RESEARCH ARTICLE OPEN ACCESS

An Electrode Shape Configuration on the Performance of Die Sinking Electric Discharge Machine (EDM): A Review

Abhijeetsinh V Makwana[1], Kapil S Banker[2]
PG Scholar[1], Assistant Professor[2]
[1,2]Department of Mechanical Engineering, Shankersinh Vaghela Bapu Institute of Technology, GTU Ahmedabad, Gujarat - 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 optimization of the parameters of the EDM machining has been carried out by using the taguchi's method for design of experiments (DOE). In this research we have used taguchi's method for design of experiments with three input parameters and their three levels of experiments. The dielectric used is kerosene diluted with water. The objective of the analysis is to optimize the process parameters of EDM with the help of taguchi method and using Minitab software.

Keywords: EDM, Electrode Shape Configuration, Taguchi Method, DOE, Parameter analysis.

I. INTRODUCTION TO DIE-SINKING EDM

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

Fig.1 Sparkonix EDM Setup

II. LITERATURE REVIEW

In this paper few selected research paper related to Die-sinker EDM.The studies carried out in these papers are mainly concerned with the different electrode shape configuration and EDM input parameters such as current, voltage, pulse on time, duty cycle, etc. and how these affect the machining

characteristics like MRR, SR, TWR, Micro structure etc.

Mr. Dr. A.K.Sarathe et al. [1] has studied that the influence of process parameters and electrode shape configuration on the machining characteristics such as surface quality, material removal rate and electrode wear. In this review he 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. He found thatthe main effects of process parameters such as peak 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 significantcontributions in MRR. The MRR increases linearly, whereas the TWR increases nonlinearly with discharge current. He also found that 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 thesquare, triangular andthediamond shaped electrodes. Also For round shaped electrodes *MRR* was the maximum and undergoes less wear followed by the square, triangular and the diamond shaped electrodes. It is because of no vulnerable sharp corner at the sparking tip.

Chandramouli S et al. conducted [2] investigating EDM process parameters by using the Taguchi method and select the optimum result from that. The effect of various process parameters on machining performance is investigated by the Taguchi method. They use the input parameters as current, pulse time on, and pulse time off and the other side of Material removal rate (MRR), Tool wear rate (TWR), and surface roughness (SR). The taguchi method is used to formulate the experimental layout, ANOVA method is used to analysis the effect of input parameters on machining characteristics and find the optimum process parameters.

D. C. Chen et al. [3] having the purpose of to find process parameters with the help of Taguchi method. The process parameters are used as current, pulse time on, duty cycle, the machining duration. In this paper they use several of method for finding the optimum parameters of EDM. The work piece material A6061-T6 aluminum alloy is used. They use the Taguchi and ANOVA method for finding Optimum result with the help of the Minitab software. The experimental investigations have considered four fundamental EDM parameters, namely the pulse current (PC), the pulse-on duration (ON), the duty cycle (DC), and the machining duration (MD). The optimum set of parameter areas, pulse time (1.5 A), pulse on duration (50 µs), duty cycle (20) and machining duration (500 ms). The surface roughness of the machined specimen determined primarily by the values assigned to the pulse current and duty cycle. The optimum parameter setting established for material process also in low surface roughness when applied to the machining of CuZn40 brass alloy specimens, and thus the general applicability of the Taguchi design solution is confirmed.

Bhola Jha, K.Ram and Mohan Rao [4] conducted an overview of technology and research in electrode designand manufacturing in sinking electrical discharge machining.He suggested number of ways to improve electrode design and devised various ways of manufacturing and reports a review on the research relating to EDM electrode design and its manufacturing for improving and optimizing performance measures and reducing time and cost of manufacturing. He finally concluded that Design and manufacturing of electrode play an important role in EDM technology.

Rajesh Choudhary *et al.* [5] conducted investigations on the machining of EN-3 1 die steel with different electrode materials (copper, brass and graphite) with electrical discharge machining (EDM) process. This study presents the analysis and evaluation of heat affected zones (HAZ) of the workpiece surfaces machined using different tool electrodes by EDM. The kerosene oil of commercial grade has been used as dielectric fluid. From the micro-structural analysis study it has been observed that heat affected zone is much deeper in the specimen machined by graphite electrode as compared to other tool electrodes. The following conclusions were arrived at: I) For the EN-3 I work material. Copper electrodes have high MRR as compared to the machining performed by graphite and brass electrodes. ii) Among the three tested electrode materials, brass electrodes produce comparatively high surface finish for the tested work material at high values of discharge current, while graphite shows the poor surface finish.

Vishal J Nadpara et al. performed **[6]** on AISI D3 tool steel using graphite electrode of 10 mm diameter. The process parameters are taken on the basis of Taguchi Method. The objective of the paper is to optimize the process parameters of machining in high. Medium and low wear factors through duty cycle. In this paper they use the input process parameters as current, duty cycle and pulse time ON and the opposite side the output process parameters as MRR and EWR. In this they also used as taguchi method for getting the optimum result of selecting the best process parameters.

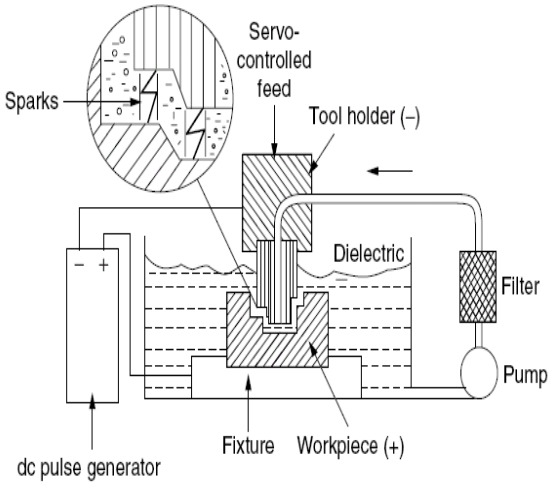

Fig.2 working principle of EDM [6]

B.S. Reddy et al. [7] carried out a study on the effect EDM parameters over MRR, TWR, SR and hardness. Mixed factorial design of experiments and multiple regression analysis techniques had been employed to achieve the desired results. The parameters in the decreasing order of importance for; MRR: servo, duty cycle, current and voltage; TWR: current, servo and duty cycle; SR: current.

Nilesh M. Vohra optimizing **[8]** of various parameters which are affected on different types of machining characteristics of EDM. The objective of this paper is to investigate the optimum cutting parameters for a work piece of SS 304 & tool material use as copper, aluminum and brass combination on fuzzy logic control based EDM. This experiment was accomplished by Taguchi Method. In this paper they use process parameters are Current, spark gap voltage, Ton, and Toff. And at the other side of output they use MRR, TWR, and SR. In the paper they conclude that the Gap voltage has highest effect on MRR.

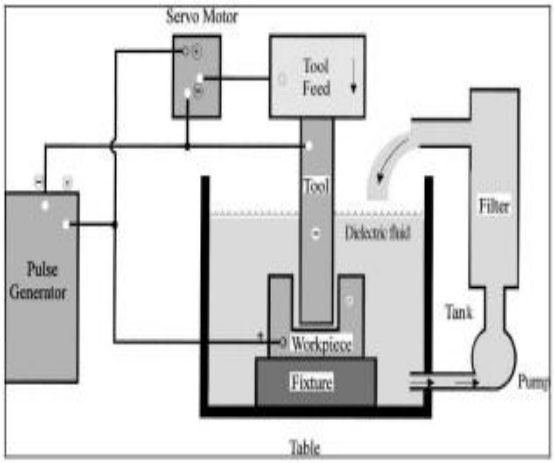

Fig.3 Experimental setup [8]

S. P. Nipanikar et al. optimizing [9] 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.

M. S. Sohani & V. N. Gaitonde & B. Siddeswarappa &A. S. Deshpande [10] 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.

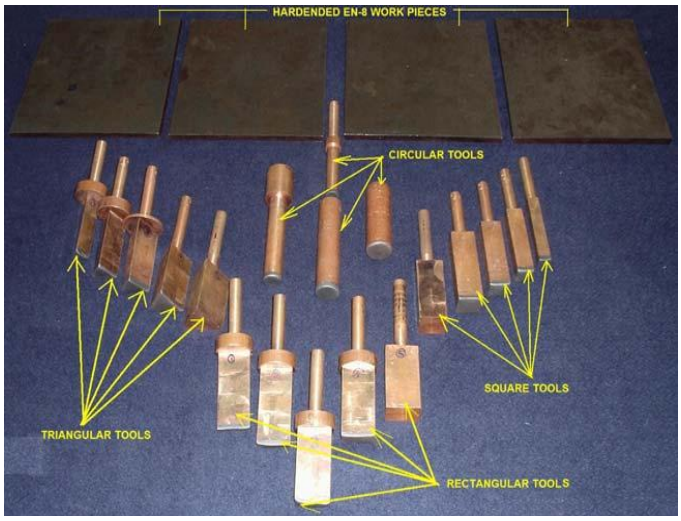

Fig.4 Photograph of tools andworkpieces used [10]

Ahsan *Ali Khan, Mohammad Yeakub Ali and Md. Mohafizul Haque* [11] 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.

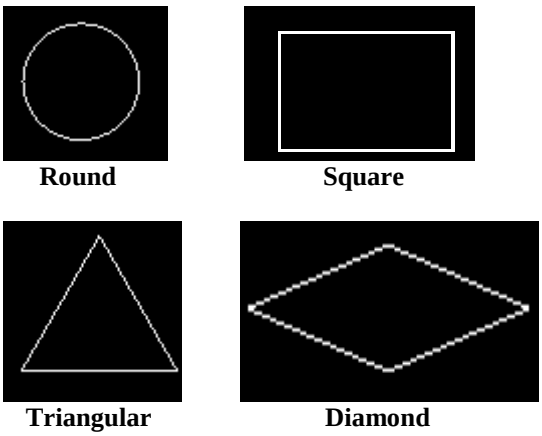

Fig.5 Selected shape configurations of electrode for die sinking EDM. [11]

The effects of the machining parameters (MRR, TWR and SR) in EDM on the machining characteristics of SKH 57 high-speed steel were investigated by **Yan- Cherng et.al [12].** Experimental design was used to reduce the total number of experiments. Parts of the experiment were conducted with the L18 orthogonal array based on the Taguchi method. Moreover, the signal-to-noise ratios associated with the observed values in the experiments were determined by ANOVA and F - test. The relationship of MRR and SR with pulse duration graph in different peak current is obtained. During the experiment MRR increases with peak current MRR initially increased to a peak at around 100 μs, and then fell.

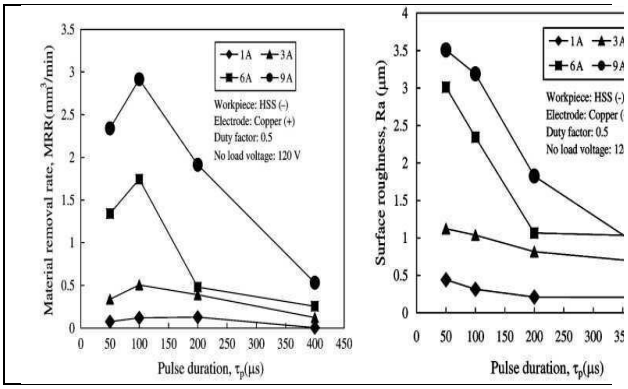

Fig.6 MRR and surface roughness with pulse duration graph[12]

Yusuf Keskin *et al [13]* conducted an experimental study for determination of the effects of machining parameters on surface roughness in electrical discharge machining (EDM). In this the data obtained for performance measures have been analyzed using the design of experiments methods and a considerably profound equation is obtained for the surface roughness using power, pulse time, and spark time Parameters. He finally concluded that Effects of machining parameters on the surface roughness values of machined components by EDM have beeninvestigated experimentally. It is apparent that the surface roughness has anIncreasing trend with an increase in the dischargeduration. This is mainly due to more discharge energy released during this time and expanding the discharge channel.

P. Narender Singh et al. [14] discuss the evolution of effect of the EDM current (*C*), Pulse ON-time (*P*)and flushing pressure (*F*) on MRR, TWR, taper (*T*), ROC, and surface roughness (SR) on machining as-cast **Al-MMC with 10% SiCp** . And use of metal matrix composites. ELEKTRAPULS spark erosion machine was used for the purpose and jet flushing of the dielectric fluid, kerosene, was employed. Brass tool of diameter 2.7mm was chosen to drill the specimens. An L27 OA, for the three machining parameters at three levels each, was opted to conduct the experiments. ANOVA was performed and the optimal levels for maximizing the responses were established. Scanning electron microscope (SEM) analysis was done to study the surface characteristics.

Puertas et al. [15] carried out results which showed that the intensity and pulse time factor were the most important in case of SR while the duty cycle factor was not significant at all. The intensity factor was again influential in case of TWR. The important factors in case of MRR were the intensity followed by duty cycle and the pulse time.

III. CONCLUSION

From all the above detailed literature review and analysis ofvarious process parameters of EDM process, the following points have been observed.

- 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.
- Cavities made by EDM die sinking may have intricate shapes and it is difficult to achieve high accuracy at the sharp corner of the cavities. The single irregular electrode contains several geometries such as flat, round, square surface, pointed tip, etc. which removes materials with different effectiveness. The present paper proposes to carefully select the EDM parameters for machining cavities with multiple and intricate shaped electrodes.

It has also been found that the copper having high material removal rate with respect to some other material like as aluminum, gun metal, brass, etc.

REFERENCES

[1] **Mr. Dr. A.K.Sarathe et al. (2014); '**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 (IJETAE) (ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 4, Issue 4, April 2014)

[2] **Chandramouli S et al. (2014); '**Optimization of Electric Discharge Machining Process Parameters Using Taguchi Method', International Journal of Advance Mechanical Engineering (IJAME) Vol.4, Issue 4, pp. 425-434, ISSN: 2250-3234

[3] **D. C. Chen et al. (2013)** 'Application of Taguchi Design Method to Optimize the Electric Discharge Machining', Journal of Achievements in Materials and Manufacturing Engineering (JAMME) Vol. 57, Issue. 2, pp. 76-82

[4] **Bhola Jha, K.Ram and Mohan Rao (2011); '**an overview of technology and research in electrode design and manufacturing in sinking electrical discharge machining'. Journal of Engineering Science and Technology Review 4 (2) (2011) 118-130

[5] **Rajesh Choudhary and et al. (2010)***'Analysis and evaluation of heat affected zones in electric discharge machining of EN-3 I die steel'*, Indian Journal of Engineering & Materials Sciences, Vol. 17, April 2010, pp. 91-98

[6] **Vishal J Nadpara et al. (2014)** 'Optimization of EDM Process Parameters Using Taguchi Method with Graphite Electrode', International Journal of Engineering Trends and Technology (IJETT) Vol. 7, Number 2, pp. 48-51, ISSN: 2231-5381

[7] **Rao P.S., Kumar J.S, Reddy K., Reddy B**., Parametric Study of Electric Discharge Machining of AISI 304 Stainless Steel, International Journal of Engineering Science and Technology, Vol. 2(8), **2010**, 3535-3550.

[8] **Nilesh M. Vohra (2013)** 'Optimization of Cutting Parameter in EDM using Taguchi Method', International Journal of Scientific Research (IJSR) Vol. 2, Issue. 1, pp. 90-95, ISSN: 2277-8179

[9] **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

[10] **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

[11] **Ahsan *Ali Khan, Mohammad Yeakub Ali and Md. Mohafizul Haque (2009);*** 'a Study of Electrode Shape Configuration on the Performance of Die Sinking EDM.' *International Journal of Mechanical and Materials Engineering (IJMME), Vol. 4 (2009), No. 1, 19 -23.*

[12] **Lin, y. - Cheng, C.-. Su, B.-. And Hwang, L.-. 2006**. Machining characteristics and optimization of machining parameters of SKH 57 high-speed steel using electrical discharge machining based on Taguchi method.

Materials and Manufacturing Processes, 21(8), 922-929.

[13] **Yusuf Keskin *et al (2005);*** 'an experimental study for determination of the effects of machining parameters on surface roughness in electrical discharge machining (EDM)'.Received: 8 July 2004 / Accepted: 3 November 2004 / Published online: 29 June 2005 Springer-Verlag London Limited 2005

[14] **Singh, P.N., Raghukandan, K., Rathinasabapathi, M. And Pai, B.C., 2004**. 'Electric dischargemachining of Al-10% sicp as-cast metal matrix composites' .Journal of Materials Processing Technology, 155-156(1-3), 1653-1657.

[15] **Puertas I., Luis C.J., Alvarez L**., 'Analysis of the influence of EDM parameters on surface quality, MRR and EW of WC-Co', Journal of Materials Processing Technology, 153-154 (**2004),** 1026-1032.