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RESEARCH ARTICLE

# ELECTRIC DISCHARGE MACHINING- A REVIEW

[1,*]Dharamjeet Singh and [2]Kanwal Jeet Singh

[1]Research Scholar, Maharaja Ranjit Singh Punjab Technical University, Bathinda, Punjab
[2]Giani Zail Singh Campus College of Engineering & Technology, Bathinda, Punjab

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ABSTRACT

Electric Discharge Machining is mainly used for very hard materials or some recently invented advance materials like; Titanium, Tungsten carbide etc. are difficult to machine with conventional machining processes. So that electric discharge machining will be preferred for these materials and composite materials are easily machined by electric discharge machine. 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 application. This review paper will be helpful for the young researches to understand the mechanism of 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 (Parkash, 2016). 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 (Haron *et al*., 2001). 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 (Singh *et al*., 2004). 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 (Yadav *et al*., 2002). The input process parameters used in EDM are dived into two categories electrical parameters and non-electrical 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.

***Corresponding author:* Dharamjeet Singh,**
Research Scholar, Maharaja Ranjit Singh Punjab Technical University, Bathinda, Punjab.

The performance measures of EDM are tool wear rate, material removal rate, surface quality, wear ratio, surface roughness, recast layer thickness, over cut and heat affected zone (Kanwal Jeet Singh, 2004). Needs of Electric Discharge Machining is when shape of the part is too complex, and difficult to machined. Composite material is machined by using EDM process. Deep hole with small holes diameter, and for a square hole is also used electric discharge machining. Very hard materials can be shaped and machined easily (Parkash *et al*., 2016). History of electric discharge machine; In 1770, English scientist Joseph Priestly studied the erosive effect of electrical discharges. Furthering Priestly research, the EDM process was invented by two Russian scientists, Dr. B. R. Lazarenko and Dr. N. I. Lazarenko, in 1943.

A controlled process was developed for the machining of metals so as to exploit the destructive effect of an electric discharge (Kanwal Jeet Singh, 2017). The first British patent was granted to (Rudorff, 1950) USA, Japan, and Switzerland developed their machining around 1950. In 1950s The RC (resistance capacitance) relaxation circuit was introduced, in which first consistent dependable control of pulse times and a simple servo control circuit to automatically find and hold a given gap between the electrode (tool) and the work-piece was developed (Singh, 2004).

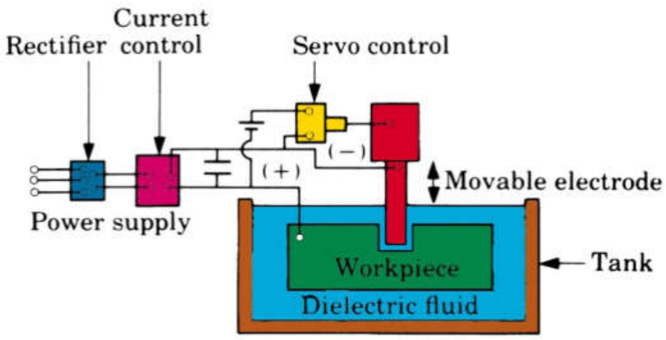


**Figure 1. Schematic of Electric Discharge Machining (Dastagiri, 2014)**

In Electro Discharge Machining process the work-piece is mounted on the machine tool table and the electrode is connected to the servo mechanism. Both the tool material and the work material are to be conductors of electricity. The tool is cathode and the work-piece is anode. A DC pulse generator helps servo mechanism to control the movement of the electrode in vertical direction and maintains proper position of the electrode relative to the work-piece (Zhao *et al*., 2003).

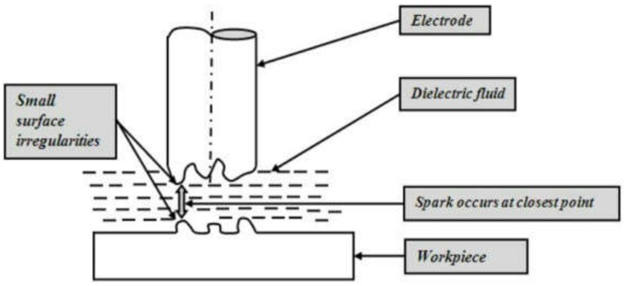


**Figure 2. Schematic diagram of Principle of EDM (Kanwal Jeet Singh, 2016)**

The basic principle of electric discharge machining process is based on the thermo-electric energy which is produced between an electrode (tool) and a work-piece submerged in a dielectric fluid with the passage of electric current. The work-piece and the electrode are separated by a specific small gap is called spark gap.

## 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, E. 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 *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. M. 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. D'Urso, C.Ravasio (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 foe 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**

After study the number of research papers, it observed that powder electro discharge machining is more complicated machining process, due to the various machining factors. Selection of input parameter plays an important role for better output response. Some selected input parameters were used in investigation by various researchers. However, the pulse on time, discharge current and grit size need some more attention. The process optimization was rarely reported in previous investigation.

**Conclusion**

- Electric Discharge Machining gives better results in terms of MRR, SR, TWR and others even in comparison with conventional machining process.
- In EDM, is material removal rate is directly proportional to surface roughness.
- In maximum reviews of EDM; discharge current is directly proportional to material removal rate, and if maximum discharge current is applied then micro cracks formed on the machined surface.
- Out of all the dielectric fluids used in EDM, kerosene oil is the best in view of viscosity because of which it flushes very well.

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