Experimental Study of Electro Discharge Machining Using Graphite as a Powder Additive for Material Removal Rate & Surface Finish of En8 Material

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Abstract:
Electrical discharge machining is a technological process use, when very complex shapes on hard materials with a high geometrical and dimensional accuracy are required. Material removal rate and surface finish are most important output parameters, which decide the machining performance. Present study attempts to optimize the process on the powder mixed electrical discharge machining (PMEDM) of En-8. In the PMEDM process, the powder particle suspended in the dielectric fluid disperses and makes the discharging energy dispersion almost uniform; it displays multiple discharging effects. Also the plasma channel becomes enlarged and widened. This phenomenon improves results in both MRR and surface finish. In this paper we have considered processing parameters; discharge current, pulse on time and concentration of graphite powder particle for the evaluation of MRR and Surface Roughness. Here we have performed 48 experiments according to Design of Experiment, with full factorial method. ANOVA analysis carried out which conclude that current is the main factor which contributes much more, but the contribution of concentration is also considerable. Here the value of MRR is improved from 41.15 mm^3/min (in conventional EDM) to 45.64 mm^3/min in powder mixed EDM. Also surface roughness is improved from its minimum value in conventional EDM 7.12 µm to 6.93 µm. Maximum MRR is obtained at 4 gm/liter concentration and surface finish obtained at 3 gm/liter concentration.
Keywords: - *Electrical discharge machining, material removal rate, surface roughness, power concentration, analysis of variance*

1. Introduction

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. As shown in fig.1, pulse discharge occurs in a small gap between the work piece and the electrode and removes the unwanted material from the parent metal through melting and vaporizing.

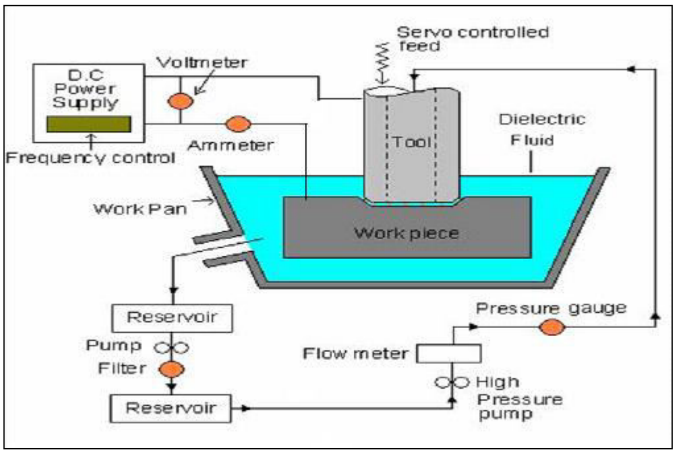

Figure 1. Schematic diagram of EDM

Electrical discharge machining (EDM) is a well-established machining option for manufacturing geometrically complex or hard material parts that are extremely difficult-to-machine by conventional machining processes. The non-contact machining technique has been continuously evolving from a mere tool and dies, making process to a micro-scale application machining, alternative attracting a significant amount of research interests.

EDM machining technology is widely used by manufacturing industries; but its low efficiency and poor surface quality issues are the key problems restricting its development. So the objective of this work is to deduce the performance improvement of conventional EDM when powder mixed dielectric fluid used. Thus this effort will try to improve output parameter of EDM by adding powder in dielectric fluid.

M. L. Jesvani [1] has evaluated measurements of surface roughness on spark-eroded samples of diff. materials. He found the roughness increased with increasing pulse energy for particular work-tool combinations. Material with a high metal removal rate has a rough surface. Quan Yan Ming, Liu You He; [2] have used additives in dielectric fluid. Additives used in the tests include some kinds of solid powder. Additives to kerosene can decrease the loss of alloy elements, increase the micro hardness, make the molten layer thinner and reduce cracks. Different additives have different optimum added quantity. Adding excessive additive is deleterious. Ranjit K. Roy [6] has given the concepts of Design of Experiment. DOE is a technique of defining and investigating all possible combinations in an experiment involving multiple factors and to identify the best combination. In this different factors and their levels are identified. In design of experiment the results are analyzed to establish the best or the optimum condition for a product or a process. The Analysis of variance (ANOVA) is the statistical treatment most commonly applied to the results of the experiment to determine the percent contribution of each factors.

2. EDM Main Components and process parameters

1. DC source
2. Dielectric medium
3. Work piece and the tool
4. Servo system. As shown in figure 1.

The selection of EDM process parameters determine the accuracy and surface finish obtain for a particular application. The following parameters are relevant for the EDM process.

- Current and Voltage
- Pulse on time and Pulse off time
- Spark frequency and Polarity
- Flushing
- Characteristics of tool and workpiece

3. Mechanism of powder mixed EDM

This section provides the basic machining mechanism of PMEDM. 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 either in the same tank or in a separate tank. For better circulation of the powder mixed dielectric, a stirring system is employed. For constant reuse of powder in the dielectric fluid, a modified circulation system is used. The experimental setup consists of a container, called machining tank. It is placed in the work tank of EDM and the machining is performed in this container. To hold the workpiece, a workpiece fixture assembly is placed in it. The machining tank is filled up with dielectric fluid.

Small dielectric circulation pump is installed for proper circulation of the powder mixed dielectric fluid into the discharge gap. The pump and the stirrer assembly are placed in the same tank in which machining is performed. Magnetic forces are used to separate the debris from the dielectric fluid. For this purpose, two permanent magnets are placed at the bottom of machining tank. The graphite powder is added into the dielectric fluid.

The spark gap is filled up with powder particles. When a voltage of 80–320V is applied between the electrode and the workpiece the powder particles get energized and behave in a zigzag fashion as shown in figure 2. These charged particles are accelerated by the electric field and act as conductors. The conductive particles promote breakdown in the gap and increase the spark gap between tool and the workpiece. Under the sparking area, the particles come close to each other and arrange themselves in the form of chain like structures between both the electrodes.

The interlocking between the different powder particles occurs in the direction of flow of current. The chain formation helps in bridging the discharge gap between both the electrodes. Due to bridging effect, the insulating strength of the dielectric fluid decreases.

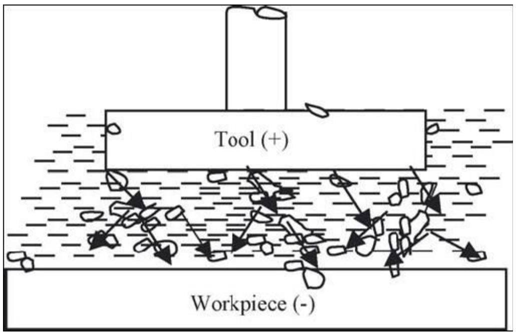

Figure 2: Principle of powder mixed EDM.

The easy short circuit takes place, which causes early explosion in the gap. As a result, series discharge starts under the electrode area. The faster sparking within a discharge takes place causing faster erosion from the workpiece surface and hence the material removal rate (MRR) increases. Figure 3.3 shows the material removal mechanism without powder and with powder.

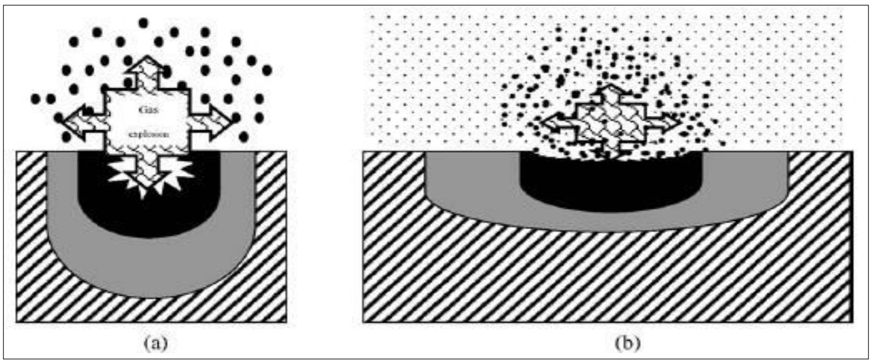

Figure 3: Schematic diagrams of material removal mechanism during the normal discharge for the working fluid (a) without powder and (b) with powders.

At the same time, the added powder modifies the plasma channel. The plasma channel becomes enlarged and widened. The sparking is uniformly distributed among the powder particles, hence electric density of the spark decreases. Due to uniform distribution of sparking among the powder particles, shallow craters are produced on the workpiece surface. This results in improvement in surface finish.

4. Design of Experiments

DOE is a technique of defining and investigating all possible combinations in an experiment involving multiple factors and to identify the best combination. In this, different factors and their levels are identified. Design of experiments is also useful to combine the factors at appropriate levels, each within the respective acceptable range, to produce the best results and yet exhibit minimum variation around the optimum results.
The design of experiment is used to develop a layout of the different conditions to be studied.

An experiment design must satisfy two objectives: first, the number of trials must be determined; second, the conditions for each trial must be specified.

4.1 Methods:

The design of experiment based on
- Factorial design,
- Taguchi method,
- Response surface method.

The technique is applied in diff. steps:
- Brainstorm the quality characteristics and design parameters,
- Design the experiments using suitable method or software,
- Conduct the experiments,
- Analyze the results to determine the optimum conditions.

4.2 Input Parameter:

- With toggle switches of current setting the value of current will change from 1.56 amp. to 25 amp.
- Pulse ON-time determines the energy of each discharge for a given power level, so for the given current level Pulse ON-time Value will be varied.
- Rotary switch is given in which the value varies from 50 µsec to 1000 µsec.
- Finally the powder concentration will be varied in the range of 3 gm/liter to 5 gm/liter.

So we have used 3 factors each having different levels.
Factor A: Current (amp.)
Factor B: Pulse on time (micro sec.)
Factor C: Concentration of powder (gm/liter)

Figure 4: Front panel of EDM for varying value of input parameter

5. Experimental Setup:

The equipment used to perform the experiments is a die-sinking EDM machine (A-25, Make: Press Mach Machine Tool Ltd, India) of which front panel is shown in figure 4. This machine has maximum current capacity of 25 Amp. Any setting in between 1 to 25 amps can be used. It can run either in normal polarity or in reverse polarity. It has 10 on time settings and 10 off time settings. Experiment has been performed with normal polarity. Table 1 shows the machining conditions of the performed experimentation performed.

Table 1: Machining conditions

Electrode	Work piece	Dielectric fluid	Flushing Condition
Material : Copper Size: Cylindrical shape with a diameter of *12mm.*	Material: EN8 Composition – C -0.36 to 0.44% Mn – 0.60 to 1 % Si - 01 to 0.4% S - 0.050 % max P - 0.050% max Size: Rectangular block of dimension: *50mm x 25 mm x5mm.*	Material: EDM oil grade EDM 30. + Graphite powder Density (g/cm^3): 1.45 Compressive strength (MPa): 110 Thermal conductivity (W/m .K): 153 Specific heat capacity (J/kg .K): 710-830	Jet flushing Flushing pressure: *0.25 kg/cm^2.*

6. Experimental Results:

The material removal rate and surface roughness produced on workpiece surface is depends on different parameters like current, pulse on time, duty cycle etc. so for a given material, the process parameters need to be adjusted in order to achieve optimum machining performance. Here no. of experiments depends on the design of experiments is carried out and results in terms of output parameter (material removal rate and surface roughness) is measured. Different results of current v/s surface roughness for 100, 200 and 500 pulses are discussed below.

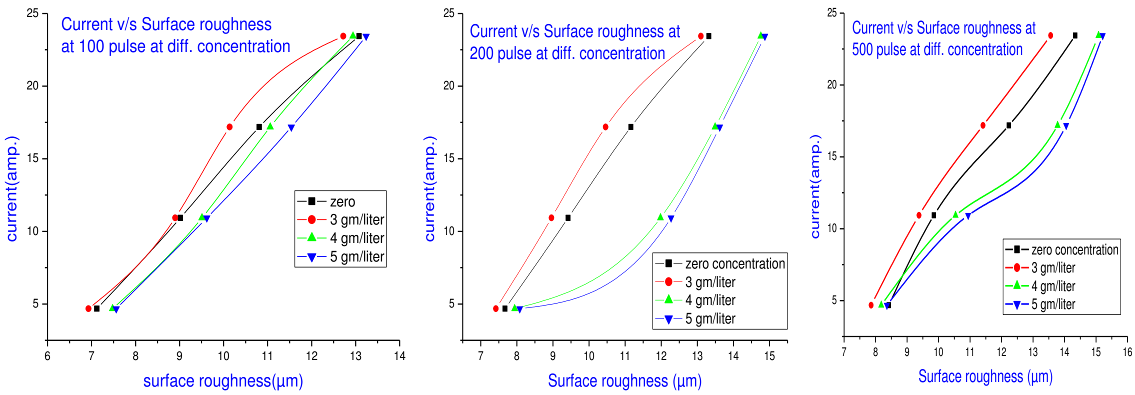

Figure 5: Current v/s SR at 100, 200 and 500 pulses at different concentration**.**

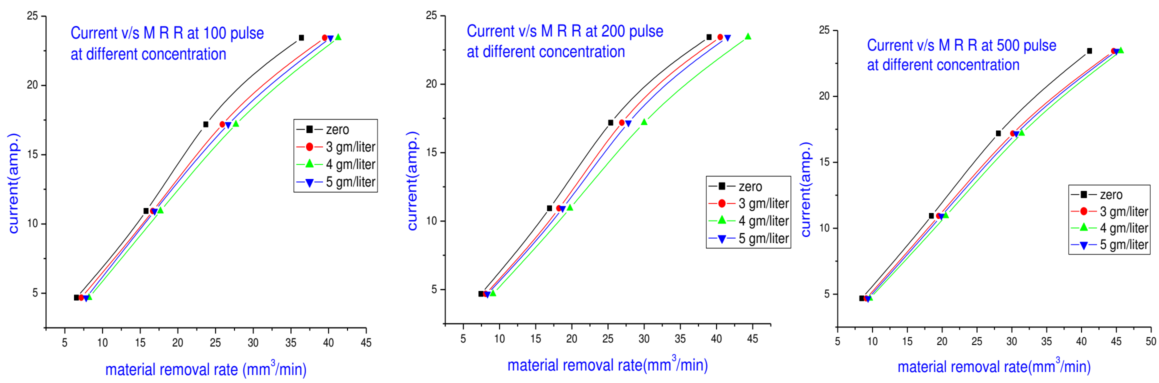

Figure 6: Current v/s MRR at 100, 200 and 500 pulses at different concentration

7. Conclusion:

From the analysis of effect of different parameters on Material removal rate we have observed that maximum material removal rate is obtained at 4 gm/liter concentration at highest current 23.44 amps. at 500 pulse on time. The value of maximum MRR is 45.64 mm^3/min.
Thus above 4 gm/liter graphite powder concentration the improvement in material removal rate is undesirable. This is due to,

1) That for the stable machining operation debris should be properly removed after each spark discharge, but due to high concentration the created debris as a result of material removal is not finding sufficient way to over it out, so the next spark occur in the presence of debris, and that is energy loss. The spark strike the debris already present and does not reach properly on the machining surface, therefore Material Removal Rate is decreases.
2) Also the high concentration would create a discharge interference phenomenon and unstable EDM operation takes place, which will reduce Material removal rate.

From the analysis of effect of different parameters on surface roughness we have observed that minimum surface roughness is obtained at 3 gm/liter concentration at lowest current 4.68 amps. at 100 pulse on time. The value of lowest surface roughness achieved is 6.93 µm. Thus above 3gm/liter graphite powder concentration the improvement in surface finish is undesirable. This is due to,

1) The high additive concentration causes powder setting problem, means with the same dielectric circulation system it is difficult to remove all additive particle from the spark gap which will create hurdle on quality of the surface finish.
2) Its higher density produces heavier impact effects on the melted zone causing slightly higher surface roughness value.
3) Also high concentration would create a discharge interference phenomenon means that number of discharge will overlay on the craters will increases surface roughness.

It can be concluded that PMEDM holds a bright promise in application of EDM, particularly with regard to process productivity and surface quality of workpiece.

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