Effect of electrode geometrical parameters in die sink EDM: A Review

Mahesh Toche [1], Akshay Tajane [2]

1 M.E. student, Mechanical Engineering Department, Gulabrao Deokar C.O.E., Faizpur, India
2 Assistant Professor, Mechanical Engg. Department, LGNSCOE, Nashik,422213 (INDIA)

ABSTRACT

Electrical discharge machining (EDM) is one of the non-traditional machining processes, based on thermo electric energy between the work piece and an electrode. In this process, the material removal is occurred electro thermally by a series of successive discrete discharges between electrode and the work piece. The parametric analysis of the EDM process by using different electrode shapes has been carried out. This Research discusses the performance of die sinking EDM due to the shape configuration of the electrode. The effect of electrode shapes configuration on the performance of die sinking electric discharge machine has been carried out. The basis of controlling sink Electrical Discharge machining depends on electrical & non electrical parameters. Performance of Electrical discharge machining is measured in terms of Material Removal Rate MRR ,Tool Wear Rate TWR. The objective of this paper is to study the effect of process parameters and electrode shape configuration on the machining characteristics such as surface quality, material removal rate and electrode wear. In this study we found better machining performance is obtained generally with the electrode as the cathode and the work-piece as an anode. In this review we observe that for high MRR main process parameters are peak current, pulse on time ,pulse off time, whereas for electrode wear are mainly influenced by peak current and pulse on time. Surface quality is mainly influenced by peak current. As far as tool shape configuration concerned best tool shape for higher MRR and lower TWR is circular, followed by square, triangular, rectangular, and diamond cross sections.

Keyword: - *EDM, electro-conductive materials, electrode geometry, Material Removal Rate ,Tool Wear Ratio(TWR), DOE, Parameter analysis*

1. INTRODUCTION

Present manufacturing industries are facing challenges from advanced materials viz. super alloys, ceramics, and composites, that are hard and difficult to machine, requiring high precision, surface quality which increases machining cost . The conventional machining of such advanced materials is often difficult due to the improved thermal, chemical and mechanical properties of new advanced materials. In EDM, a potential difference is applied between the tool and work piece. Both the tool and the work material are to be conductors of electricity. The tool and the work material are immersed in a dielectric medium. A gap is maintained between the tool and the work piece. Depending upon the applied potential difference and the gap between the tool and work piece, an electric field would be established. If the work function or the bonding energy of the electrons is less, electrons would be emitted from the tool (assuming it to be connected to the negative terminal). Such emission of electrons are called or termed as cold emission. The “cold emitted” electrons are then accelerated towards the job through the dielectric medium. As they gain velocity and energy, and start moving towards the job, there would be collisions between the electrons and dielectric molecules. Such collision may result in ionization of the dielectric molecule depending upon the work function or ionization energy of the dielectric molecule and the energy of the electron. This cyclic process would increase the concentration of electrons and ions in the dielectric medium between the tool and the job at the spark gap. The concentration would be so high that the matter existing in that channel could be characterized as “plasma”. The high speed electrons then impinge on the job and ions on the tool. The kinetic energy of the electrons and ions on impact with the surface of the job and tool respectively would be converted into thermal energy or heat flux.

Such intense localized heat flux leads to extreme instantaneous confined rise in temperature which would be in excess of 10,000 C such localized extreme rises in temperature leads to material removal. Material removal occurs due to instant vaporization of the material as well as due to melting. Thus to summarize, the material removal in EDM mainly occurs due to formation of shock waves as the plasma channel collapse owing to discontinuation of applied potential difference.Die sinking electrical discharge machining (EDM) is one of the most widely used techniques for the fabrication of die and mold cavities which are finally used for mass production of metals and polymer products by replication such as die casting, injection molding, etc. In any replication process, it is expected that the quality mold will faithfully duplicate its shape and surface texture. Inaccurate duplications cause problems in assemblies, operations as well as lower the aesthetic view. In die sinking EDM the electrode produces exactly its opposite shape on the work material EDM does not make direct contact between tool and workpiece where it can eliminate the mechanical stresses, vibration during machining . Material of any hardness can be cut as long as the material can conduct electricity. EDM techniques have developed in many areas. The trends on activity carried out by researcher depend on the interest of and the availability of technology. This is achieved by the development of different types of spark generation and optimizing production parameter. Although due to a great number of variable and a variety of products, an optimal machining process performance is very difficult to achieve.

2. LITERATURE REVIEW:

M. S. Sohani & V. N. Gaitonde & B. Siddeswarappa &A. S. Deshpande studied Investigations into the effect of tool shapes with size factor consideration in sink electrical discharge machining (EDM) process. He presents paper with the application of response surface methodology (RSM) for investigating the effect of tool shapes such as triangular, square, rectangular, and circular with size factor consideration along with other process parameters like discharge current, pulse on-time, pulse off-time, and tool area. Also The RSM-based mathematical models of material removal rate (MRR) and tool wear rate (TWR) have been developed using the data obtained through central composite design. He finally concluded that the best tool shape for higher MRR and lower TWR is circular, followed by Triangular, rectangular, and square cross sections. From the parametric analysis, it is also observed that the interaction effect of discharge current and pulse on-time is highly significant on MRR and TWR, whereas the main factors such as pulse off-time and tool area are statistically significant on MRR and TWR.

Lin et al. applied grey relational analysis for solving the complicated interrelationships between process parameters and the multiple performance measures. Taguchi approach has also been used by many other researchers to analyze and design the ideal EDM process .Main non-electrical parameters are flushing of dielectric, workpiece rotation and electrode rotation. These non-electrical parameters play a critical role in optimizing performance measures. Researches on flushing pressure reveal that it affects the surface roughness, tool wear rate, acts as coolant and also plays a vital role in flushing away the debris from the machining gap . Work piece rotary motion improves the circulation of the dielectric fluid in the spark gap and temperature distribution of the work piece yielding better MRR and SR . Similarly, electrode rotation results in better flushing action and sparking efficiency. Therefore, improvement in MRR and SR has been reported due to effective gap flushing by electrode rotation .Major performance measures in EDM are MRR, TWR and SR. For MRR, research work has been focused on material removal mechanism and methods of improving MRR .

Similarly for TWR, research work on tool wear process and methods of improvement in TWR has been reported . Though EDM is essentially a material removal process, efforts have been made to use it as a surface treatment method and/or an additive process also. Many surface changes have been reported ever since the process established itself in the tool rooms of manufacturing industry .Fenggou and Dayong (2004) applied ANN technique to determine and optimize the machining parameters (current peak value and pulse width-on) in an EDM sinking process. GA was employed to optimize and train the developed ANN to enhance the training speed. Processing depth was the considered response. Su et al. (2004) applied GA adapted to ANN to determine the optimal EDM process parameters, like pulse-on time, pulse-off time, high-voltage discharge current, low-voltage discharge current, gap size, servo-feed, jumping time and working time. MRR, SR and tool wear rate (TWR) were the responses. The GA-based NN model could be able to determine the optimal process parameters from rough cutting stage to finish cutting stage.

S. P. Nipanikar et al. optimizing of process parameters of EDM by the taguchi method. In this they used work piece material as AISI D3 steel material. The Taguchi method is used to formulate the experimental layout, to analyze effect of each parameter on the machining characteristics, and to predict the optimal choice for each EDM parameters such as current, gap voltage, and duty cycle and pulse time on. They use output parameters as MRR and EWR and Radial overcut. The Martial Removal Rate is mainly affected by peak current, and least affected by duty cycle. The EWR is mainly affected by peak current and least influenced by gap voltage. The peak current has maximum effect on radial over cut, and least affected by gap voltage.

Ahsan Ali Khan, Mohammad Yeakub Ali and Md. Mohafizul Haque conducted a review of Study of Electrode Shape Configuration on the Performance of Die Sinking EDM. He concluded the performance of die sinking EDM due to the shape configuration of the electrode. In addition of the above conclusion he also concluded that the effect of electrode shape on material removal rate (*MRR*), electrode wear rate (*EWR*), wear ratio (*WR*), and average surface roughness (R_a) has been investigated for mild steel work material and copper electrode. The shapes of the electrodes were round, square, triangular, and diamond of constant cross-sectional area of 64 mm_2. Experiments were repeated for three current values of 2.5, 3.5, and 6.5 A. finally Electrodes of four different shapes of constant cross-sectional area were used for experiment with different discharge current. The *MRR*, *EWR*, *WR*, and surface roughness were measured and analyzed.

3. WORKING

The working principle of EDM process is based on the thermoelectric energy. This energy is created between a workpiece and an electrode submerged in a dielectric fluid with the passage of electric current. The workpiece and the electrode are separated by a specific small gap called spark gap. Pulsed arc discharges occur in this gap filled with an insulating medium, preferably a dielectric liquid like hydrocarbon oil or de-ionized (de-mineralized) water . Schumacher described the technique of material erosion employed in EDM as still arguable. This is because ignition of electrical discharges in a dirty, liquid filled gap, when applying EDM, is mostly interpreted as ion action identical as found by physical research of discharges in air or in vacuum as well as with investigations on the breakthrough strength of insulating hydrocarbon liquids. This fig,1 is shown the electric setup of the Electric discharge machining.

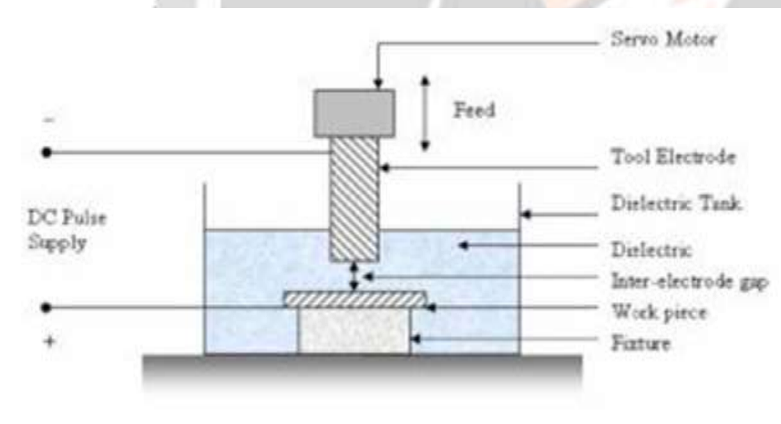

Fig.1-Setup of die sinking EDM

The tool is made cathode and work piece is anode. When the voltage across the gap becomes sufficiently high it discharges through the gap in the form of the spark in interval of from 10 of micro seconds. And positive ions and electrons are accelerated, producing a discharge channel that becomes conductive. It is just at this point when the spark jumps causing collisions between ions and electrons and creating a channel of plasma. A sudden drop of the electric resistance of the previous channel allows that current density reaches very high values producing an increase of ionization and the creation of a powerful magnetic field. The moment spark occurs sufficiently pressure developed between work and tool as a result of which a very high temperature is reached and at such high pressure and temperature that some metal is melted and eroded. Such localized extreme rise in temperature leads to material removal. Material removal occurs due to instant vaporization of the material as well as due to melting. The molten metal is not removed completely but only partially As the potential difference is withdrawn as shown in Fig.2, the plasma channel is no longer sustained.

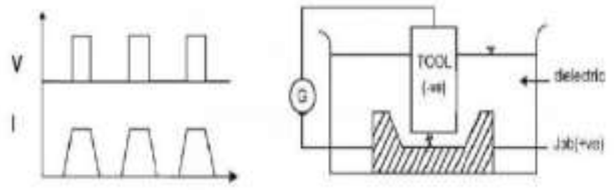

Fig.2-Working Principle of die sinking EDM

3.1 Important Parameters of EDM:

(i)Spark On-time (pulse on time or Ton): The duration of time (μs) the current is allowed to flow per cycle.Material removal is directly proportional to the amount of energy applied during this on-time. This energy is really controlled by the peak current and the length of the on-time.

(ii)Spark Off-time (pulse off time or Toff): The duration of time (μs) between the sparks (that is to say, on-time). This time allows the molten material to solidify and to be wash out of the arc gap. This parameter is to affect the speed and the stability of the cut. Thus, if the off-time is too short, it will cause sparks to be unstable.

(iii)Arc gap (or gap): The Arc gap is distance between the electrode and workpiece during the process of EDM. It may be called as spark gap. Spark gap can be maintained by servo system.

(iii)Discharge current (peak current Ip): Current is measured in amp allowed to per cycle. Discharge current is directly proportional to the Material removal rate.

(iv) Duty cycle (τ): It is a percentage of the on-time relative to the total cycle time. This parameter is calculated by dividing the on-time by the total cycle time (on-time pulse off time).

(v)Voltage (V): It is a potential that can be measure by volt it is also effect to the material removal rate and allowed to per cycle. Voltage is given by in this experiment is 50 V.

(vi)Diameter of electrode (D): It is the electrode diameter which taken part in work.

(vii)Over cut – It is a clearance per side between the electrode and the workpiece after the machining operation.

3.2 Effect of process parameter on MRR, TWR:

The variations of discharge current with MRR and TWR are shown in Figs. 3 and 4, respectively.

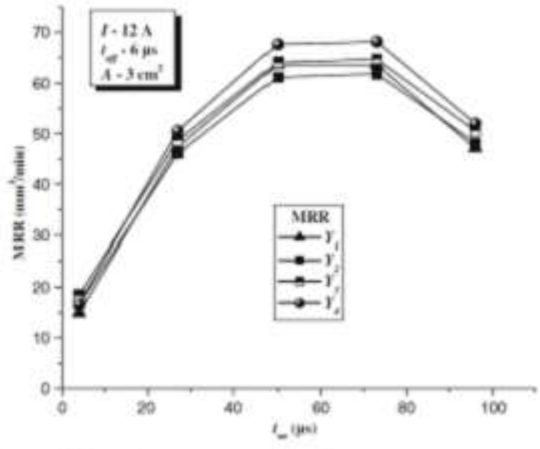

Fig. 5 Effect of pulse on-time (t_{on}) on MRR

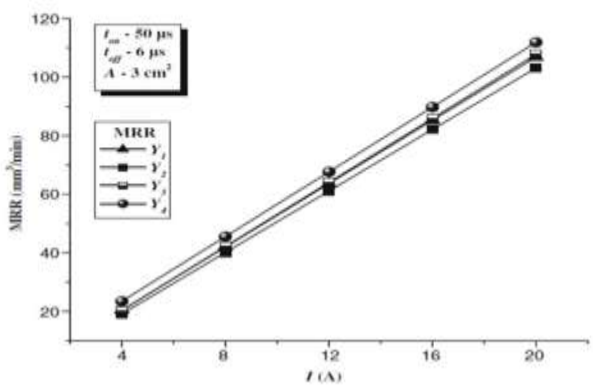

Fig. 3 Effect of discharge current (I) on MRR

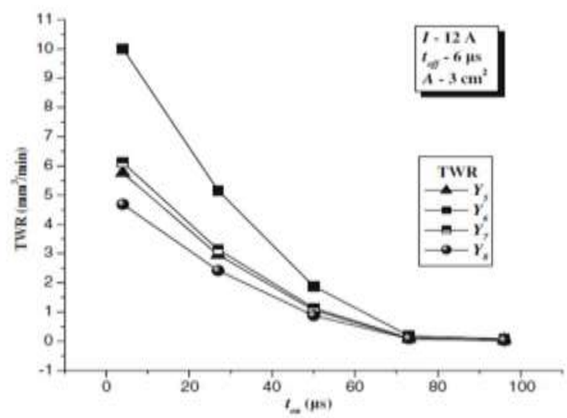

Fig. 6 Effect of pulse on- time (t_{on}) on TWR

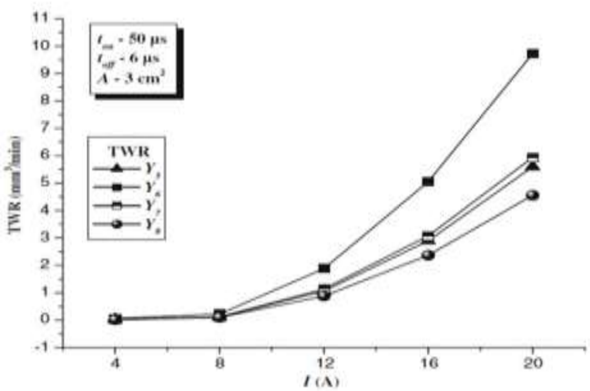

Fig. 4 Effect of discharge current (I) on TWR

As seen in figures, the MRR as well as TWR both increase with discharge current. The MRR (Fig. 3) increases linearly with current, whereas the TWR (Fig. 4) increases nonlinearly with current. This is due to the fact that an increase in discharge current increases the pulse energy that leads to an increase in heat energy rate, which is subjected to both of the electrodes, and in the rate of melting and evaporation. Thus, the MRR as well as TWR increase with discharge current, which closely agree with the previous investigations .Figures 5 and 6 show the variations of MRR and TWR with pulse on-time duration. The longer pulse on-time duration results in higher MRR up to half way in the beginning but then starts decreasing with further increase in pulse on-time duration (Fig. 5). This event has been attributed to the increase of input energy in high pulse on time duration, which results in more chopping on the gap between the workpiece and tool electrode, creating a short circuit which decreases the efficiency of electrical spark erosion. In other words, short pulse on-time duration causes less vaporization, whereas long pulse on-time duration causes the plasma channel to expand, resulting in less energy density on workpiece, which is insufficient to melt and/or vaporize the workpiece material . Thus, the MRR has exhibited increasing tendency in the beginning and maximum at half way of pulse on-time duration, but then starts decreasing with further increase in pulse on-time duration for the range of investigation carried out. On the other hand, TWR rapidly decreases with increase in pulse on-time duration in the beginning but then starts decreasing slowly and further stays constant for longer pulse on-time durations as seen in Fig. 6. The reasons for low tool wear rate at longer pulse on-time duration settings are mainly due to:

•Decreasing spatial current density of discharge channel with increasing discharge pulse on-time duration.
•Longer time for heat transfer from the molten crater to the body of tool, which results in less material removal from the crater
•Higher wear resistance of the tool due to carbon attached to the surface

4. CONCLUSIONS

EDM has brought many improvements in machining process in recent years. The capability of machining complex and convoluted, contours and hard material has made EDM as one of the most popular machining processes. EDM is independent on the mechanical properties of workpiece. Design and manufacturing of electrode play an important role in EDM technology. The present review paper reports research and development work carried out by various researchers in the same field. The effect of different type tool geometries with constant area of cross section yet not investigated and influence of these on performance measure in EDM. There is a very scant work is done in this area by researcher and there is a large scope for future investigation.The main effects of process parameters such as discharge current, pulse on time, pulse off time, higher-order effect of pulse on time, and the interaction effect of discharge current and pulse on time have significant contribution in MRR. The best tool shape for higher MRR and lower TWR is circular, followed by Triangular, rectangular, and square cross sections. The MRR increases linearly with discharge current. And the MRR increases with pulse on-time duration and then starts decreasing with increase in pulse on time duration. The influence of the shape of electrodes on surface roughness is found to be insignificant. However, a round shape electrode produces a smoother surface followed by the square, triangular and the diamond shaped electrodes.

5. REFERENCES

[1] Manish Vishwakarma , Vishal Parashar, V.K.Khare ;Advancement in Electric Discharge Machining on metal matrix composite materials in recent International Journal of Scientific and Research Publications, Volume 2, Issue 3, March 2012 1 ISSN 2250-3153 pp.1

[2] Hassan, EI-Hofy. (2005): Advanced Machining Processes, McGraw-Hill, pp. 36-37.

Haron, C.H., Deros, B.M., Ginting, A. and Fauziah,M. (2001), ―Investigation on influence of machining parameters when machining tool steel using EDM‖,Journal of Materials Processing Technology, Vol.116, pp. 84-87

[3] Dewangan, S.K. (2010), ―Experimental Investigation of Machining Parameters for EDM using U- shaped Electrode of AISI P20 Tool Steel‖, NIT Rourkela,pp. 4-6,15,18

[4] S. R. Nipanikar (2012) „Parameter Optimization of Electro Discharge Machining of AISI D3 Steel Material by Using Taguchi Method", Journal of Engineering Research and Studies (JERS) Vol. 3, Issue. 3, pp. 7-10, ISSN: 0976-7916

[5] Jianxin, D. and Taichiu, L. (2002), ―Effect of ultrasonic surface finishing on the strength and thermal shock behavior of the EDM ceramic composite‖, International Journal of Machine Tools & Manufacture, Vol.42, pp. 245-250.

[6] Rudorff, D.W., 1961 ―Spark machining and its development‖, Metal Treatment and Drop Forging, 28 (186), 120–124.

[7] Luis, C.J., Puertas, I., Villa, G., 2005 ―Material removal rate and electrode wear study on the EDM of silicon carbide‖, Journal of Materials Processing Technology, 164–165, 889–896

[8] Pandey, P.C., and Shah, H.S. (1980). Modern Machining Processes.New Delhi. Tata Mcgraw-Hill.

[9] Shailesh Kumar , Experimental Investigation of Machining Parameters for EDM Using U-shaped Electrode of AISI P20 Tool Steel pp.17,18:Master Thesis

[10] Mr. Mohd Yussni Bin Yaakob (2008).Electrical Discharge Machining-Die Sinking.Universitiy Tun Hussein On Malaysia (UTHM).

[11] Van Tri, N. (2002). Electrical discharge machining of aluminum alloy using classical design of experiment approach. University Technology Malaysia: Master Thesis

[12] Pandit, S.M., Mueller, T.M., 1987 ―Verification of on-line computer control of EDM by data dependent systems‖, J. Eng. Ind., 109, 109– 121.

[13] Lin, C.L., Lin, J.L., Ko, T.C., 2002, ―Optimization of the EDM process based on the orthogonal array with fuzzy logic and grey relational analysis method‖, International Journal of Advance Manufacturing Technology, 19 (4), 271–277.

[14] Lin, J.L., Wang, K.S., Yan, B.H., Tarng, Y.S., 2000, ―Optimization of the electrical discharge machining process based on the Taguchi method with fuzzy logics‖, Journal of Materials Processing Technology, 102, 48–55.

[15] Marafona, J., Wykes, C., 2000, ―A new method of optimizing material removal rate using EDM with copper tungsten electrodes‖, Int. J. Mach. Tools Manuf., 40(2), 153–164.

[16] Lonardo, P.M., Bruzzone, A., 1999, ―Effect of flushing and electrode material on die inking EDM‖, CIRP Annals - Manufacturing Technology, 48 (1), 123– 126.

[17] Guu, Y.H., Hocheng, H., 2001, ―Effects of workpiece rotation on machinability during electrical discharge machining‖, Journal of Material and Manufacturing Processes, 16(1), 91–101.

[18] Soni, J.S., Chakraverty, G., 1994, ―Machining characteristics of titanium with rotary electro-discharge machining‖, Wear, 171, 51– 58.

[19] Prashant Mulmule,Akshay Tajane ― FEA Analysis of chain link for finding Optimization Parameters International Journal of Advanced Research & Innovative ideas in education, vol-3,issue-2, 2017

[20] M. S. Sohani & V. N. Gaitonde & B. Siddeswarappa & A. S. Deshpande (2009); 'Investigations into the effect of tool shapes with size factor consideration in sink electrical discharge machining (EDM) process.‟ Received: 3 May 2008 / Accepted: 31 March 2009 / Published online: 28 April 2009 Springer-Verlag London Limited 2009

BIOGRAPHIES (Not Essential)

Author Photo-1	Mr.Mahesh Toche is PG scholar at North Maharashtra University Jalgaon. He has 6 years of teaching expeience
	Prof.Akshay Tajane is Assistant Professor at L.G.N.Sapakal College of Engineering Nashik He has 9 years teaching experience and 3 years industrial experience