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A Review-Electrical Discharge Machining

Rahul D. Shelke[1], Siddiqui Mohd Imran[2]
[1]*(Everest College of Engineering and Technology, Aurangabad, India)*
[2]*(Everest College of Engineering and Technology, Aurangabad, India)*
Corresponding Author: Rahul D. Shelke

Abstract: *Electrical discharge machining (EDM) is one of the earliest non-traditional machining processes. EDM process is based on thermoelectric energy between the work piece and an electrode. Amongst the various machining processes EDM is one of the most attractive alternatives for the industry due to its attractive attribute of not non-contact of tool and workpiece that leads to very little or no force exert in the tool and work piece. Electrical discharge machining is a process for shaping hard metals and forming deep complex shaped holes by spark erosion in all kinds of electro-conductive materials. In EDM, a process utilizing the removal phenomenon of electrical discharge in dielectric, the working fluid plays an important role affecting the material removal rate and the properties of the machined surface. Also, input parameters plays important role in determining the Material removal rate and surface quality. In this paper authors have reviewed the different types of electrical discharge machining, dielectric fluids used in the machining process and effect of peak current, voltage and pulse on time parameters on response parameters like material removal rate and tool wear rate. this research work carried out in the development of EDM within the past decades for the improvement of machining characteristics.*

Keywords: *Dielectric fluid, Electrode, Electrical discharge machining, Material removal rate, Tool wear rate*

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I. Introduction

Electrical discharge machining (EDM) is a non-traditional concept of machining which has been widely used to produce dies and molds. It is also used for finishing parts for aerospace and automotive industry and surgical components. This technique has been developed in the late 1940s where the process is based on removing material from a part by means of a series of repeated electrical discharges between tool called the electrode and the work piece in the presence of a dielectric fluid [1]. Beside its wide machining range of difficult to machine materials like titanium and ultra- hard ceramics like reaction bonded silicon carbide (RB-Sic), EDM have some disadvantage like low material removal rate and poor surface quality[2].

The electrode is moved toward the work piece until the gap is small enough so that the impressed voltage is great enough to ionize the dielectric. Short duration discharges are generated in a liquid dielectric gap, which separates tool and work piece. The material is removed with the erosive effect of the electrical dis-charges from tool and work piece. Since then, EDM has experienced a dramatic evolution. EDM process can be classified according to the type of dielectric fluid used. Dielectric fluid is an extremely important function regarding the quality of the machined parts. Since different dielectrics have different cooling rates and compositions, the choice of dielectric plays an important role in the EDM process. Dielectric media, circulated between the electrode and work piece, must be carefully selected and applied to maintain peak performance and control of the electrical spark. The four basic functions of dielectric oil (specific to sinker EDMs and specially designed wire EDMs) are: insulation, ionization, cooling, removal of waste particles [3].

The modern machining processes are now replacing the conventional machining processes rapidly for many applications due to their significant advantages which are proving beneficial to a greater extent to the present industrial scenario. The Requirements of industrial Introduction products have started increasing and new materials are getting introduced which are very hard in nature and difficult to cut by conventional machining processes. Successful machining of such materials by the modern machining processes has added significant lifeline to the industrial growth and given new dimensions to the quality of components. These processes work on a particular principle by making use of certain properties of materials which makes them more suitable for some applications and at the same time put some limitations on their use. These processes involve large numbers of respective process variables and selection of exact parameters setting is very crucial for these highly advanced machining processes which may affect the performance of any process considerably. Due to involvement of a large number of process parameters, random selection of these process parameters within the range will not serve the purpose. The situation becomes more severe in case if more number of objectives are involved in the process. Such situations can be tackled conveniently by making use of optimization techniques for the parameter optimization of these processes [4]. The EDM process has the advantage of spark-erosion in order to machine the hard-to-cut material and then easily achieve the required shapes, complex shape and sizes with enhancing machining productivity and better dimensional accuracy [5].

II. Types of EDM

The EDM process is most widely used by the mold-making tool and die industries, but is becoming a common method of making prototype and production parts, especially in the aerospace, auto-mobile and electronics industries in which production quantities are relatively low. There are different types of EDM available which is briefly discussed below [3].

2.1 Sinking EDM

In the sinking EDM fig.1 process, a mirror image of tool shape occurs on the surface of work piece. In this process, copper or graphite is generally used as electrode material [3]. The dielectric liquid is filtrated to remove debris particles and decomposition products. Hydrocarbons dielectric is normally used since the surface roughness is better and tool electrode wear is lower compared to the de-ionized water [6].

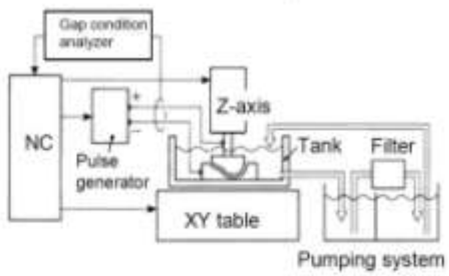

Figure 2.1: Sinking Electrical Discharge Machining

The thermal energy generates a channel of plasma between the cathode and anode. When the pulsating direct current supply is turned off, the plasma channel breaks down. This causes a sudden reduction in the temperature allowing the circulatin
g dielectric fluid to implore the plasma channel and flush the molten material from the work piece surface [3].

2.2 Wire EDM

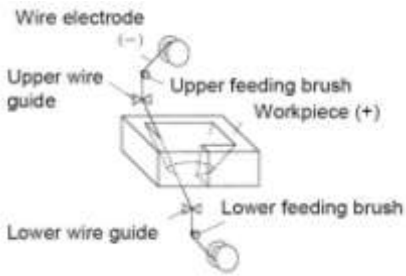

Figure 2.2: Wire Electrical Discharge Machining

Wire-cut EDM (WEDM) fig.2 is one of the most favorable variants owing to its ability to machine conductive, exotic and high strength and temperature resistive (HSTR) materials with the scope of generating intricate shapes and profiles. It uses a thin continuously traveling wire feeding through the work piece by a micro-processor eliminating the need for elaborate reshaped electrodes, which are required in the EDM [3]. Normally the wire electrode is brass wire or coated steel wires but in case of thin wires tungsten or molybdenum wires are used. To reduce vibration and deflection tension is applied to the wire resulting in deteriorated cutting accuracies. Water is the most often used as the dielectric liquid but its specific electrical conductivity should be decreased using de-ionizing resins to avoid electrolysis and to keep high open voltage[6]. Wire EDM process is widely applied not only in tool and die-making industry, but also in the fields of medicine, electronics and the automotive industry [3].

2.3 Micro EDM

Micro Electrical Discharge machining is quite similar with the principals of Electrical Discharge Machining. EDM has a high capability of machining the accurate cavities of dies and molds. EDM is an effective technique in the production of micro components that are smaller than 100µm. The discharge power is dissipated in the plasma channel with amount between 2% and 10%. The channel acts as a heat source on the surface of the work piece. [6]. In micro-wire EDM, a wire which has a diameter down to 0.02 mm is used to cut through a work piece. In die-sinking micro-EDM, an electrode is used containing micro-features to cut its mirror image in the work piece. In micro EDM drilling, micro-electrodes (of diameters down to 5–10 m) are used to 'drill' micro-holes in the work piece. In Micro-EDM milling, micro-electrodes (of diameters down to 5–10 m) are employed [3].

2.4 Powder mixed EDM (PMEDM)

In the last few decades PMEDM has gained popularity over conventional EDM due to enhance process capabilities of EDM. In PMEDM process suitable size and amount of different fine powder material (aluminum, chromium, graphite, copper, or silicon carbide, etc.) is mixed into EDM dielectric fluid, which reduces the insulating strength of dielectric fluid and increases the spark gap distance between workpiece and tool electrode as a result process become more stable thus increasing the material removal rate and improve the surface quality as compared to conventional EDM [2]. The powder particles get energized and behave in a zigzag fashion fig. 3. 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 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 [3].

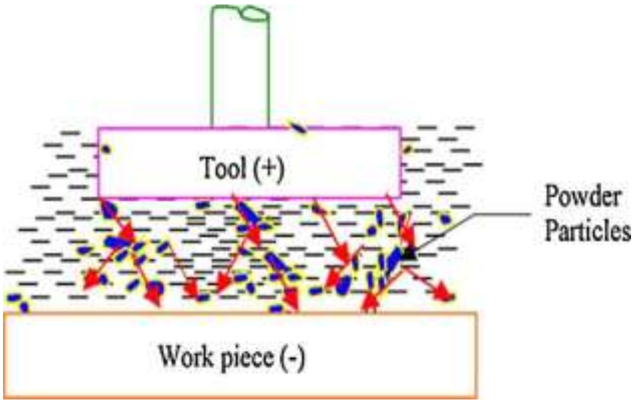

Figure 2.3: Principle of powder mixed EDM

2.5 Dry EDM

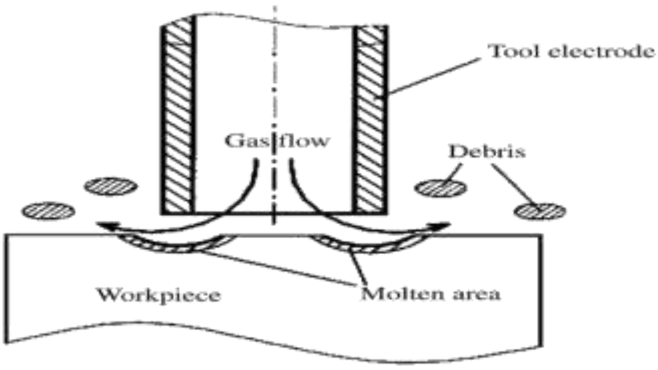

Figure 2.4: The principle of dry EDM

In this process a thin walled pipe is used as tool electrode through which high-pressure gas or air is supplied. The role of the gas is to remove the debris from the gap and cooling of the inter electrode gap[3].The technique was developed to decrease the pollution caused by the use of liquid dielectric which leads to production of vapors during machining and the cost to manage the waste[1].

III. Process Parameters

The process parameters can be divided into two categories, i.e., Electrical and Non-electrical parameters

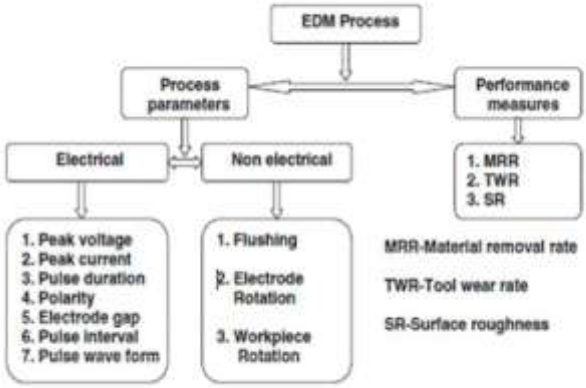

Figure 3.1: Electrical and Non electrical parameter

3.1 Electrical Parameters

3.1.1 Intensity (I): Represents the different power levels that the EDM machine generator is capable of supplying.

3.1.2 Pulse duration (ti): It is defined as the amount of time per cycle (expressed in microseconds) during which the electric current is allowed to flow as shown in above fig 5.

3.1.3 Duty cycle (η): It is the proportion of pulse duration (ti) with respect to the total cycle time. This factor is calculated by dividing the pulse duration (ti) between the total cycle time.

3.1.4 Open-circuit voltage (U): It is the value of potential difference which is established between the part to EDM and the electrode, just before the electrical discharge is produced.

3.2 Non-Electrical Parameters

Main non-electrical parameters are flushing of dielectric fluid, workpiece rotation, and electrode rotation. These non-electrical parameters play a critical role in optimizing performance measures.

3.2.1 Rotation of Tool Electrode: This normal to the work surface and with increasing the speed, a centrifugal force is generated causes more debris to remove faster from the machining zone. The centrifugal force generated throws a layer of dielectric in to the machining gap, induces an atmosphere for better surface finish.

3.2.2 Injection Flushing: Removes eroded particles from the gap for efficient cutting and improved surface finish of machined material. Flushing also enables fresh dielectric oil flow into the gap and cools both the electrode and the work piece.

3.2.3 Tool geometry: This concerned with the shape of the tool electrodes.ie. Square, Rectangle, Cylindrical, Circular etc. The ratio of length /diameter of any shaped feature of material. The tool having less aspect ratio gave higher value of TWR. Thus with increasing the size of electrode more good performance of EDM takes place.

3.2.4 Tool Material: (Electrode) having higher thermal conductivity and melting point are used as a tool material for EDM process of machining. The factors that affect selection of electrode material include metal removal rate, wear resistance, desired surface finish, cost of electrode material manufacture and material and characteristics of work material to be machined [5].

IV. Dielectric fluid

4.1 Functions of a dielectric fluid

The sinker EDM process has primarily used oil for the dielectric fluid. The dielectric fluid in a sinker EDM serves a number of functions:

1) The dielectric fluid works as a medium through which controlled electrical discharges occur.

2) The dielectric fluid works as a quenching medium to cool and solidify the gaseous EDM debris resulting from the discharge.
3) The dielectric fluid works as a medium used to carry away the solidified EDM debris from the discharge gap to the filter system.
4) The dielectric fluid works as a heat transfer medium to absorb and carry away the heat generated by the discharges from both the electrode and the work piece.

4.2 Types of dielectric fluid
4.2.1 Mineral oils

According to Wikipedia "Mineral oil or liquid petroleum is a by-product in the distillation of petroleum.

4.2.2 Kerosene

Kerosene was one of the first popular dielectric oils. Its primary benefit is that it has very low viscosity and flushes very well. Unfortunately, it has many drawbacks:

1) Low flash point
2) High volatility
3) Odor
4) Skin reactions

In the "old days", there were numerous EDM fires and explosions attributed to the use of kerosene.

4.2.3 Mineral seal

Mineral seal oil takes its name from the fact that it originally replaced oil derived from seal blubber for use in signal lamps and lighthouses. Mineral seal is petroleum based product that has many as a dielectric fluid in the early days of EDM. In fact, it is still listed as approved aerospace dielectric oil today. Unfortunately, it has been identified as having some potentially carcinogenic components, and thus its use is no longer recommended.

4.2.4 Transformer oil

Transformer oil is another mineral oil based product that was tailored for use in EDMs due to its dielectric properties. Earlier generations of transformer oil were compounded with PCBs. Trans-former oil has no current application in EDM.

V. Performance Parameters

These parameters measure the various process performances of EDM result.

5.1 Material removal rate (MRR):

MRR is calculated by the difference of weight of work piece before and after experiment.

$$MRR= \frac{W1-W2}{T_m} \text{ (gm/min)} \quad \ldots (5.1)$$

Where,ₒ
W1 is the initial weight of work piece in gm;
W2 the final weight of work piece in gm;
Tm the machining time in minutes;

5.2 Tool wear rate (TWR):

The ratio of amount of electrode to the amount of work piece removal is defined as the wear ratio.
There are four methods that are known to evaluate the electrode wear ratio by means of measuring weight, shape, length, and total volume respectively.

$$TWR= \frac{E1-E2}{T_m} \text{ (gm/min)} \quad \ldots (5.2)$$

Where,
E1 is the initial weight of electrode in gm,
E2 final weight of electrode in gm;
Tm the machining time in minutes ;[4]

VI. Conclusion

Many researchers have worked in this field about the study of various aspects of EDM process. The contribution of EDM to industries such as cutting new hard materials make EDM technology remains indispensable. EDM is the most versatile and most conventional, unconventional machining method capable of producing highly complex shape and it is independent of the mechanical properties of the workpiece material as long as it is conductive. With continuous improvement in the metal removal efficiency and the embodiment of numerical control, the viability of the EDM process in terms of the type of applications can be considerably enhanced. The basis of controlling the EDM process mostly relies on empirical methods largely due to the stochastic nature of the sparking phenomenon involving both electrical and non-electrical process parameters. However, several means of improving the machining performance commonly measured in terms of MRR, TWR and SR have been made with a staggering research interest been paid to the metallurgical properties of EDMed part.

In this paper, an overview of different types of EDM machining, process parameters, dielectric fluids and major response parameters were studied.

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