To Examine the Effect of Process Parameter on Surface Roughness and Material Removal Rate in Electrical Discharge Machining

Er.Ram Bilash Kushwaha[1], Er.Vivek kumar[2], Er. Sushil kumar singh[3]

[1]*Assistant Professor, Mechanical Engineering Department,SSITM aligarh*

[2]*Assistant Professor, Mechanical Engineering Department, ACET Aligarh*

[3]*Assistant Professor,Mechanical Engg Department, Galgotias University greater Noida*

Abstract- **Electrical discharge machining is a process for capable of machining geometrically deep complex shaped holes and shaping hard metals by arc erosion in all kinds of electro conductive materials that are difficult to machine by any other non-traditional process. The objective of this project is to study the influence of operating parameter of EDM on machining characteristics such as surface quality, material removal rate and surface roughness of work piece produced. The thermal erosion theory is most accepted mathematical model for evaluating material removal during EDM process. The present works generate a thermal electrical model for spark generated by electrical discharge in liquid media and determine the temperature distribution of tool and work piece. For single discharge test, copper and En-19 is used as specimens. Better machining performance is obtained generally with the electrode as the cathode and work piece as anode. Study ware carried out on the influence of the parameter such as peak current in high temperature. Finite element method is used to solve the underlying governing equations. Material removal rate and maximum surface roughness are determined in varying condition of current.**

Index Terms- **EDM, parameters, electrode, cathode, anode, peak current, voltage.**

I. INTRODUCTION

In principle, EDM process is thermo-electric in nature and removes material from the work piece by series of discrete sparks between tool and work electrodes immersed in a dielectric medium. The electrode is moved towards the work piece until the gap is small enough to ionize the dielectric. Short duration discharges are generated in a liquid dielectric gap, which separates tool and work piece.

The material is removed with the erosive effect of the electrical discharges from tool and work piece. There is no direct contact between electrode and work piece which eliminate mechanical stresses, chatter and vibration problems during machining. Since erosion is produced by electrical discharges, both electrode and work piece have to be electrically conductive. In this process, the machining force is much smaller than that in cutting processes, because molten metal can be removed with a very small force. EDM uses electric energy by discharge which occurs as a result of dielectric breakdown between positive tool electrode and negative work piece. As tool electrode approaches to a work piece, the electric filed between tool and work piece is larger and larger. And then it comes to a point where a spark occurs. This is known as the fluid-ionization point and it is based on the dielectric strength of the fluid and the distance between the electrode and work piece. Dielectric fluid has non-conductive property which is between anode and cathode. When discharge occurs, the voltage drops about to the range of from 25V to 45V. When spark discharge occurs, which is the electricity flowing through the ionized column of dielectric, there is no variation of voltage but the amplitude of current rises quickly to a constant value set by operator. Within the ionized column, electrons separate from the dielectric-fluid atoms and flow from the negative-polarity electrode toward the positive-polarity work piece. Since the dielectric-fluid atoms in the column are missing electrons, they are positively charged, and flow from the positive polarity work piece toward negative-polarity electrode. This streaming of electrons and positive ions is known as plasma channel. Plasma channels that are surrounded by bubbles which occur by vaporization of dielectric fluid grow during on-time.

Fig.1 EDM machine used for the experiment

REVIEW OF LITERATURE

Mukund R.Patel et al. (1989) [9] presented an erosion model for anode material. The model accepts power rather than temperature as boundary condition at plasma/anode interface. P. Madhu et al. (1991) [10] proposed a model for predicting the material removal rate and depth of damaged layer during EDM. The transient heat conduction equation for the work piece which accounts for the heat absorption due to melting has been solved by Finite Element Method. Philip T. Eubank et al. (1993) [11] developed a variable mass, cylindrical plasma model for sparks created by electric discharge in a liquid media. High plasma temperatures and pressures persist in the plasma even after long pulse times. J.C. Rebelo et al. (2000) [8] presented an experimental study on the effect of EDM parameters on material removal rate (MRR) and surface quality, when machining high strength copper-beryllium alloys. A. Kulkarni et al. (2002) [1] attempted to identify the underlying mechanism of the electrochemical discharge machining process through experimental observations of time-varying current in the circuit. B. Lauwers et al. (2007) [3] presents a detailed investigation of the material removal mechanisms of some commercially available electrical conductive ceramic materials through analysis of the debris and the surface/sub-surface quality. Shankar Singh et al. (2009) [12] reported the results of an experimental investigation carried out to study the effects of machining parameters such as pulsed current on material removal rate, surface roughness. Drayl D.Bitonto et al. (1989) [5] presented a simple cathode erosion model for EDM process. This point heat-source model accepts power rather than temperature as the boundary condition at the plasma/cathode interface. H.T. Lee et al.(2011) [6] presented a study of the relationship between EDM parameters and surface crack by using a full factorial design, based upon discharge current and pulse on time parameters on D2 and H13 tool steels as materials. Josko Valentincic et al. (2013) [7] proposed that rough machining parameters have to be selected according to size of the eroding surface to achieve a high material removal rate and low electrode wear. The work presented shows that the electric current signals depend on size of the eroding surface. C.H. Che Haron et al. (2014)[4] determined the possible correlation between the EDM parameter (current) and the machinability factors (material removal rate and electrode wear rate). The material removal rate of the work piece material and wear rate of electrode material obtained based on the calculation of the percentage of mass loss per machining time.

MATERIAL METHODS

The electric field in a conducting material is governed by Maxwell's equation of conservation of charge. It states that the divergence of the current density is equal to the negative rate of change of the charge density. That is given as

$$\nabla . J = -\frac{\delta \rho}{\delta t} \quad (1)$$

Assuming steady state direct current

$$I = \frac{dQ}{dt} \text{ and } r_c = \frac{dQ}{dV.dt} \quad (2)$$

$$\int_V r_c \, dV = \int dI = \int_S J.nds \quad (3)$$

Where V is any control volume whose surface is S, n is the outward normal to S, J is the electrical current density (current per unit area), and r_c is the internal volumetric current source per unit volume.

The divergence theorem can be used to convert the surface integral into volume integral that is given as,

$$\int_V \nabla . J \, dV = \int_S J.n \, ds \quad (4)$$

Using equation (3) equation (4) becomes,

$$\int_V \nabla . J dV = \int_V r_c \, dV \tag{5}$$

Where $\nabla = \hat{\imath}\frac{\partial}{\partial x} + \hat{\jmath}\frac{\partial}{\partial y} + \hat{k}\frac{\partial}{\partial z}$

So the above equation can be written as,

$$\int_V \left(\hat{\imath}\frac{\partial}{\partial x} + \hat{\jmath}\frac{\partial}{\partial y} + \hat{k}\frac{\partial}{\partial z}\right) . J dV = \int_V r_c \, dV \tag{6}$$

The component of current in $\hat{\imath}$ direction is given as,

$$\int_V \frac{\partial}{\partial x} J dV = \int_V r_c \, dV$$

Or $\left[\frac{\partial}{\partial x} J - r_c\right] dV = 0\backslash$

Since the volume is arbitrary, this provides the point wise differential equation so,

$$\left[\frac{\partial}{\partial x} J - r_c\right] = 0 \tag{7}$$

Constitute behavoir

The flow of electric current is described by ohm's law:

$$J = \sigma^E . E \tag{8}$$

Where σ^E is the electrical conductivity matrix. The conductivity can be isotropic, orthotropic, or fully antis tropic.

E is the electrical field intensity given as:

$$E = -\frac{\delta\varphi}{\delta x} \tag{9}$$

Since a potential rise occurs when a charged particle moves against the electrical field, the direction of the gradient is opposite to that of the electrical field. Using this definition of the electrical field, Ohm's law is rewritten as:

$$J = -\sigma^E . \frac{\delta\varphi}{\delta x} \tag{10}$$

Introducing Ohm's law, the governing conservation of charge equation written as,

$$\int_V \frac{\partial\delta\varphi}{\partial x} . \sigma^E . \frac{\delta\varphi}{\partial x} dV = \int_V r_c \delta\varphi \, dV + \int_S J\delta\varphi \, dS \tag{11}$$

Thermal Energy Balance

The heat conduction behaviour is described by the basic energy balance relation that is given as,

$$\int_V \rho U \delta\theta d + \int_V \frac{\partial\delta\varphi}{\partial x} . \text{k} . \frac{\delta\varphi}{\partial x} dV = \int_V \delta\theta r \, dV + \int_S \delta\varphi \, q dS \tag{12}$$

Where $\delta\varphi$ the electrical potential is field and $\delta\theta$ is temperature field, V is the volume of solid material with surface area S, ρ is the density of material, U is the internal energy, k is the thermal conductivity of material, q is heat flux per unit area of body, r is the heat generated within the body.

Surface conditions

The surface S of an body consists of two part, one on which boundary conditions can be prescribed S_P and other that can interact with nearby surface of other body S_i. The boundary conditions that include the electrical potential $\varphi = \varphi(x,t)$, temperature $\theta = \theta(x,t)$, electrical current density $j = j(x,t)$, heat flux, $q = q(x,t)$ and surface convection and radiation conditions. The surface interaction model involves heat conduction and radiation effects between the interface surfaces.

Spatial Discretization

Finite element model is approximated as a finite set of equations by introducing interpolation functions. Discretized quantities are indicated by uppercase superscripts. The Discretized quantities represent nodal variables with nodes shared between adjacent elements. The virtual electrical potential field is interpolated by,

$$\delta\varphi = N^N \delta\varphi^N \tag{13}$$

Where N^N is the interpolation functions.

Mechanism of Material removable rate (MRR)

The material removable rate is expressed as the ratio of the difference of weight of the work piece before and after machining to the machining time and density of material.

$$\text{MRR} = \frac{w_{jb} - w_{ja}}{t \times \rho}$$

RESULTS AND DISCUSSION

Actual EDM cycle consists of OFF Time and On Time. In this model, the process is assumed to be having a continuous sparking for a long period of computational machining cycle time (i.e. zero off time). Table 1 shows the material properties set for copper,En-19 and the EDM oil used as the dielectric fluid during the analysis.

Material property	Copper (cathode)	En-19 (anode)	EDM Oil (dielectric)
Density (g/mm^3)	$8920x10^{-6}$	$7700x10^{-6}$	$5.7x10^{-8}$
Conductivity (W/mm K)	$400x10^{-3}$	$222x10^{-12}$	0.06
Resistivity (Ω-mm)	$1.7x10^{-11}$	$22.2x10^{-11}$	1
Specific heat (J/gk)	$385x10^{-3}$	$437x10^{-3}$	15

Table 1: Material Properties for FEA

Experimental Data:

Electric discharge Machine = ELECTRONICA ELECTRAPULS PS 50 ZNC with servo head

EDM oil specific gravity = 0.763

Voltage = 15V-25V

Maximum current = 68 amps

Diameter of electrode = 30 mm

Diameter of work piece material = 50 mm

Machining time = 5 minute

The chemical composition of work piece material is

Elements	C	Si	Mn	P_{max}	S_{max}	Cr	Mo
Composition (wt. %)	0.35 - 0.45	0.10 - 0.35	0.50 – 0.80	0.50	0.50	0.90 - 1.50	0.20 - 0.40

given in table 2.

Table 2: Chemical composition of En-19

The Table (3) containing the values of current intensities and volume of material. With different current intensity (I) values, volume of material removal Maximum Surface roughness is calculated.

SI.NO	Current intensity (I) Amps	Volume of material Removed(μm^3)×10^9	R_{max} (mm)
1	68	1.8337	0.615
2	58	1.0897	0.45
3	44	0.1813	0.15
4	36	0.0904	0.12

Table 3: FEA results of Current intensities and volume of material removal.

Graph shows that volume of material removal and maximum surface roughness Rmax for different current intensities. It is clear from the plot that volume of material removal rate is increase with increase of current. From 36 amps to 44 amps there is little increase in volume of material removal. But it increase uniformly from 44 amps to 68 amps.

Maximum surface roughness Rmax with corresponding current intensities is shown in fig 3. Better surface finish is obtained with less current. With increase in current maximum surface roughness is increased. So for finishing cut the current should be less as possible.

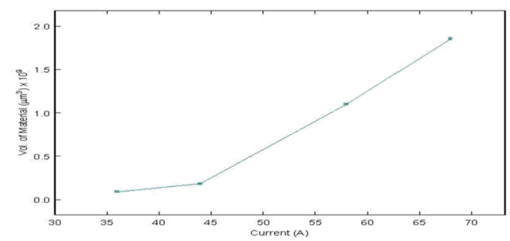

Fig 2: Volume of material removal with different current intensities for FEA

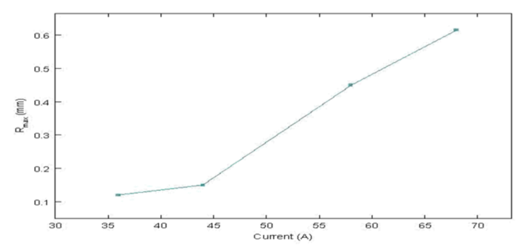

Fig 3: Rmax values with various current intensities for FEA

Material removal rate with varying pulse ON time (TON) and current values are shown in table 4. The difference in weights, volume of material removal and material removal rate are presented in the table.

SI.No	Ip Amps	T_{ON}	Machining Time (min)	Initial Weight (grams)	Final Weight (grams)	Difference in Weight (grams)	Volume of Material Removal(mm^3)	MRR (mm^3/min)
1	5	100	5	178.43	178.27	0.16	20.78	4.16
2	15	100	5	171.42	169.97	1.45	188.31	37.66
3	5	150	5	170.01	169.81	0.20	25.97	5.19
4	15	150	5	169.81	168.01	1.80	233.77	46.75
5	5	200	5	159.56	159.34	0.22	28.57	5.71
6	15	200	5	159.34	157.18	2.20	285.71	57.14

Table4: Material removal rate with varying pulse ON time (TON) and current values.

Graph shows that for TON = 100 with increase in current the material removal rate increases. The volume of material removal is increasing as current the current is increasing and hence the material removal rate is also increasing for TON = 150 and 200.

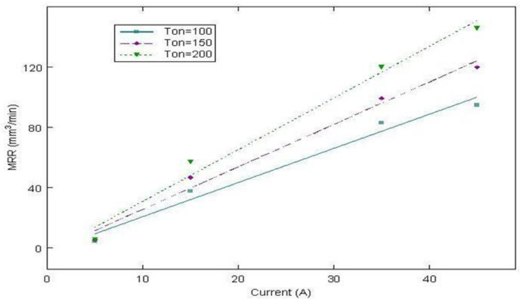

Fig 4: Material removal rates with varying current

CONCLUSION

1.When current increases, the MRR also increases. The higher the current, intensity of spark is increased and results high metal removal will take place.

2.When current intensity increased, surface roughness is also increased. Because due to increase in current, the spark intensity is increases. So material removal rate per minute increases. Finally surface roughness increase.

3.Volume of material removal and material removal rate per minute is calculated and its variation with current is in agreement with FEA results.

REFERENCES

[1] A. Kulkarni, Sharan R. and Lal G.K., "An experimental study of discharge mechanism in electrochemical discharge machining" International Journal of Machine Tools & Manufacture, Volume 42, (2002):p.1121-1127.

[2] Abbas Mohd Norliana, Solomon.G.Darius and Bahari Fuad Md., "A review on current research trends in electrical discharge machining (EDM), International Journal of Machine Tools & Manufacture, Volume 47, (2007):p.1214-1228.

[3] B.Lauwers. , Kruth J.P. , Liu W. , Eeraerts W. , Schacht B. and Bleys P., "Investigation of material removal mechanisms in EDM of composite ceramic materials" Journal of Materials Processing Technology, Volume 149, (2007):p.347-352.

[4] Che Haron .C.H, Md. Deros .B, Ginting.A. and Fauziah.M, "Investigation on the influence of machining parameters when machining tool steel using EDM" Journal of Materials Processing Technology, Volume 116, (2014):p.84-87.

[5] Drayl D.Bitonto, Eubank P.T., Patel M.R. and Barrufet.M.A, "Theoretical models of the electrical discharge machining process-I: a simple cathode erosion model" Journal of Applied Physics, Volume 66, (2010):p.4095–4103.

[6] H.T Lee. And Tai T.Y., "Relationship between EDM parameters and surface crack formation" Journal of Materials Processing Technology, Volume 142, (2011):p.676-683.

[7] Josko Valentincic and Junkar Mihael, "On-line selection of rough machining parameters" Journal of Materials Processing Technology, Volume 149, (2013):p.256-262.

[8] J.C.Rebelo, Dias A. Morao, Mesquita Ruy, Paulo Vassalo and Mario Santos, "An experimental study on electro-discharge machining and polishing of high strength copper-beryllium alloys" Journal of Materials Processing Technology, Volume 108, (2000):p.389-397.

[9] Mukund.R.Patel, Barrufet.M.A., Eubank.P.T. And DiBitonto.D.D, "Theoretical models of the electrical discharge machining process-II: the anode erosion model" Journal of Applied Physics, Volume 66, (1989):p. 4104–4111.

[10] P.Madhu ,Jain.V.K.and Sundararajan.T, "Analysis of EDM process: A Finite Element Approach", Computers in Engineering ASME, (1991), Volume 2:p.121-127.

[11] Philip.T,,Eubank. Patel.M.R., Barrufet.M.A. And Bozkurt.B, "Theoretical models of the electrical discharge machining process-III: the variable mass, cylindrical plasma model", Journal of Applied Physics, Volume 73, (1993):p. 7900–7909.

[12] Singh Shankar, Maheshwari S. and Pandey P.C., "Some investigations into the electric discharge machining of hardened tool steel using different electrode materials" Journal of Materials Processing Technology, Volume 149, (2009):p.272-277.

[13] Yan.B.H, Lin.Y.C and Huang.F.Y, "Surface modification of Al–Zn–Mg alloy by combined electrical discharge machining with ball burnish machining" International Journal of Machine Tools & Manufacture, Volume 42, (2002):p.925-934. s