Research Paper

Volume : 2 | Issue : 2 | Feb 2013 • ISSN No 2277 - 8179

Effect of Powder Mixed Dielectric Medium on Tool Wear Rate in EDM

Engineering

KEYWORDS : EDM, Taguchi Design, Orthogonal array, PMEDM, etc.

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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 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. 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. In this paper, the effect of powder mixed dielectric on tool wear rate (TWR) in EDM has been observed. Experiments were designed using Taguchi method and appropriate Orthogonal Array 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.

1. 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. Different non-traditional machining techniques are progressively used in manufacturing of complex machining components in modern metal industry. However the capability of electrical discharge machining (EDM) to develop temperature of about 8000- 12000 oC, to melt material of any hardness value and makes its use in manufacturing of mold, die, automotive, nuclear reactor, spacecraft and surgical components. This technique uses thermal energy to machine all electrical conductive, high strength and temperature-resistant materials in a contactless manner. But the low machining efficiency and poor surface quality are the major drawbacks of this process which restricts its use in mechanical manufacturing. To overcome these drawbacks and to enhance process capabilities researchers did a lot of work. Rotating of electrode, orbiting of electrode, changing the tool material, application of ultrasonic vibrations and addition of powders in dielectric fluid of EDM are some of the techniques suggested by researchers to enhance process capabilities. The performance of Powder Mixed electric discharge machining (PMEDM) depends on the four different types of input parameters i.e electrical parameters, non electrical parameters, electrode parameters and powder parameters. The objective of this paper is to obtain the effect of powder mixed dielectric medium on tool wear rate in EDM.

2. Working Principle of EDM

The basic working 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 medium begins to ionize, the current starts flowing and the potential drops to a level of about 35 volts. Most of the electrode wear occurs during the ionization time.

3. 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

It is known from the previous research works that out of the above listed parameters, four parameters directly affect the 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. 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. With straight polarity, the energy available per discharge at work surface is higher as compared to the tool electrode and consequently tool wear rate is also effected.

3.1 Experimental Design

As the objective of this research work is to study the effect of powder mixed in the dielectric upon TWR through material transfer from powder suspended in the dielectric medium by changing the various input machining process parameters, the design variables can be summarized as follows:

a) Two powders to be suspended in the dielectric one by one; namely graphite and copper.

b) Three levels of peak current to be used; because the non-linear behavior of process parameters can only be studied if more than two levels of a parameter are used.
c) Three levels of pulse on-time to be used.
d) Three levels of pulse off-time to be used.

For the design of experiments, Taguchi methods have been used. Using Taguchi design, L27 Orthogonal Array has been selected and experiments were performed according to the set of combinations of factors of L27 OA. Various factors for this study were Peak current, pulse on-time, pulse off-time and dielectric. For all these parameters, there were three levels of variation. For current, pulse on-time, pulse off-time and dielectric values at various levels are 2, 4 and 6 Amp; 3, 4 and 5 knob values; 5, 6 and 7 knob values and No additive, copper and graphite as additive. Work-piece was of EN-31 die steel and the electrode selected was of copper. Once all the parameters have been decided and level values were set, experimentation was performed.

The machining parameters that have been kept fixed throughout the experimentation are as follows:

Table 3.1 Fixed Input Process Parameters

S. No.	Machining Parameter	Fixed Value
1	Open Circuit Voltage	135 ± 5% Volts
2	Polarity	Straight
3	Machining Time	20mm
4	Type of Di-electric	Kerosene
5	Electrode Quill Movement	10.4
6	Powder Concentration in Di-electric	15g/liter

4. Analysis and Experimentation
The values of the input process parameters for the EDM are as under:

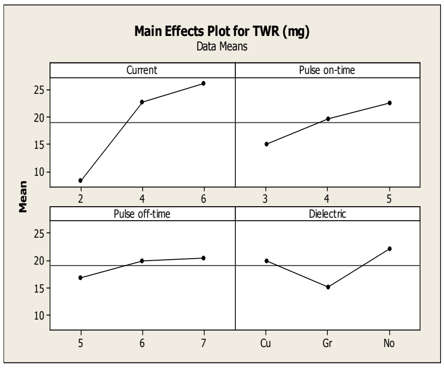
Peak Current: 2, 4, 6 Amperes
Pulse on-time: 3, 4, 5 µsec. (knob positions)
Pulse off-time: 5, 6, 7 µsec. (knob positions)

The values of the pulse off-time have been chosen towards the higher side with the aim of providing adequate cooling time to the recast material.

Table 4.1 Values of various responses and SNR

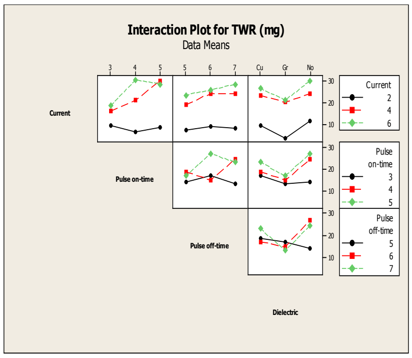
Exp. No.	Current (Amp.)	Pulse on-time (µ sec.)	Pulse off-time (µ sec.)	Dielectric	TWR (mg)	SNR for TWR
1	2	3	5	No Additive	12	-21.5836
2	2	3	6	Cu	12	-21.5836
3	2	3	7	Gr	5	-13.9794
4	2	4	5	Cu	7	-16.9019
5	2	4	6	Gr	3	-9.5424
6	2	4	7	No Additive	10	-20
7	2	5	5	Gr	3	-9.5424
8	2	5	6	No Additive	13	-22.2788
9	2	5	7	Cu	10	-20
10	4	3	5	No Additive	12	-21.5836
11	4	3	6	Cu	20	-26.0206
12	4	3	7	Gr	17	-24.6089
13	4	4	5	Cu	20	-26.0206
14	4	4	6	Gr	18	-25.1054
15	4	4	7	No Additive	26	-28.2994
16	4	5	5	Gr	26	-28.2994
17	4	5	6	No Additive	35	-30.8814
18	4	5	7	Cu	30	-29.5424
19	6	3	5	No Additive	19	-25.575
20	6	3	6	Cu	20	-26.0206
21	6	3	7	Gr	18	-25.1055
22	6	4	5	Cu	30	-29.5424
23	6	4	6	Gr	24	-27.6042
24	6	4	7	No Additive	38	-31.5956
25	6	5	5	Gr	22	-26.8684
26	6	5	6	No Additive	34	-30.6295
27	6	5	7	Cu	30	-29.5424

4.1 Experimental results for TWR:
The experimental results for TWR are obtained with the help MINITAB 16 software and the Main Effects Plot and Interaction Plots for TWR are shown in graph 4.1 and 4.2 respectively.



Graph4.1 Effect of various factors on the TWR

Graph 4.1 shows the effect of various factors upon the Tool wear rate. Tool is made up of copper. It is clear from the graphs that TWR also increases with increase in current, pulse on-time and pulse off-time and powder suspended powders give better results than that of the kerosene only. Graphite suspended kerosene gives the better results that are lesser TWR than that of copper suspended dielectric.



Graph 4.2 Interaction plot for TWR

Graph 4.2 gives the interactive effect of various factors upon the Tool Wear Rate. It shows that for current and pulse on-time combination, with increase in the current value, TWR wear rate also increases and the TWR rate is highest for highest levels. It is clear from the graphs that when Graphite is added to the kerosene, tool wear rate reduces to the minimal for a particular set of combination of current, pulse on-time and pulse off-time.

From the above graph 4.1 and 4.2, it is found that the optimum combination for micro hardness is A1B1C1D3. The theoretical optimum value for response ηopt is given as under;

ηopt = m + ($m_{A_1} m_{A_1}$ - m) + ($m_{B_1} m_{B_1}$ - m) + ($m_{C_1} m_{C_1}$ - m)
ηopt = = -24.0087 + 12.9873 + 2.7775 + 2.4453
= -5.7986.
And the corresponding value of TWR is given by;
yopt2 = $10^{\frac{-\eta_{opt}}{10}} 10^{\frac{-\eta_{opt}}{10}}$ = 3.8006

or yopt = 1.9495
So the optimal value of TWR is 1.9495 for this experimental set up.

4.2 ANOVA table of Tool Wear Rate

Source	Adj. SS	DOF`	Variance / Adj. MS	F Test	F Crictical	SS'	C (%)	Remark
Current (A)	1600.07	2	800.04	102.398	5.14	1579.69	62.2013	S
Pulse on time (B)	260.52	2	130.26	16.672	5.14	240.1412	9.443	S
Pulse of time (C)	70.30	2	35.15	4.498	5.14	49.9212	1.96311	NS
Dielectric (D)	230.30	2	115.15	14.738	5.14	209.9212	8.2549	S
AxB	289.04	4	72.259	9.248	4.53	248.2825	9.7635	S
AxC	23.26	4	5.815	5.815	4.53			NS
AxD	22.59	4	5.648	5.648	4.53			NS
Error	46.88	6	7.813					
Total	2542.96	26			11.78	100	100	
e-pooled	163.03	16	10.18937					

DOF: Degree of Freedom; Seq. SS: Sequential sum of squares; Adj. SS: Adjusted sum of squares; Adj. MS: Adjusted mean square; S: Significant; NS: Non-Significant; C%: Contribution Percentage

From the ANOVA table 4.2, the important factors which affect the Tool wear rate are the current, pulse on time and dielectric. Since the value of F is large for current so it is most significant factor. Also the interaction between current and pulse on time is significant among all the interactions considered. Out of all the factors, current has the maximum impact upon the Tool wear rate. From the graphical results it is clear that as the current increases, tool wear rate also increases. Current is directly proportional to discharge energy and pulse on-time means the time for which the tool-job are under the effect of spark energy. With increase in current and pulse on-time, tool wear rate also increases and hence the same is the result from ANOVA table.

5. CONCLUSIONS

From the experimental work, it has been concluded that the PMEDM (Powder Mixed Electric Discharge Machining) has significant effect on the tool wear rate. The Tool Wear Rate is higher with Copper as an additive and less when Graphite is used in dielectric. As current is directly proportional to discharge energy and pulse on-time. With increase in current and pulse on-time, tool wear rate also increases.

The TWR is 3.685gms/µsec. when no additive is mixed in kerosene dielectric medium and this TWR decreases to 3.315gms/µsec. when Copper powder is mixed with dielectric medium and it again decreased to 2.5185gms/µsec. when Graphite powder is mixed with the dielectric medium. As it is known that lesser the TWR means higher the Tool Life, so it is clear that Tool life increases with the addition of Graphite powder in the dielectric medium.

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