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Effect Of Powder Mixed Dielectric On Surface Properties In Electric Discharge Machining

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Abstract: In the process technology, as there are numerous advances at rapid rate, a large number of new materials are being developed every day. These materials have the combination of properties, like light weight, corrosive resistance, high strength etc., which is not easy to obtain in general. The important aspect is that they satisfy the demands of today's industry, but the major problem is that it is very difficult to machine the newly developed materials. So, in order to manipulate them, newer machining methods have been developed. These methods are more efficient than the conventional ones. Electric discharge machining (EDM) is one of the most widely used methods among the new techniques. The main reason behind the popularity of the EDM is that its capability of machining the hard to machine materials and intricate shapes. EDM has been employed to effect/change the surface properties such as roughness and hardness of the die steels by varying the electrode material and by adding the various powders in the dielectric. In this thesis work the literature available in the area of Surface modification by PMEDM (Powder Mixed EDM), EDM in general and effect of PMEDM on Tool Wear Rate and Material Removal Rate has been reviewed. Experiments were designed using Taguchi method so that effect of all the parameters could be studied with minimum possible number of experiments. Using Taguchi method, Appropriate Orthogonal Array has been chosen 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. From the point of view of industrial applications, die steel is a very important material and that's why for the purpose of experimentation EN31 die steel with copper electrode and kerosene as dielectric has been used.

Keywords*:* EDM, Taguchi design, PMEDM, Orthogonal Array.

I. INTRODUCTION

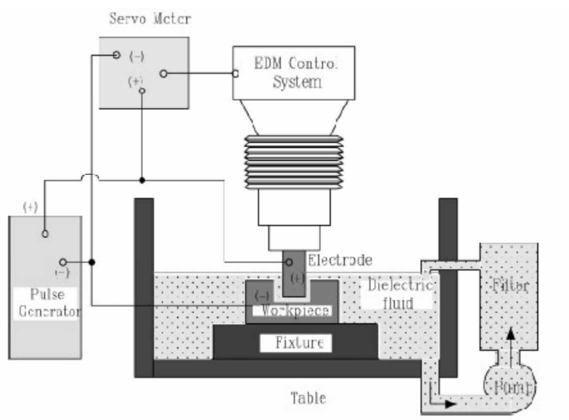
Traditional machining processes work on the principle that the tool is harder than the work-piece. Some materials, however, are too hard or too brittle to be machined by conventional methods. The use of very hard nickel-based and titanium alloys by the aircraft engine industry, for example, has stimulated non conventional machining methods. By conventional methods their machining is not only costly but also results into poor surface finish and shorter tool life. To overcome these difficulties, a number of
Newer Machining Methods have been developed. These methods are not conventional in the sense that material removal does not occur due to plastic deformation and with the formation of chips.

These methods have found successful applications in several important industries for

machining of components having complicated shapes made of hard materials like tungsten carbides, super-alloys, ceramics, refractory materials etc. Newer machining methods can be classified on the basis of the type of energy they
employ for purpose of metal removal. Broadly speaking they can be classified as below:
1. Mechanical Metal Removal Processes.
2. Electro-chemical Metal Removal Processes.
3. Thermal Metal Removal Processes.
Mechanical methods are characterized by the fact that material removal is due to the application of mechanical energy in the form of high frequency vibrations or kinetic energy of an abrasivejet.

II. ELECTRIC DISCHARGE MACHINING

The basic principle in EDM is the conversion of electrical energy into thermal energy through a series of discrete electrical discharges occurring between the electrode and work piece immersed in the dielectric fluid. The insulating effect of the dielectric is important in avoiding electrolysis of the electrodes during the EDM process. Spark is initiated at the point of smallest inter-electrode gap by a high voltage, overcoming the dielectric breakdown strength of the small gap. At this stage, erosion of both the electrodes takes place. 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. The cumulative effect of a succession of sparks spread over the entire work piece surface leads to its erosion to a shape which is approximately complementary to that of the tool. The dielectric serves to concentrate the discharge energy into a channel of very small cross-sectional area. It also cools the two electrodes and flushes away the products of machining from the gap. The electric resistance of the dielectric influences discharge energy and time of spark initiation. As the work piece is spark-eroded, tool has to advance through the dielectric towards it. A servo system is employed to ensure that the electrode moves at a proper rate to maintain the right spark gap, and to retract the electrode, if short-circuiting occurs. Spark energy is the product of peak current and pulse-on time and since these process variables can be readily adjusted; machining conditions can selected for particular effects needed. Although the process is very complex, when the electrode is separated from the work piece, potential in the open circuit voltage is usually about 100V. As the dielectric begins to ionize, current starts flowing and the potential drops to a level of about 35 volts. Most of the electrode wear occurs during the ionization time.
Electric Discharge Machining (EDM) is used particularly when geometrically complex shapes need to be incorporated into high-strength, electrically conductive materials.



The requirements of high quality surface vary depending on the fields of application. Spark
Erosion machines, generators and suitable subassemblies were further developed during the last few years. As a result, the eroded surface quality and material removal rates have increased. Nowadays, the average roughness of Ra = 0.1µm and a Rim zone thickness of about l µm can be achieved. The increasing requirements imposed on dies and moulds subject to high levels of stress, in particular,

often necessitate special finish machining after the erosion process. Vast research work has been concerned with powder mixed EDM (PM-EDM). An improvement on the surface roughness and surface quality has been achieved with this process. By lowering the breakdown strength of the insulating dielectric fluid and increasing the discharge probability, powder additives can cause higher material removal rates (MRR). The Electric Discharge machining (EDM) has been widely used as a material removal process to produce parts, dies and molds for several decades. It is only recently that surface modification methods by EDM have been studied. Like other machining methods, EDM machining is also divided into two phases: Rough machining and Finish machining. The finish machining phase requires high surface quality, while rough machining phase requires high machining efficiency with a certain quality. Numerous research results show that Powder Mixed EDM (PM-EDM) machining can distinctly improve the surface roughness and surface quality in the finish machining phase and obtain nearly mirror surface effects, which have lead to the development and application of PMEDM machining in finish machining. [1]

III. PROCESS PARAMETERS:

3.1 Discharge Voltage

Discharge voltage in the EDM is related to the spark gap and breakdown strength of the dielectric. Before current can flow, the open gap voltage increases until it creates an ionization path through the dielectric. Once the current starts to flow, voltage drops and stabilizes at the working gap level. The preset voltage determines the width of the spark gap between the leading edge of the electrode and work piece. Higher voltage settings increase the gap, which improves the flushing conditions and helps to stabilize the cut. MRR< TWR and surface roughness increases with increasing open circuit voltage because electric field strength increases.

3.2 Peak Current

This is the amount of power used in discharge machining, measured in units of amperage and is the most important machining parameter in EDM. During each on-time pulse, the current increases until it reaches a preset level, which is expressed as the peak current. Higher currents will improve MRR but at the cost of TWR and surface finish.

3.3 Pulse On-time & Off-time

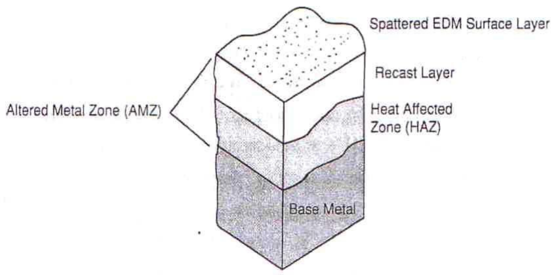
Each cycle has an on-time and off-time that is expressed in units of microseconds. Since all the work is done during on-time, the duration of these pulses and the number of cycles per second are important. Metal removal is directly proportional to the amount of energy applied during the on-time. The energy is controlled by the peak current and the length of the pulse on-time. The resulting crater will be deeper and broader than a crater produced by a shorter on-time. Excessive on-times can be counter productive when the optimum on-time for each electrode-work material combination is exceeded, material rate starts to decrease.

3.4 Polarity

The polarity of the electrode can be either positive or negative. The current passing the gap creates high temperatures causing material evaporation at both electrode spots. As the electron processes show quicker reaction, the anode material is worn out predominantly. This causes minimum wear to the tool electrodes and becomes of importance under finishing operations with shorter on-times. However while longer discharges, the early electron process predominance changes to positron process, resulting in high tool wear. In this experiment setup, positive polarity is selected.

3.5 Electrode Gap

The tool servo-mechanism is of considerable importance in the efficient working of EDM and its function is to control responsively the working gap of the set value. Mostly electro-mechanical systems are used. The most important requirements for good performance are gap stability and the reaction speed of the system; the presence of the backlash is practically undesirable.



Layers of EDMed surface

The EDM process changes not only the surface of the Work piece metal, but also the subsurface. Three layers are created on the top of the unaffected Work piece metal. The spattered EDM surface layer is created when expelled molten metal and small amounts of electrode materials form spheres and spatter the surface of the Work piece. This spattered material can be easily removed. The next layer is the recast layer. The action of EDM has actually altered the metallurgical structure and characteristics in the recast layer. This layer is formed by the unexcelled molten metal solidifying in the crater. The molten metal is rapidly quenched by the dielectric. Micro-cracks can form in this very hard, brittle layer. The last layer is the Heat Affected Zone or Annealed layer, which has only been heated, not melted. The depth of the recast layer and the heat affected zone is determined by the heat sinking ability of the material and the power used for the cut. This altered metal zone influences the quality of the surface integrity. [1]

IV. PROBLEM IDENTIFICATION

It is observed that although a lot of work has been done in the field of Electric Discharge Machining related to Material Removal Rate and Tool Wear Rate. But effect of PMEDM (Powder Mixed Electric Discharge Machining) on the various process parameters such as Material Removal Rate and Tool Wear Rate has not been studied yet. In past, work has been done using various powders such as nickel, Silicon, Titanium etc., but no one has tried yet Copper powder. Copper is a highly conductive material, so its interesting to study the effect of copper mixed dielectric upon the Material Removal Rate and Tool Wear Rate and the results are compared with that of Graphite powder. Further effect of PMEDM has also been studied upon Micro-Hardness and Surface Roughness of machined surface of the EN-31 die steel work-piece. [2]

V. OUTLINE OF THESIS WORK

The objective of this work is to study the effect of powder mixed dielectric upon the Material Removal Rate and Tool Wear Rate. For the purpose of experimentation, EN 31 die steel is used along with copper electrode. Kerosene has been used as dielectric. Reason for using kerosene as dielectric is that it is a good carrier of heat and has good flushing properties. The percentage of carbon in EN 31 die steel is 0.35%, which is very small as desired. Copper and graphite powders were added into the dielectric and their effect has been studied. Experiments were designed using Taguchi method so that effect of all the parameters has been studied with minimum possible number of experiments. Using Taguchi method, Appropriate Orthogonal Array has been chosen and experiments have been performed as per the set of experiments designed in the orthogonal array. Signal to Noise ratio are also calculated to analyze the effect of PMEDM more accurately.

VI. DESIGN OF STUDY

A large number of input process parameters can be varied in the EDM process, each having its own impact on output parameters such as Material Removal Rate (MRR), Tool Wear Rate (TWR), and hardness of machined surface, surface finish, dimensional accuracy and overall surface integrity. Various input parameters are:

a. Discharge Voltage
b. Peak Current
c. Pulse Waveform
d. Pulse on-time
e. Pulse off-time
f. Pulse Frequency
g. Polarity
h. Electrode Gap
i. Type of Dielectric flushing

The effect of each of these parameters on EDM process is discussed in the literature review in detail. It is also known from the previous research works that out of the above listed parameters, four parameters directly affect the MRR and TWR in EDM. These four parameters are **peak current, pulse on-time, pulse off-time and polarity**. Out of these parameters, three parameters have been investigated thoroughly in this research work. One parameter **polarity** is kept fixed for the whole experiment. The range of first three parameters is decided by approach varying one parameter at a time. Polarity has been fixed as **straight polarity** (electrode negative) for all the experiments because it is desirable setting for material transfer to occur. [4]

VII. DISCUSSION

This chapter includes the details of the experimental work performed on EDM machine along with the results of the experimental work. The objective of the experimentation is to study the effect of powder mixed dielectric upon the MRR, TWR, micro hardness and surface roughness mainly using die steel as the raw material. Also the effect has been studied on the Hardness and roughness of the machined surface. Signal to noise ratio was determined and graphs were generated on the basis of experimental data, analyzed and then SNR are determined. Three sets of experiments were conducted as under:

1. Experimental set up with no powder as additive.
2. Experimental set up with powder1 as additive.
3. Experimental set up with powder2 as additive.

VIII. SUMMARY

The objective of the work carried out is to study the effect of powder mixed dielectric (PMEDM) upon two very important parameters of the Electric Discharge Machining i.e. Material Removal Rate and Tool Wear Rate. Also the effect was studied on the Micro hardness and Surface roughness of the work-piece. For the purpose of experimentation EDM machine, which is installed in Machine Tool Laboratory at Mewar University has been utilized. The machine has the capability to vary the polarity, peak current, pulse on time, pulse off-time, pulse duration etc. Considering the capability of the machine and the output required for the experimentation, peak current, pulsed on-time and pulse off-time were decided to be taken as the variable and all the other factors have to be kept fixed. Two powders were mixed into the dielectric kerosene in order to study the effect of powder mixed dielectric on machining parameters decided.

IX. CONCLUSION

From the study it has been concluded that the PMEDM (Powder Mixed Electric Discharge Machining) has significant effect on the material removal rate and tool wear rate as well as upon surface properties like surface roughness and micro hardness. With the addition of the powders in the dielectric, material removal rate has been increased to a great extent and the tool wear rate has been reduced. Graphite gives better results in terms of Material removal rate and tool wear rate as well as in case of hardness and roughness also in comparison to copper powder. So, it is concluded and suggested to use graphite as an additive for PMEDM in comparison to that of copper. Thus, PMEDM can be employed for making micro structures and compositions which are otherwise difficult with other processes like casting, forging, etc.

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