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## Powder Mixed Dielectric in EDM –An overview

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#### Abstract :

Among all the non-conventional machining methods, electric discharge machining (EDM) is one of the most popular machining methods for the manufacturing of press tools and various dies . Powder mixed electric discharge machining (PMEDM) is one of the recent innovations for the enhancement of capabilities of EDM process. Since long, EDM researchers have explored a number of ways to improve performance measures in EDM process. Despite a range of different approaches Power Mixed Dielectric has the potential to improve the efficiency of EDM in cost effective way. This paper reviews the research trends in EDM process by using water and powder mixed dielectric as dielectric fluid.

## Keywords : EDM , Dielectric , PMEDM

#### **1. Introduction to EDM Process :**

Although the erosive effect of electrical discharge machining was first invented by an English scientist Joseph Priestly in 1770 the machining of metals and diamond with electrical discharges has been done only in 1930s. In 1980s with the initiation of Computer Numerical Control (CNC) in EDM brings remarkable advancement by improving the efficiency of the machining operation. EDM machines have become so stable with the regular improvement in the process, so that these can be used for long interval of time

under monitoring by an adaptive control system. This process enables machining of any material, which is electrically conductive, irrespective of its hardness, shape or strength. The improvement of EDM have since then been intensely sought by the manufacturing sector yielding enormous economic benefits and generating keen research interests[3].

EDM is basically a non conventional machining and the basic principal followed is the conversion of electrical energy into thermal energy through a series of discrete electrical discharges occurring between the electrode (tool) and workpiece immersed in a dielectric fluid . Spark is initiated when high voltage is applied between the electrode and workpiece at smallest point distance as shown in Figure 1. Metal starts eroding from both the surfaces of workpiece as will as electrode. After each discharge, the capacitor is recharged from the DC source through a resistor and the spark that follows is transferred to the next narrowest gap. At the end sparks spread over the entire workpiece surface leads to its erosion, or machining to a shape which is mirror image of the tool.[2]

Electrode

Figure 1 Spark initiation in EDM process



The dielectric fluid helps discharge energy to concentrate into a channel of very small cross-sectional area. It also acts as coolant and flushes away the particles of machining from the gap. The electrical resistance of the dielectric fluid influences the discharge energy at the time of spark initiation. Early discharge will occur, if the resistance is low. If resistance is large, the capacitor will attain a higher value of charge before the spark occurs. As the erosion on the workpiece surface takes place the tool has to be advanced through the dielectric towards it. A servo system, which is employed to maintain the gap voltage between the workpiece and electrode with a reference value, is to ensure that the electrode moves at a proper rate towards workpiece, and to retract the electrode if short circuiting occurs. The volume of material removed per discharge is typically in the range of 10<sup>-6</sup>–10<sup>-4</sup> mm<sup>3</sup> and the metal removal rate (MRR) is usually between 2 and 400 mm<sup>3</sup>/min depending on specific application. During the EDM process the electrical energy created between workpiece and electrode passes through a gap in dielectric fluid. The energy over a small region leads to deeper crater which reduces surface finish; hence dielectric fluids with high thermal conductivity are needed to improve the performance.

#### **1.1 Classification of basic EDM Parameters**

The Process parameters can be divided into different categories i.e. electrical, non-electrical Parameters, electrode parameters, powder parameters etc. shown in Figure 2.



Figure 2 Process parameters and performance measures of EDM Process[2]

The effect of various parameters on the efficiency of EDM was greatly discussed[1,2,3] and a few were mentioned below

## 1.2 Electrical parameters

## 1.2.1Peak current

The peak current is the amount of power used in EDM and measures in unit of amperage. During each pulse on-time, the current increases until it reaches a preset level, which is expressed as the peak current. Higher amperage is used in roughing operations and in cavities or details with large surface areas. *1.2.2 Discharge voltage* 



The preset voltage determines the width of the spark gap between the leading edge of the electrode and workpiece. MRR, tool wear rate (TWR) and surface roughness increases, by increasing open circuit voltage, because electric field strength increases. However, the impact of changing open circuit voltage on surface hardness after machining has been found to be only marginal. Discharge voltage in EDM is related to the spark gap and breakdown strength of the dielectric.

## 1.2.3 Pulse on time and pulse off time

These are expressed in units of microseconds. Metal removal is directly proportional to the amount of energy applied during the pulse ontime . With longer pulse duration, more workpiece material will be melted away. The resulting crater will be broader and deeper than a crater produced by shorter pulse duration. Modern power supplies allow independent setting of pulse on-times and pulse off-times. Typical ranges are from 2 to  $1000\mu$ s. In ideal conditions, each pulse creates a spark. However, it has been observed practically that many pulses fail if duration and interval are not properly set, causing a loss of the machining efficiency.

## 1.2.4. Polarity

The polarity of the electrode can be either positive or negative. But the excess material is removed from side which is positive. In general, polarity is determined by experiments and is a matter of tool material, work material, current density and pulse length combinations. Modern power supplies insert an opposite polarity "swing pulse" at fixed intervals to prevent arcing. A typical ratio is 1 swing pulse for every 15 standard pulses.

## 1.2.5. Electrode gap

Basic 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.

## 1.3 Non- Electrical parameters

## 1.3.1. Dielectric flushing

The dielectric fluid used in EDM have characteristics of high dielectric strength and quick recovery after breakdown, effective quenching and flushing ability, good degree of fluidity and easily available. TWR and MRR are affected by the type of dielectric and the method of its flushing . A control feature that is available on many machines to facilitate is vibration chip removal or cyclic reciprocation of the servo-controlled tool electrode to create a hydraulic pumping action. 1.3.2. Rotating the workpiece

In addition to the flushing of the dielectric, the techniques of applying rotational motion to the sparking process also affect the EDM performance. Work piece rotary motion was also studied by researchers to improve the circulation of the dielectric fluid in the spark gap and temperature distribution of the workpiece yielding improved MRR and SR.

## 1.3.3. Rotating the electrode

Similarly, the performance measures of the EDM process also improves by the introduction of the rotary motion to the electrode. It serves as an effective gap flushing technique, which significantly improves the MRR and SR. It was found that the vibratory motion yields comparable effects as the rotary motion of electrode improving the MRR, enhancing the surface quality of workpiece and increasing the stability of machining



process.

#### 1.4. Electrode parameters

## 1.41. Electrode material

Generally, by using a sufficient number of electrodes of material having a low wear ratio, it is possible to produce the same accuracy of machining as with a single electrode of material with a high ratio.

1.4.2. Electrode design and size

EDM produce a mirror image of tool on the workpiece. However, a certain amount of clearance should be provided between the tool and work cavity. The magnitude of the clearance varies with the rate of metal removal, the material of the tool and workpiece. The major research interest in the production of electrodes using the rapid prototyping technique is also used. (PMEDM) to avoid the wastage of kerosene oil, a small dielectric circulating system is designed. A stirring system is incorporated to avoid the particle settling. For constant reuse of powder mixed dielectric fluid, magnetic forces are used to separate the powder particles from the debris produced due to machining. PMEDM has a different machining mechanism from the conventional EDM. In this process, a suitable material in the powder form is mixed into the dielectric fluid of EDM.

## 2. Research Fields Relevant to EDM

EDM is basically a material removal process. The researches have classified the numerous EDM research interests referred in the papers into four different major areas as shown in Figure 3. Enormous work has been reported ever since the process established itself. However, in this section discussion is only about water and powder mixed dielectric as dielectric fluid.

## 1.5 Powder parameters

In powder mixed electric discharge machining



Figure 3. Research areas of EDM [1]

## 3. EDM with Powder-Mixed in

## **Dielectric Fluid (PMEDM)**



The mechanism of PMEDM is totally different from the conventional EDM . A suitable material in the powder form is mixed into the dielectric fluid of EDM[4]. When a suitable voltage is applied, the spark gap filled up with additive particles and the gap distance setup between tool and the workpiece increased from 25-50 to 50-150 mm . The powder particles get energized and behave in a zigzag fashion Figure 4. 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.



# Figure 4. Principle of powder mixed EDM [4,5,9]

An extensive survey has been done by so many researchers [1,2,4] on powder mixed dielectric and research findings revealed that the dielectric fluids with powder particle offers significantly better thermal properties relative to those of conventional dielectric fluids. In the powder mixed EDM powder of different materials are mixed in dielectric fluid. The floating particles impede the ignition process by creating a higher discharge probability and lowering the breakdown strength of the insulating dielectric fluid. As a result, MRR, SR is increased, TWR is lowered and sparking efficiency is improved. The nano powder suspended in dielectric medium increases the gap between tool and workpiece which in turn causes the stability of the process, thereby increasing the machinability. . H.K. Kansal proved that PMEDM holds a bright promise in application of EDM, particularly with regard process to productivity quality of and surface workpiece[6,8,9].

For achieving surface modification by powder-mixed dielectric, an inverse or reverse polarity arrangement (negative tool electrode) is universally recommended. Some of the powders that have already been used are Ni, Co, Fe, Al, Cr, Cu, Ti, C (graphite), Si, SiC and Mo with quoted grain sizes between 1µm and 100µm. Few of such works are summarized below.

Jeswani in 1981 conducted experiments with addition of 4 g/l of fine graphite powder in the dielectric and found that MRR improved by 60% and electrode wear ratio reduced by about 15% . Extended investigations carried out in Germany show high efficiency application of mixture water and glycerin for reducing disadvantages in EDM-sinking using pure water [7].

Okada in year 2000 purposed that the hardness of the modified surface became higher with increase in pulse duration and powder concentration. A distinct influence of the addition of aromatic hydrocarbons to the dielectric fluid on the ignition and breakdown phase of single discharges has also been reported



by [10].

Furutani in 2001 investigated by using titanium powder in kerosene dielectric and obtained titanium carbide layer of hardness 1600HV on carbon steel with a negatively polarized copper electrode, 3A peak current and 2µs pulse duration[11] and also a deposition method for solid lubricant layer of molybdenum disulphide by suspending its powder in the dielectric to produce parts for ultra high vacuum applications has been proposed in the year 2003.

. The process has some drawbacks, which include the difficulty in ensuring that the powder is held in suspension. In order to address the problem of powder settling, Wu has contributed a lot to the field of EDM and tried different research aspects including adding a surfactant along with aluminium powder in the dielectric and observed a more apparent discharge distribution effect which resulted in a surface roughness Ra value of less than 0.2µm.

Researchers are also tried different mediums like distilled water, tap water, kerosene, benzene solution as dielectric to observe the performance of EDM with powder particle dispersions.[5]

Other hand, when Tzeng and Chen [12] conducted experiments on SKD-11 steel with aluminium, chromium, copper and silicon carbide powders, they found that aluminium powder gave the best surface finish followed by chromium, whereas copper powder generated the worst surface characteristics. The contributions to the field of Powder mixed dielectric has been increased in the past few years[13,14] because of having advantages of efficiency with low costs. It is going to be extended to a considerable figure in the coming years.

## 4. Conclusion

Elaborate scrutiny of the research work reveals that the material removal mechanism of EDM process is very complex and theoretical modeling of the process is very difficult. Powder mixed dielectric is a good research promising area. Most of the research work has been with Al, Si, and graphite powders and some with other types of powder like Cr, Ni, Mo, etc., but only a few has touched the introduction of using Nano powders in to EDM. Most of the available research works on powder-mixed dielectric have studied the impact of such machining on MRR, surface roughness and TWR etc. Much investigation and more trails are needed to check the applicability and measure the performance of EDM with Powder particles in dielectric.

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