

Analysis of the influence of parameters of EDM of EN-24 for Material Removal Rate and Tool Wear Rate

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ABSTRACT: EDM is a non-contact technique of material removal and utilizes sparks from the electrode to remove the material from the work piece. Since the introduction of the process EDM has evolved as an attractive means of making tool and dies for micro scale parts with a highest degree of dimensional accuracy and surface finish quality. The current study on EDM is performed for EN-24 as work piece and copper as tool to establish the influence of EDM parameters on material removal rate and tool wear rate. The investigation concludes that both material removal rate and tool wear rate are majorly influenced by the peak current and pulse off time. Pulse on time was least influencing parameter for both performance measures.

KEYWORDS: EDM, MRR, TWR, EN-24

I. INTRODUCTION

Electrical discharge machining is basically electro-thermal non-traditional material removal process which is widely use to produce dies, punches, moulds, finishing parts for aerospace and automotive industry, nozzles, machining of ceramics and composites and surgical components. The energy is created between a work piece and an electrode submerged in a dielectric fluid with the passage of electric current. A necessary condition for producing a discharge is ionization of dielectric. Suitable voltage is applied and intensity of dielectric field between them builds up. The electrons break loose from the surface of cathode and are impelled towards the anode under field forces. While moving, the electrons collide with the neutral molecules of dielectric and causes ionization. When this happens, there is an avalanche of electrons flowing towards anode, resulting in a discharge of energy which is seen as spark. The discharge leads to the generation of extremely high temperature causing fusion of the metal and the dielectric fluid at the point of discharge. The metal in the form of liquid drops is dispersed into space surrounding the electrodes by the explosive pressure of gaseous product in the discharge. The continuous flushing of the dielectric is necessary for efficient removal of debris.

In an investigation conducted by Deepu P.Nair et al [1] of surface characteristics of M300 Steel concluded that the parameter current was found to be the most effective on the surface roughness followed by the voltage and pulse on time. Another investigation conducted by George et al [2] optimized the machining parameters in the EDM machining of C-C composite using Taguchi method. The process variables affects electrode wear rate and MRR, according to their relative significance, are gap voltage, peak current and pulse on time respectively. S. Ben Salem et al [3] conducted experiments by experimental design methodology and found that a fewer number of experiments are required to find optimum result and the surface roughness equation shows that the current intensity is the main influencing factor on roughness.

In a research carried out by V. Chandrasekaran et al [4] on WC/5ni Composites Using Response Surface Methodology concluded that the MRR is maximum for all compositions. As the percentage of nickel increases the thermal conductivity of the composition increases since the nickel material is easily

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removed from the surface of the parent material. So the MRR increases with percentage of nickel. The surface roughness increases with increase in current and flushing pressure irrespective of %Ni. The optimum Ra values decreased with increasing electrode rotation. Francesco Modica et al [5] aimed of investigation to shed a light on the relation and dependence between the material removal process, identified in the evaluation of material removal rate (MRR) and tool wear ratio (TWR), and some of the most important technological parameters (i.e., open voltage, discharge current, pulse width and frequency), in order to experimentally quantify the material waste produced and optimize the technological process in order to decrease it. Kumar Sandeep [6] studied aspects related to surface quality and metal removal rate which are the most important parameters from the point of view of selecting the optimum condition of processes as well as economical aspects. It reported the research trends in EDM.

Lau et al [7] stated the feasibility of using Electrical Discharge Machining (EDM) as a means of machining carbon fiber composite materials. Machining was performed at various currents, pulse durations and with different tool materials and polarities and they concluded that it is entirely feasible machine carbon fiber composite materials by EDM process. Copper electrodes prove to be better than graphite electrodes in terms of tool wear and surface finish. Positive polarity should be used for machining carbon fiber composite materials in order to achieve a low tool wear ratio. Amoljit S Gill et al [8] carried experiment on En31 with Cu-Cr-Ni Powder Metallurgy Tool and found that peak current is the most contributing parameter towards surface roughness. Navdeep Malhotra et al [9] surface roughness of EN-31 Die Steel found that the current and pulse on time have maximum influence on surface roughness. Lower the value of current better the surface finish and same effect in case of pulse on time. H.T. Lee [10] found the relationship between the EDM parameters and surface cracks formation on the basis of discharge current and pulse on time parameters for EDM machining of D2 and H13 tool steel and concluded that surface roughness increases when pulse on time and pulse current increases. He also found that increased pulse-on duration will increase both the average white layer thickness and also the induced stress. These two conditions tend to promote crack formation.

II. EXPERIMENTAL DETAILS

Work piece: EN-24 of 10 mm thickness and 8 mm diameter.

Tool Material: Copper of 20 mm length and 3 mm diameter.

Taguchi approach is applied which is a powerful tool for design of experiments and is very effective in dealing influence of responses for multi-variables. It is a simple, effective and systematic approach for finding the optimum level of machining parameters.

The present investigation is performed by varying peak current, pulse off time and pulse on time so as to observe their influence on material removal rate and tool wear rate.

Table 1: The levels of EDM parameters

Parameters	Unit	Levels
Peak Current (I_p)	A	1 4 7
Pulse on Time (T_{on})	μ sec	10 15 20
Pulse off Time	μ sec	20 40 60

III. RESULTS AND DISCUSSIONS

3.1 Material Removal Rate

The rate of material removal from the work piece is known as material removal rate. Some material is melted and then evaporated according to process parameters of electrical discharge machine during machining. The investigation for material removal rate is as follows.

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Table 2: Calculation of mean S/N ratio for MRR

Level	Ip	Ton	Toff
1	-16.625	-14.775	-7.439
2	-3.290	-2.999	-7.863
3	-2.111	-4.252	-6.723
Delta	14.514	11.776	1.140
Rank	1	2	3

The analysis of variance for MRR is illustrated in Table 3. It depicts that peak current is the major influencing factor for MRR with 45.18% contribution while pulse on time is the second most dominating parameter with a contribution of 37.49%. Pulse off time has the least affect on MRR.

Table 3. ANOVA for MRR

Source	DOF	SS	Adj MS	F Value	Contribution
Ip	2	1.0741	0.5371	2.79	45.18%
Ton	2	0.8913	0.4456	2.31	37.49%
Toff	2	0.0265	0.0132	0.07	1.11%
Error	2	0.3854	0.1927		16.22%
Total	8	2.3773			100%

Figure 2 presents the mean effect plot for MRR. It shows that the MRR increases with both peak current and pulse on time. Initially MRR increases at a faster rate with current but with further increase in current, the pace slows down. Moreover, with increase in level of pulse on duration the MRR increases but the trend changes on higher level and the MRR starts to degrade. This is due to the fact that there is lesser time for removal of the debris from the gap and hence the effectiveness of sparks is reduced.

Pulse off time is the least influencing parameter for MRR and has only 1.11% contribution.

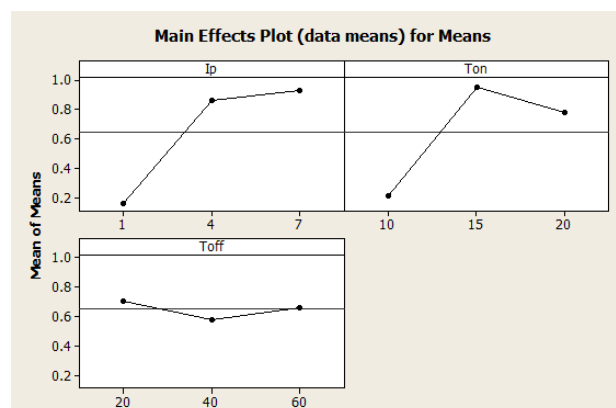


Figure 2. Main Effect Plot For Means For MRR

Figure 3 illustrates the interaction plot between MRR and pulse on time at different levels of peak current. The plot elucidates that the material removal rate increases with EDM parameters at initial two levels. But at higher value of peak current, the MRR tends to get reduced with increase in the value of pulse on duration.

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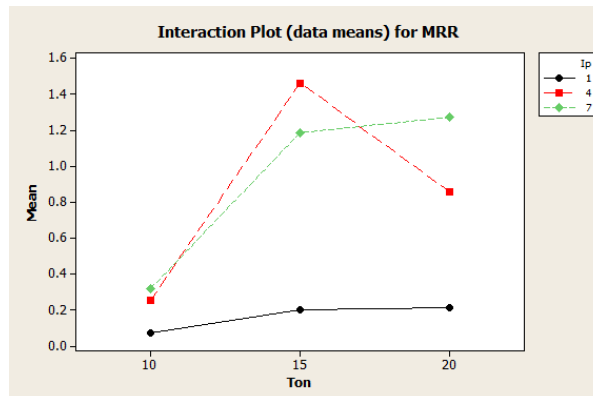


Figure 3. Relation between MRR and EDM parameters

3.2 Tool Wear Rate

In The rate of tool wear from the tool used to machine the work piece is known as tool wear rate. Some material is melted and then evaporated according to process parameters of electrical discharge machine during machining. The investigation carried out for tool wear rate is as follows.

Table 4. Calculation of mean S/N ratio for TWR

Level	Ip	Ton	Toff
1	43.22	35.49	29.24
2	26.13	29.55	30.61
3	24.23	28.54	33.73
Delta	18.98	6.95	4.49
Rank	1	2	3

From ANOVA Table 5 it is clear that current is the most significant factor for TWR with 56.31% contribution where as pulse on time is found to be the second most influencing parameter with a contribution of 27.81%. Pulse off Time is observed to be least effecting for TWR with only 8.65% contribution.

Table 5. ANOVA for TWR

Source	DOF	SS	Adj MS	F Value	Contribution
Ip	2	0.0067	0.00335	7.80	56.31%
Ton	2	0.0033	0.00165	3.85	27.81%
Toff	2	0.0010	0.0005	1.20	8.65%
Error	2	0.0009	0.00045		7.23%
Total	8	0.0119			100%

In figure 4 it is depicted that the tool starts to degrade with increase in levels of peak current and pulse on time while with pulse on time reverse trend is followed. Since peak current and pulse on time are the most dominating parameters, hence the plot obtained for them are linear line that are showing increasing trend. On the other hand, the curve obtained for pulse off time is a linear line which is presenting a declining trend.

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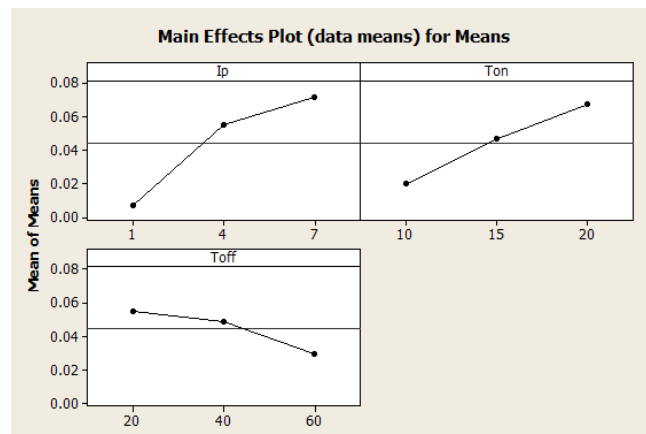


Figure 4: Main Effect Plot For Means For Surface Roughness

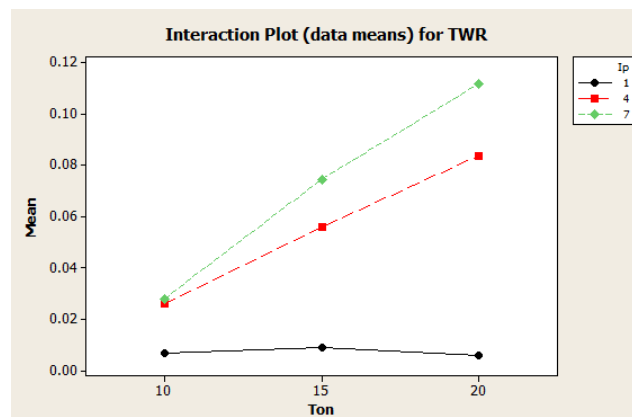


Figure 5: Relation between Surface Roughness and WEDM parameters

Figure 5 depicts the interaction plot between tool wear rate and pulse on time at constant level of peak current. It is found that at initial level of current, the curve obtained for TWR with pulse on duration is almost flat. While increasing the value of peak current, it is found that TWR tends to increase with pulse on time. This is because high heat and intense energy generation within the zone of machining that leads to wearing of the tool material.

IV. CONCLUSIONS

The present analysis carried out on EN-24 using copper as tool to find the relation between the parameters of EDM with MRR and TWR has following conclusions:

1. Peak current and Pulse on time are the major influencing parameters for MRR. On the other hand, pulse off time has almost negligible influence on MRR.
2. Heat generated and intensity of spark energy are mainly responsible for influencing the MRR and TWR. Higher level of EDM parameters creates high heat and high intensity of spark.
3. TWR is also influenced mainly by peak current and pulse on time. A minute influence of Pulse on time on surface roughness. On the other hand, pulse off time was observed on TWR.

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