection between surface integrity and mechanical strength.

Ziada, P. Koshy (2007) concluded that electrical discharge sinking operations by using rotating curvilinear tools. The observation was made that the rotating tools are motivated by the principle called Reuleaux Triangle. It enhances the flushing of working gap through rotation and translation of tool while concurrently maximizing the frontal machining area. **Pecas, Henriques (2007)** studied nevertheless current EDM technologies have major limitations when dealing with fine surface finish over large process area. EDM with powder-mixed dielectric (PMD-EDM) has been a focus of an intense research work in order to overcome these technological performance barriers. It was found that the sensitivity of the surface quality measures to the electrode area is smaller when mixed powder dielectric is used.

Yan-Cherng Lin et al. (2008) has work to optimize the machining parameters in magnetic force assisted EDM. The experimental results show that the magnetic force assisted EDM has a higher MRR, a lower relative electrode wear ratio (REWR), and a smaller surface roughness (SR) as compared with standard EDM. **Sivapirakasam et al (2011)** studied that the influence of process parameters on the breathing zone concentration of the aerosol generated from the electrical discharge machining process using Taguchi methodology. The main process parameters influencing the quantity of exposure were peak current and pulse duration. The composition of aerosol generated from the EDM process depends on the composition of the electrode materials as well as the boiling point of its constituents. **Raoul Rath et al. (2012)** presented the influence of anode material on the break-down behavior in dry EDM and compared the material removal rate and tool wear ratio of dry electrical discharge machining with different tool electrode and work-piece materials by fixed EDM parameters.

The comparison shows that major influence on the material removal rate is caused by the work-piece material on the discharge behavior. **Rajesh, M. Dev Anand (2012)** has work to optimize the EDM process using response surface methodology and genetic algorithms. Multiple regression model and modified genetic algorithm model are developed as efficient approaches to determine the optimal machining parameters in electric discharge machine. Linear regression model have been developed to map the relationship between machining parameters and output responses. The most influencing factor obtained by the response table is the working current for the EDM process.

Teimouri, H. Baseri (2013) has work to optimize the magnetic field assisted EDM using the continuous ant colony optimization (ACO) algorithm. A rotary tool with rotary magnetic field has been used to better flushing of debris from the machining zone in electric discharge machining process. The objective of the optimization is achieving the maximum MRR subject to appropriate operating constraints on SR and domains of input parameters of magnetic field intensity, rotational speed of the tool and product of current and pulse on-time. **Abdul Sabur et al. (2013)** investigated the effect of input power on the material removal rate and to explore material removal mechanism. The observation was made that an adhesive copper foil is used as an assisting electrode and copper tool electrode with negative polarity. The material is removed by spalling, little bit by melting and vaporization, and another be removed by increasing the input power and other parameters be constant.

Li et al (2013) analyzed on multi-mode pulse power supply for array micro holes machining in micro-EDM. A new type of micro-energy pulse power with a variety of processing modes is developed. The pulse power can supply a variety of power supply modes, including RC mode, TR mode, TRT mode, TC mode and TCT mode. By comparing the surface quality of micro-hole from these kinds of power supply mode, it has been found that RC power supply mode is suitable to process micro holes. The 6×6 array micro holes have been processed with the designed micro pulse power, whose hole spacing is 0.1 mm. **Xiao-peng LI et al. (2014)** theoretically analyzed and experimentally investigated the influence of the high frequency pulse on electrode wear in micro-EDM. Time-varying electromagnetic field generates the eddy current under high frequency of discharge current is able to change the current density on surface of electrode and plays an important role in change of electrode topography during micro-EDM process. **Dastagiri, A. Hemantha Kumar (2014)** concluded that the peak current, discharge power increases, the highest temperature reached on the work is also increases during the EDM, hence more MRR achieved. There is a much influence with the pulse duration on the crater depth and radius. Depth of crater increases with pulse duration but for longer pulse on times it starts decrease, whereas the radius of crater increases due to increase in spark radius with pulse duration.

Cheol-Soo Lee et al. (2015) compares the electrode wear of EDM-drilling and the die-sinking EDM. Electrode wear is rapid in EDM-drilling as compared to die-sinking EDM and makes it difficult to control the electrode feed and machine precisely. The wear amount depends on discharging environment such as material type and hole shapes. **Jingyu PEI et al (2016)** investigated to verify the model and to show that the error of the compensation length is within 2um. The

observation was made that the evenness of machined surface with depth of 86um was within 10um. So, fix length compensation method can be used to 3D cavity machining. **Xiuzhuo Fu et al. (2016)** investigated that the open voltage and capacitance were the main influence factors, with the increase of both, the surface roughness (SR) rapidly increased. The conclusion was made that the open voltage (U) and capacitor (C_2) are the main influence factors of discharge energy and have most effect on surface roughness. **Qingyu Liu et al. (2016)** introduced the working principles and characteristics of piezoelectric self adaptive micro-EDM. Piezoelectric self adaptive micro-EDM is more suitable for micro machining compared to the conventional micro-EDM due to its higher processing stability and efficiency. The theory of similarity is introduced and the evolutions of machining time and tool wear length of micro-EDM with and without piezoelectric actuator are evaluated by discussing the similarity precision and similarity difference which are dimensionless values which can quantify the deviation of size effects in micro-EDM. It is concluded that the smoother machining process of piezoelectric a self adaptive EDM can result in weaker size effects, so the machining performances of piezoelectric self-adaptive micro-EDM are easier to be predicted.

Yinsheng Fan et al. (2016) analyzed on maintaining voltage of spark discharge in EDM and studied the characteristics between spark discharge gap voltage of pulse power under the modes of pulse power. It also theoretically proves that there exists maintaining voltage of spark discharge in the process of transistor resistor pulse power and transistor inductor pulse power, while does not exist in process RC pulse power. So, maintaining voltage of spark discharge is not inevitable phenomenon in EDM and it is associated with circuit structure of pulse power. **Bryan Lee et al. (2016)** overviewed of the potential of using dual-topography EDM on titanium as a surface modification technique for dental and orthopedic implant applications and highlighted the use of novel multi-current machining approach to create dual-topography surfaces with both micron and enhanced sub-micron topographies. After testing it is noted that EDM modified surfaces increased ALP activity compared to untreated titanium. **Tomohiro Koyano et al. (2016)** studied on the effect of external hydrostatic pressure on material removal rate of EDM. Sinking EDM was carried out on drilled holes under some hydrostatic pressure in order to clarify the influence of gas bubbles. High speed camera observation showed that the gas bubbles were ejected from the machining gap under lower pressure. The material removal rate was increased by setting the external pressure at an optimal value especially when the machining depth was deep.

Margareta Coteata et al. (2016) identified the solution for a pulse generator which could be incorporated and used in equipment for electrical discharge machining of small dimensions. In order to obtain electrical discharge equipment able to be used both for electrical discharge machining of small dimensions surfaces and for finishing surfaces by micro-electrical discharges, a pulse generator including two circuits was used. The relaxation circuit could be used for finishing and super-finishing machining process, while a circuit using a transistor characterized by high speed of commutation could be used for developing electrical discharge roughing machining process. **Risto et al. (2016)** optimized the EDM drilling process to increase the productivity and geometrical accuracy

with different electrode diameters, a specified borehole diameter of 2.00 mm was produced. The impact of the used electrode diameter and required discharge energy on the geometrical accuracy and productivity was investigated. **Parveen Goyal et al. (2017)** investigated the surface properties of EN-31 die-steel after machining with powder metallurgy EDM electrodes. It has been found that Copper-Manganese (70:30) is better composite material electrode as it gives highest surface micro-hardness as compared to Copper-Manganese (80:20) and copper electrodes. It has been observed that the micro hardness is highest for the maximum peak current and maximum pulse on time which may also be due to more heating and rapid quenching of machined surface, so composite Copper-Manganese material electrode may be recommended in industries for machining of EN-31 die steel.

Yash Pachaury, Puneet Tondon (2017) overviewed of ceramics and ceramic based composites electric discharge machining and the result was made that the machining of insulating ceramic materials is increasing rapidly. EDM be a major machining process for fabrication of ceramic components. **Urso, C. Rivasio (2017)** studied the influence of process parameters and the thermal and electrical properties of work-piece and electrode materials on the performance of micro-EDM drilling. The material technology (MT) indexes, taking into account EDM process parameters, electrical and thermal properties of both work piece and electrode materials, were proposed for evolution of MRR, TWR, DOC, TR. These indexes resulted to be affected by electrode properties, while not all the work piece Characteristics seem to have a significant effect for the index elaboration.

GAP IN LITERATURE REVIEW

It observed from literature review, Electro Discharge Machining (EDM) is more complicated machining process due to the complexity of input parameters. Carefully selection of the input machining factors gives optimum results. Some selected input parameters were used in investigation by various researchers. However, the pulse on-time, discharge current and powder concentration need some more attention. The process optimization was rarely reported in previous investigation.

Conclusion

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

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