To Investigate Electrode Wear Rate on Steel Material with Different Parameters on EDM Machine

Avinash Sarode, A.J.Parmar, Snehal Junnarkar

Department of Mechanical Engineering, University of Mumbai, Lokmanya Tilak College of engineering, Koparkhairane, Navi Mumbai, India

Abstract—*The studies of an experimental investigation evaluate the effects of EDM machining parameters such as MRR, EWR with two different electrode materials. The process parameters such as Input current, Pulse on time and duty cycle keeping flushing pressure constant. With the use of Design of Experiment The full factorial design of experiment* $(L2)^4$ *is used to study the effects of machining parameters on die steel material. Investigations selected the machine* **Model Electra plus leader-1-znc** *Electra machine, through practical, investigation the output parameters of EDM increases with the increase in input current and the best machining rates are achieved with copper electrodes, better surface roughness compare to brass electrode. A brass electrode with higher input current and maximum pulse on time resulted in more EWR compared to copper electrodes.*

Keywords— Electrode Wear Rate, Steel Material , EDM.

I. INTRODUCTION

ELECTRICAL DISCHARGE MACHINE

Electrical discharge machining (EDM) is used for manufacturing process during complicated work and precision results. The material is removed with the erosive effect of the electrical discharge channel. The work-piece material removed in the form of crater and tool material removed in the form of debris at the melting temperature. During process higher temperature is controlled by dielectric fluid. During the process work piece material as well as electrode material is removed. To know the EWR during EDM process used four different parameter, and Brass as well as Copper electrode, output of EWR measured with the use of ANOVA.

OBJECTIVES OF WORK

Objectives of the project for used steel material are as follows, 1) To examine the Electrode wear rate, influence of process parameters such as Electrical Parameter, input current, pulse on time and duty cycle, 2) To investigate which Electrode give maximum MRR and minimum wear by using Copper and Brass electrode.3) To compare MRR and EWR by using copper and Brass electrode on die steel material using ANOVA.

Fig.1:Electronica, Model Electra plus leader-1-znc

APPLICATIONS

Main applications of EDM are Tool room work, metal cutting dies, injection and blow molding dies, automobile and aerospace applications. An essential requirement of the aerospace applications those grooves are thin, complex and demands higher dimensional stability. EDM is mainly used to machine, difficult materials and high strength temperature resistant alloys.

II. LITERATURE REVIEW

Die steel and steel has wide range of physical and Mechanical properties which are available in the Indian market depending on their Carbon percentage. Liao et al. had given details about electrical discharge machining (EDM) as a well established non-conventional machining option for manufacturing electrically conductive and geometrically complex or hard material parts. [1] Singh and Ghosh, showed that the electrostatic forces and stress distribution acting on cathode electrode are the major causes of metal removal for shot pulses. In addition, reverse polarity of sparking alters the material removal phenomenon with an appreciable amount of electrode material depositing on the work-piece surface.[2] Lee L.C.and Lim L.C. have reviled to get quality surface finish the spark should have minimum voltage as well as minimum gap between electrode and work piece. When the electrode is close to the work piece the electrostatic force between the anode and cathode will increase. This attractive force will increase deflection making bigger sparks and produces bigger crater causing increase in the surface roughness.[3] Moroa et al. (1998) did surface roughness and micro crack analysis of AISI 1045 steel with both copper and copper chromium composite electrode for positive as well as negative polarity machining.[4] Pawade and Brahmankar had shown the effect of electrode shape, where they used a cylindrical, reverse tee and dovetails Copper electrodes for experiments. The other parameters, electrode rotation and electrode shape have moderate influence on MRR. However, duty cycle has insignificant effect on MRR. The influence of EDM parameters, found from the main effects plots that at 8 Amp, the MRR is lowest. As the pulse current increases to 14 Amp, a sudden increase in the MRR is observed. Further increase in pulse current to 22 Amp produces higher MRR. It means MRR is high when the electrode is stationary. It is observed that pulse current and electrode shape have more significant influence on surface roughness. [5]Marafona et al. worked on Copper and Tungsten electrodes, the parameters such as discharge voltage, input current, duty cycle, During the EDM process, both tool and work piece undergo surface modification. Many researchers have looked at modification of the work piece, but few have examined modification of the tool. [6] Chen et al. showed that migration of elements from work piece to the tool electrode occurs using both high and low current intensities, [7] Some authors have claimed that most of the electrode wear is due to evaporation and fusion Eubank. However, it was pointed out that the EDM material removal is caused by violent explosion of the super-heated electrode as it melts from the melt cavities at the end for the machine pulse. Mohari and Pandey claim that carbon on the tool surface inhibits the wear of the tool electrode. [8]

III. EXPERIMENTAL SET UP

Input current	310 to 400 V.
Output Voltage	415 +/- 1% Phase to Phase.
Tolerance	+/- 15 V.
Correction range	35 Volt.
Frequency range	48 to 52 Hz
Work Table Dimension	550Max.350mm Min.
Traverses(x,y,z)	300,200,250 mm
Max. Job height	250
Pulse generator	550 znc
Pulse generator type	MOSFET
Max.MRR with Cu ele.	350 mm^3/min

The electric discharge machine (Make: Electronica, Model Electra plus leader-1-znc*)* which is showed in figure 1, with constant servo gap head facility was used for conducting the experiments. This experiment evaluate the detailed experimental study employed to determine the effect of Copper and Brass electrode of various mechanical and electrical process parameters; used on steel material for practical work. The machinability measured in terms of material removal rate (MRR), electrode wear rate. Electrical parameters used are Input current, pulse on time, duty cycle. Mechanical parameters used is cylindrical tool with constant flushing pressure. The experiments were planned using full factorial $L2^4$Design of Experiment that is 16 run and two replicates. Therefore, total 32 experiments.

Work piece material. Used steel material was selected as a work material. The sample was received in the form of late. The final dimensions made out of plate were 52 **x** 52 **x** 12 mm Hardness of material was HBW70 before hardening and HBW 265 after hardening.

Electrode material. Copper and Brass Electrode were used as a electrode material, copper is good conductor to thermal and electrical and is a pure material while brass is a composite material and it has lower melting temperature compare to copper. The experimental process is carried out to select which is the best electrode material for EDM machining work.

Electrode material **Copper and Brass**
Tool shape **Cylindrical shape**
Density **1400 m/ unit volumetric**
Hardness **17 BHN for Cu**

PROCESS PARAMETERS

Used three electrical parameters and two mechanical parameters for practical work with minimum and maximum level, which are as follows,

Table 1

Control Factors	Parameter	Level-I	Level-II
A	Pulse Current Ip(Amps)	5	25

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B	**Pulse on Time Ton**	**50**	**100**
C	**Duty Cycle %**	**4**	**12**
D	**Electrode Type**	**Cu**	**Brass**

Material Removal Rate (MRR)

Material Removal Rate is the material removed in a given amount of time. It is formulated as below and is expressed in mm^3/min. or grams per minute. Generally, material removal rate is increased with intensity of current and this causes more surface damage in the machine surfaces. The MRR can calculated as,

$$MRR = W_{wb} - W_{wa} / t_m \qquad (1.1)$$

Electrode Wear Rate. Electrode wear rate affects the dimensional accuracy of machined component. It can be calculated by the ratio of weight difference of the sample and electrode before and after the EDM process to the machining time. Tool (electrode) wear rate is expressed as,

$$EWR = W_{tb} - W_{ta} / t_m \qquad (1.2)$$

MEASUERMENTS AND RESULTS

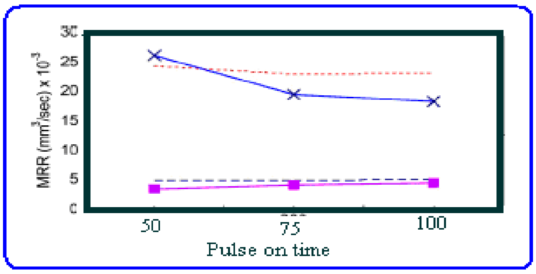

Fig.2: Results

(MRR – Other parameter - Ton)

MRR = 0.010026 - 0.000284805(Dcy) + 0.00662781(Ele.Geo.) + 0.00215969(Ele. Type) + 0.000123891(Ip) - 0.0000115562(Ton)

Analysis of variance for MRR

For this purpose a statistical software Minitab was used. In this experiment, each effect having P-value less than 0.05 is considered as significant for 95% confidence interval. All the effect with P-value together greater than 0.05 are non significant and therefore is discarded. It is observed from ANOVA that pulse on time tool type and tool geometry is most significant factor for all responses.

Effect of current on MRR, MRR increases with an increase in the input current from 5 to 25 Amperes. Since increasing the input current would increase the discharge energy of a single discharge, the discharge craters generated on machined surface became larger and surface quality becomes rough and resulted in increase of MRR.

The effect of Pulse on time on MRR. Here the increase of pulse on time gives reverse result, as in the low level of 50 τ_{on} pulse off time is more and at higher level 100 τon reduces the pulse off time. Material removal rate becomes low because of long idle time and very short spark time which creates problem for flushing of crater and debris. Also at low level carbon particles stuck on the face of the electrode which causes minimization of MRR.

The effect of Duty Cycle on MRR During the process at low level 4 % Duty Cycle MRR decreases while at high level at 12% Duty Cycle it will not make much difference on MRR. The main reason behind this is pulse off time is less at high duty cycle. At high level of duty cycle the developed Carbon is stuck on the face of the electrode which causes direct contact between work piece and electrode; As a result it reduced MRR causes more Carbon, which makes dielectric fluid dirty.

Table 2: Analysis of Variance for EWR

Source	Sumof Squares	d.f.	Mean Square	F-Ratio	P-Value	Rank
A :Input Curr.	0.00006	1	0.00006	0.31	0.5807	
B:Pulseon Time	0.0012	1	0.0012	5.60	0.022	4
C: Duty Cycle	0.0001	1	0.0001	0.49	0.488	
D: Ele. Type	0.00003	1	0.0000	0.14	0.7117	
E:Ele.	0.0015	1	0.0015	6.87	0.0118	3
AB	0.00023	1	0.0002	1.03	0.3159	
AC	0.00004	1	0.00004	0.20	0.6596	
AD	0.00019	1	0.0001	0.84	0.3628	
AE Ip+Tool	0.00348	1	0.0034	15.43	0.0003	1
BC	0.00001	1	0.00001	0.05	0.8226	
BDTon+T. type	0.0019	1	0.0019	8.68	0.0050	2
BE	0.00014	1	0.0001	0.64	0.4292	
CD	0.00026	1	0.0002	1.17	0.2841	
CE	0.00016	1	0.0001	0.72	0.4002	
DE	0.00011	1	0.0001	0.50	0.4817	
Blocks	0.00001	1	0.00001	0.01	0.9361	
Total error	0.01062	37	0.0002			
Total (corr.)	0.02026	63				

The effect of input current, As per table-2 5 Amp. of current, EWR is less than 25-Amp. of Current. Because as the current decreases it decreases its density and same way the spark will also decreases and it minimize EWR. Here

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the main reason for low level improvement of EWR because at low level die steel will not melt as fast as high level current.

The effect of Pulse on time on EWR, As per Figure during the process as it proves by the graph that at low level 50 τ_{on}, EWR is low and at high level 100 τ_{on}. it increases EWR. As pulse on time increase it decreases pulse off time which significantly increases EWR.

The effect of duty cycle on EWR, As per Figure duty cycle at low level 4 % off time is more compare to high level which gives advantage to flush away all crater and debris, and minimize EWR. At high level it will not get enough time so certain impurities comes in between tool and work piece causes not much difference in EWR.

Effect of Electrode material on EWR, As per Figure Pure Copper electrode is a good conductor of Current and heat, Brass is a composition of Copper and Zink. Causes compare Copper Brass loses its density because Zn has low melting temperature and die steel having high melting temperature which improves EWR.

Table.3: Estimated table for EWR

Effect	Estimate	Stnd. Error	V.I.F.	Rank
Average	0.0105	0.0010	1.0	
A:Inputcurr.	-0.0021	0.0020	1.0	
B:Pul. ontime	0.00066	0.0020	1.0	
C:DutyCycle	0.00139	0.0020	1.0	
D:Ele.Mate.	0.00130	0.0020	1.0	
E:Ele.Geom.	0.00663	0.0020	1.0	2
AB	-0.00004	0.0020	1.0	
AC Ip + Dcy	0.00782	0.0020	1.0	1
AD	-0.00291	0.0020	1.0	
AE	-0.0011	0.0020	1.0	
BC	0.0042	0.0020	1.0	3
BD	0.0018	0.0020	1.0	
BE	-0.0014	0.0020	1.0	
CD	-0.00450	0.0020	1.0	
CE	-0.00074	0.0020	1.0	
DE	0.00115	0.0020	1.0	
Block	0.00033	0.00209	1.0	

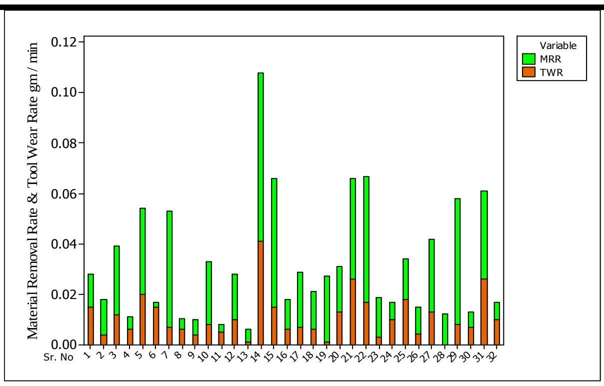

Fig.4.25:Bar chart of MRR & EWR

IV. CONCLUSIONS

During practical Investigation, designs of experiments were carried out to assess the effects of various process parameters on a die steelmaterial. To evaluate the desired objectives maximum material removal rate, minimum electrode wear rate were observed with following conclusions ;

a. Die steelmaterial have maximum MRR with Brass electrode.
b. Brass have maximum electrode wear rate.
c. Brass electrode produces poor surface finished and higher Carbon rate which makes dielectric fluid dirty.
d. Copper electrode MRR on die steel is limited but surface finished is better than brass electrode.
e. Copper electrode rate is minimum compare to Brass electrode.

V. FUTURE SCOPES

To improve MRR further scope for evolving electrode. Also chance for ultrasonic system used for to improve MRR.

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