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Experimental Investigation for Optimizing EDM Parameters for Die Steel D3 to analyze MRR, TWR and Radial Overcut

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Abstract: EDM is a non-contact machining process that is used to machine hard materials that are difficult to work by other conventional processes. Due to the advancement in production, EDM is used widely in all industries. The present research conducted on Die Steel D3 using copper as tool for establishing the relation between EDM parameters and performance measure. Peak current, pulse on time and pulse duty factor were selected as EDM parameters whose influence was assessed on material removal rate, tool wear rate and radial overcut. The results revealed that peak current is the major influencing parameter for material removal rate and radial overcut while pulse on time is the most dominating factor for tool wear rate. Voltage is found to be the least influencing parameter for all the performance measures.
Keywords: EDM, MRR, TWR, Die Steel D3, Radial Overcut

I. INTRODUCTION

EDM is achieved by a discharge taking place between two closest points tool and workpiece. The discharge creates intense heat near the zone which melts and evaporates the materials. To improve the effectiveness of the process, the setup of workpiece and the tool are immersed in dielectric fluid (EDM oil). If both the electrodes are made of same material, the electrode connected to positive terminal erodes at a faster rate as compared to the one connected to the negative lectrode. Hence the workpiece is made the anode. A suitable gap, called spark gap, is maintained between the tool and the workpiece surfaces. Spark occurs at the point at which the tool and the workpiece are the closest and since the point changes after each spark, the spark travels all over the workpiece surface. Hence uniform material removal all over the surface is achieved, and finally workpiece conforms to the shape of tool.

A study conducted was by Subramanian Gopalakannan and Thiagarajan Senthilvelan [1] to find the effect of pulsed current on material removal rate, electrode wear, surface roughness and diameteral overcut for corrosion resistant stainless steels. The material was machined with different electrode materials such as Cu, Cu-W and graphite. It was seen that the output performance parameters such of EDM increase with pulsed current. The results show that higher material removal rate was achieved while using copper electrode whereas for copper-tungsten, it yielded lower electrode wear, smoother surface finish and good dimensional accuracy.

The study of Pravin R. Kubade and V. S. Jadhav [2] investigated the influence of EDM parameters on EWR, MRR and ROC while machining of AISI D3 material with a copper electrode. The parameters considered were pulse-on time (Ton), peak current (Ip), duty factor (t) and gap voltage (Vg). It is concluded that the MRR is majorly influenced by peak current while the other factors have very less influence on material removal rate. Electrode wear rate is majorly dominated by peak current and pulse on time, whereas duty cycle and gap voltage has very less influence on electrode wear rate. Peak current is the most influencing parameter for radial overcut followed by duty cycle and pulse on time with almost negligible influence by gap voltage.

For studying the dominance of process parameters and electrode shape and design configuration on the machining characteristics like surface quality, material removal rate and electrode wear Shishir Mohan Shrivastava and A.K. Sarathe [3] conducted investigation and found better machining performance was obtained generally with the electrode as the cathode and the work-piece as an anode and it was observe that for high MRR main process parameters are peak current, pulse on time ,pulse off time, whereas for electrode wear were mainly influenced by peak current and pulse on time. Surface quality was mainly influenced by peak current. For tool shape configuration, concerned best tool shape for best MRR and lowest TWR is circular, followed by square, triangular, rectangular, and diamond cross sections.

In a research, Abhishek Gaikwad, Amit Tiwari, Amit Kumar and Dhananjay Singh [4] studied the effect of control factors (i.e., current, pulse on time, pulse off time, fluid pressure) for maximum material removal rate (MRR) and minimum electrode wear rate (EWR) for EDM of hard material Stainless steel 316 with copper as cutting tool electrode. The electrical factors and non electrical factors were focused by the researchers which governs the MRR and the TWR. The paper is based on DOE and for optimization of

EDM process parameters. Taguchi technique is used for the work which is a statistical decision making tool and helps in reducing the number of experiments and the error associated with it. The research concluded that the pulse off time, current have significant influence on material removal rate and electrode wear rate respectively.

In an investigation conducted by Y. H. Guu [5] of surface characteristics of Fe-Mn-Al alloy analyzed by means of the atomic force microscopy (AFM) technique and concluded that the higher discharge energy caused more frequent melting expulsions, leads to deep and large crater formation on surface of work, resulting in a poor surface finish.

Another investigation conducted by George et al [6] optimized the machining parameters in the EDM machining of C-C composite using Taguchi method. The process parameters influence electrode wear rate and MRR, according to their relative significance, are selected as gap voltage, peak current and pulse on time respectively. C.H. Cheron [7] machined XW42 tool steel and concluded that material removal rate with Cu electrode is greater than graphite electrode. He also concluded that Cu is suitable for roughing surface while graphite is suitable for finishing surface.

A similar study was conducted by Ahmet Hascalık and Ulas¸ Caydas [8] using parameters such as pulse current and pulse duration and concluded that electrode material has an obvious effect on the white layer thickness, the material removal rate, surface roughness and electrode wear are increasing with process parameters.S. Ben Salem et al [9] 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 [10] 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 removed from the surface of the parent material. Hence the MRR increases with increase in percentage of nickel. The surface roughness also increases with current and flushing pressure irrespective of the percentage of Nickle. The optimum Ra values decreased with increasing electrode rotation. Francesco Modica et al [11] carried experiments for investigation to throw light on the relationship and dependence between the material removal process, identified in the evaluation of material removal rate (MRR) and tool wear ratio (TWR), and important technological parameters that are open voltage, discharge current, pulse width and frequency, so as to experimentally quantify the material waste produced and for optimizing the technological process in order to decrease it. Kumar Sandeep [12] investigated the aspects related to the surface quality and metal removal rate that are the most important parameters from the point of view for selecting the optimum level condition of processes and with the economical aspects. It reported the current research trends in EDM process.

Lau et al [13] 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 are found to be better than graphite electrodes for tool wear and surface finish. Positive polarity should be considered for machining carbon fiber composite materials so as to achieve a low tool wear ratio.

II. DESIGN OF EXPERIMENT AND EXPERIMENTATION

1) *Machine:* ELECTRONICA ZNC EDM machine available at Dilawar Engineering Works, Lucknow.
2) *Workpiece:* Die Steel D3 of 8mm thickness and 10mm diameter.
3) *Tool:* Copper of 25mm length and 5mm diameter.
4) *Factors Under Consideration:* Peak current, Pulse on time and Pulse duty factor.
5) *Performance Measures:* Material Removal Rate, Tool Wear Rate and Radial Overcut.
6) *DOE Technique:* Taguchi Approach with L9 orthogonal array.

The parameters selected for present research are peak current, pulse on time and pulse duty factor and the performance measures are material removal rate, tool wear rate and radial overcut. As discussed earlier, the experiments were designed on the basis of Taguchi L9 orthogonal array and the experiments were performed accordingly. Scanning electron microscopy was performed to estimate the radial overcut of the EDM machined hole. The following table 1 shows the set of parameters with their levels.

TABLE I: EDM PROCESS PARAMETERS AND THEIR LEVELS

S.No.	Parameters	Units	Level 1	Level 2	Level 3
1	Peak Current	A	2	5	8
2	Pulse-on-time	µsec	10	15	20
3	Pulse duty factor	τ	5	7	9

Fig. 1 Setup of EDM for experiments

TABLE I: EXPERIMENTAL VALUES OF MATERIAL REMOVAL RATE, TOOL WEAR RATE AND RADIAL OVERCUT

Exp. No	Peak Current	Pulse on Time	Pulse duty factor	Material Removal Rate (mm³/min)	Tool Wear Rate (mm³/min)	Radial Overcut (ROC) (mm)
1	2	10	5	0.205	0.060	0.113
2	2	15	7	0.267	0.078	0.124
3	2	20	9	0.598	0.394	0.131
4	5	10	7	0.532	0.156	0.137
5	5	15	9	0.669	0.392	0.146
6	5	20	5	1.473	1.294	0.152
7	8	10	9	0.970	0.213	0.161
8	8	15	5	0.965	0.283	0.169
9	8	20	7	2.145	1.413	0.178

III.RESULTS AND DISCUSSION

A. Material Removal Rate

The rate of material removed from the surface of workpiece is analysed by initially noting the weight of work specimen before and after machining. Further the machining time is noted for each specimen. Using the following relation, the material removal rate is calculated for each specimen which is tabulated in table II above.

$$Material\ Removal\ Rate = \frac{Workpiece\ weight\ loss\ (gms) \times 1000}{Workpiece\ density\ \left(\frac{gm}{cm^3}\right) \times Machining\ time\ (minutes)}$$

ANOVA was performed and is tabulated in table III. ANOVA reveals that the major influencing parameter for material removal rate are peak current and pulse on time with a contribution of 49.70% and 42.69% respectively while the pulse duty factor has negligible influence on material removal rate and imparts a contribution of only 2.76%.

TABLE III: ANOVA for MRR

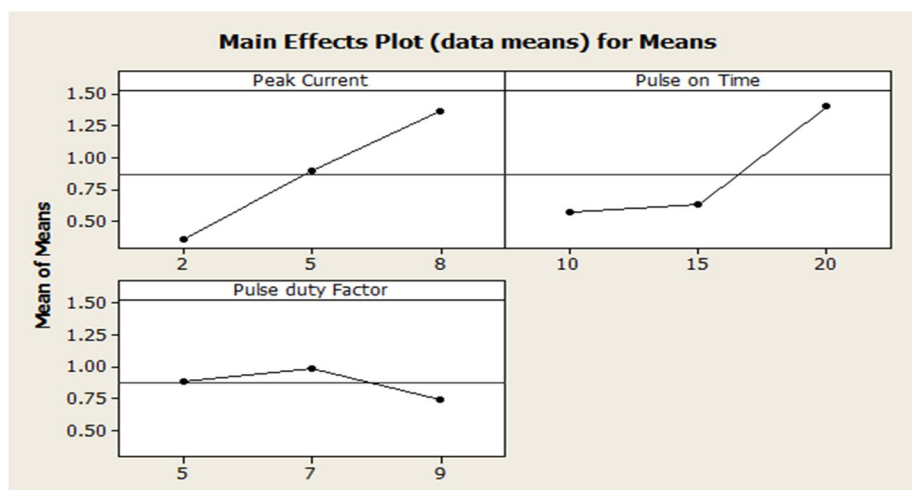| Source	DOF	SS	Adj MS	F Value	Contribution
Current	2	1.51219	0.75610	10.25	49.70%
Pulse on Time	2	1.29910	0.64955	8.81	42.69%
Pulse duty factor	2	0.08392	0.04196	0.57	2.76%
Error	2	0.14750	0.07375		4.85%
Total	8	3.04272			100 %

Fig. 2 Main effect plot for MRR

The figure 2 above presents the mean effect plot for MRR. It shows that the MRR increases with both peak current and pulse on time. It is observed that both these factors have major dominance on MRR. This is because of the intensity of sparks and high discharge energy obtained at higher levels of parameters. Further it is observed that with increase in the level of peak current and pulse on time, the MRR follows an increasing trend. This is because the intensity of sparks is more at higher level of parameters and hence MRR value increases.

Pulse duty factor is the least influencing parameter for MRR and has only 2.76% contribution. It is observed from the graph that MRR tends to increase and then decrease with increase in pulse duty factor.

B. Tool Wear Rate

The rate of tool material removed from the surface of tool is analysed by initially noting the weight of tool specimen before and after machining. Further the machining time is noted for each specimen. Using the following relation, the tool wear rate is calculated for each specimen which is tabulated in table II above.

$$Material\ Removal\ Rate = \frac{Tool\ weight\ loss\,(gms) \times 1000}{Tool\ material\ density\ \left(\frac{gm}{cm^3}\right) \times Machining\ time\ (minutes)}$$

ANOVA was performed and is tabulated in table IV. ANOVA reveals that the major influencing parameter for tool wear rate is pulse on time with a contribution of 67.46% and peak current is the second most dominating parameter for tool wear rate with a contribution of 19.12%. The pulse duty factor has negligible influence on tool wear rate and imparts a contribution of only 4.38%.

TABLE IV: ANOVA for TWR

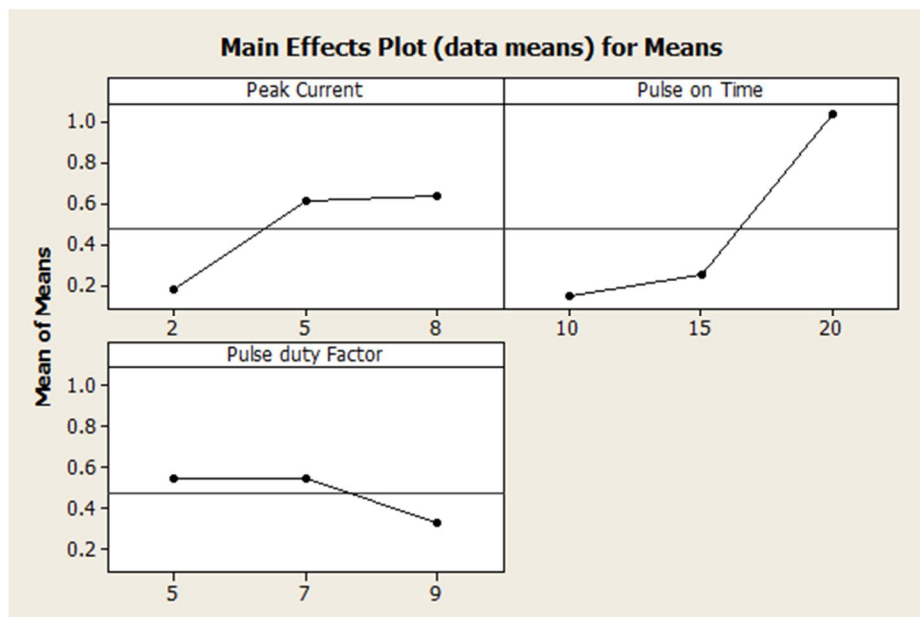| Source	DOF	SS	Adj MS	F Value	Contribution
Current	2	0.40186	0.20093	2.12	19.12%
Pulse on Time	2	1.41752	0.70876	7.47	67.46%
Pulse duty factor	2	0.09189	0.04595	0.48	4.38%
Error	2	0.18988	0.09494		9.04%
Total	8	2.10115			100%

Fig. 3 Main effect plot for TWR

The figure 3 above illustrates that the tool starts to degrade with increase in levels of peak current. With further increase in peak current, the TWR is almost constant. With pulse on time, initially TWR increases at a slower pace but with increase in Ton, the TWR increases drastically. With pulse off time, the TWR curve initially is observed to be almost flat. With increase in pulse off time from 7 to 9 μsec, the TWR tends to get reduced.

Pulse on time is the major influencing parameter for tool wear rate with a contribution of 67.46%.

C. Radial Overcut

The Radial Overcut in EDM is a defect of machining caused by sparks striking the circumference of the machined hole. These sparks will increase the diameter of the machined hole as compared to diameter of the tool. The radial overcut is measured through scanning electron microscopy. The figure 4 shows SEM image of sample 1 and sample 9 after machining of the hole.
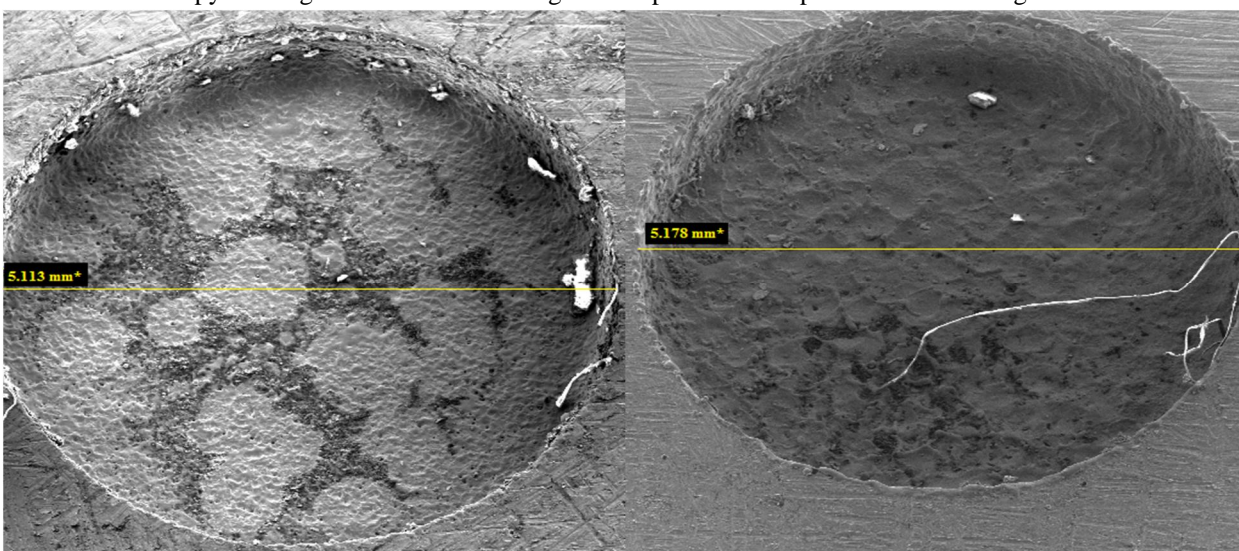

Fig. 4 SEM image of machined sample 1 and sample 9 for Radial Overcut

ANOVA was performed and is tabulated in table V. ANOVA reveals that the major influencing parameter for Radial Overcut is peak current with a contribution of 86.93% while pulse on time and pulse duty factor has negligible influence on Radial Overcut and imparts a contribution of only 11.93 and 0.50% respectively.

TABLE V: ANOVA for Radial Overcut

Source	DOF	SS	Adj MS	F Value	Contribution
Peak Current	2	0.0023647	0.0011823	131.37	86.93%
Pulse on Time	2	0.0003247	0.0001623	18.04	11.93%
Pulse duty Factor	2	0.0000127	0.0000063	0.70	0.50%
Error	2	0.0000180	0.0000090		0.64%
Total	8	0.0027200			100%

Fig. 5 Main effect plot for Radial Overcut

The above graph shows the effect of input parameters on Radial Overcut. By increasing the peak current and pulse on time, the Radial Overcut increases and the hole size start to increase. Peak current is the most dominating factor for Radial Overcut with a contribution of 86.93% and has major influence on it. Higher intensity sparks are generated at higher levels of peak current, hence influence of peak current is highest and Radial Overcut increases with increase in the value of peak current. Pulse on time is found to be the second most dominating parameter for Radial Overcut with a contribution of 11.93%. Pulse duty factor plot is almost flat and has negligible influence on Radial Overcut and has a contribution of only 0.50%.

IV. CONCLUSIONS

This experimental study was conducted to optimize the input machining parameters in Electrical Discharge Machining of Die Steel D3 using copper electrode with L9 orthogonal array of Taguchi method. Current, Pulse on Time and Pulse duty Factor were selected as input machine parameters which are varied to find their interactions with performance measures. The results show the performance of parameters at different levels for optimizing the MRR, TWR and Radial Overcut of Die Steel D3. Following conclusions are made from the investigationexperimental study:

A. MRR increases with both peak current and pulse on time. It is observed that both these factors have major dominance on MRR. This is because of the intensity of sparks and high discharge energy obtained at higher levels of parameters.
B. Pulse duty factor is the least influencing parameter for MRR and has only 2.76% contribution. It is observed from the graph that MRR tends to increase and then decrease with increase in pulse duty factor.
C. The tool starts to degrade with increase in levels of peak current. With further increase in peak current, the TWR is almost constant. With pulse on time, initially TWR increases at a slower pace but with increase in Ton, the TWR increases drastically.
D. With pulse off time, the TWR curve initially is observed to be almost flat. With increase in pulse off time from 7 to 9 µsec, the TWR tends to get reduced.
E. Pulse on time is the major influencing parameter for tool wear rate with a contribution of 67.46%.

F. The peak current and pulse on time are major influencing factors for Radial Overcut and it increases with the increase in the level of parameters.

G. Peak current is the major dominating factor for Radial Overcut with a contribution of 86.93% and has major influence on it. Higher intensity sparks are generated at higher levels of peak current, hence influence of peak current is highest and Radial Overcut increases with increase in the value of peak current.

H. Pulse on time is found to be the second most dominating parameter for Radial Overcut with a contribution of 11.93%. Pulse off time plot is almost flat and has negligible influence on Radial Overcut and has a contribution of only 0.50%.

REFERENCES

[1] Subramanian Gopalakannan and Thiagarajan Senthilvelan "Effect of Electrode Materials on Electric Discharge Machining of 316 L and 17-4 PH Stainless Steels" Journal of Minerals and Materials Characterization and Engineering, 2012, 11, 685-690.

[2] Pravin R. Kubade and V. S. Jadhav "An Experimental Investigation of Electrode Wear Rate (EWR), Material Removal Rate (MRR) and Radial Overcut (ROC) in EDM of High Carbon-High Chromium Steel (AISI D3)" International Journal of Engineering and Advanced Technology (IJEAT) ISSN: 2249 – 8958, Volume-1, Issue-5, June 2012.

[3] Shishir Mohan Shrivastava and A.K. Sarathe "Influence of Process Parameters and Electrode Shape Configuration On Material Removal Rate, Surface Roughness And Electrode Wear In Die Sinking EDM: A Review" International Journal of Emerging Technology and Advanced Engineering Volume 4, Issue 4, April 2014.

[4] Abhishek Gaikwad, Amit Tiwari, Amit Kumar and Dhananjay Singh, "Effect of EDM parameters in obtaining maximum MRR and minimum EWR by machining SS 316 using Copper electrode" International Journal of Mechanical Engineering and Technology (IJMET) ISSN 0976.

[5] Y.H. Guu and Max Ti-Quang Hou, "Effect of machining parameters on surface textures in EDM of Fe-Mn-Al alloy" Material Science and Engineering A 466 (2007) 61-67.

[6] PP.M. George, B.K. Rahunath, L.M. Manocha and Ashish M. Warrier, "EDM machining of carbon composite a Taguchi approach", Journal of Material Processing Technology 145(2004) 66-71.

[7] C.H. Cheron, J.A Ghani, Y.K. Seong and C.Y. Swee, "Copper and graphite electrodes performance in electrode discharge machining of XW42 tool steel" journal of materials processing technology (2008).

[8] Ahmet Hascalık and Ulas Caydas "Electrical discharge machining of Titanium alloy (Ti–6Al–4V)" Applied Surface Science 253 (2007) 9007–9016.

[9] S. Ben Salem , W. Tebni , E. Bayraktar, "Prediction of surface roughness by experimental design methodology in Electrical Discharge Machining (EDM)", Journals of Achievements in Materials and Manufacturing Engineering Volume 49 Issue 2 December 2011.

[10] V. Chandrasekaran, D. Kanagarajan, R. Karthikeyan, "Optimization of EDM Characteristics of WC/5ni Composites Using Response Surface Methodology", International Journal of Recent Technology and Engineering (IJRTE) ISSN: 2277-3878, Volume-2, Issue-5, November 2013.

[11] Francesco Modica, Valeria Marrocco, Giacomo Copani and Irene Fassi Sustainability 2011, *3*, 2456-2469; Sustainable Micro-Manufacturing of Micro-Components via Micro Electrical Discharge Machining.

[12] Kumar Sandeep, Research Journal of Engineering Sciences Volume 2(2), 56-60, February (2013) "Current Research Trends in Electrical Discharge Machining".

[13] W.S. Lau, M. Wang and W.B. Lee, "Electric discharge machining of Carbon fiber composite materials" Int. J. Machine Tools Manufacture. Volume 30, No. 2, pp.297-308, 1990.

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