International Journal of Materials Science
ISSN 0973-4589 Volume 12, Number 2 (2017), pp. 307-314

http://www.ripublication.com

Analyses of Output Parameters of ECDM Using Different Abrasives – A Review

Balwinder Singh and Rahul O. Vaishya

Department of Production & Industrial Engineering,
PEC University of Technology, Chandigarh, India

Abstract

The specific requirements of Advanced materials in Advanced industries like nuclear reactor, Automobiles, Aeronautic have raise the need of Advance machining processes which can machine such materials with high material removal rate as well as desired surface quality. Electrochemical discharge machining (ECDM) is one of the hybrid advance machining processes which have potential to machine advance materials with good surface quality desired by Industries. The selection of parameter for higher Material removal rate, higher Surface finish and minimum Tool Wear Rate is very essential during ECDM. In this present review Paper, a study of the effective Parameters of ECDM has been carried out with their specific role in Material removal; Surface Finish and Tool wear Rate. The optimized range of parameters by different optimizing techniques has been summarized.

Index Terms- Optimization Techniques, Electrochemical Discharge Machining, Material Removal Rate, Surface Finish, Tool Wear Rate.

I. INTRODUCTION

Advanced Machining Processes came into need in the advanced industries like nuclear reactors, aeronautics, automobiles, therefore the demand increases for the material which have high strength temperature resistant (HSTR) alloys. To enhanced the capabilities of the machining processes, two or more than two machining process are combined to take advantage of the worthiness of the constituent processes are called hybrid processes . Electrochemical machining process is also one of the hybrid processes which combine the Electro Chemical Machining (ECM) and Electric Discharge Machining (EDM) process together. It can be used for machining electrically non-conductive advanced engineering materials such as glass and ceramics. Electrochemical discharge machining process are mainly for micro-machining and scribing hard and brittle non-conductive materials such as glass (mainly Pyrex, plexi and optical) ceramic, refractory bricks, quartz and composite materials which examines the influence of electrolyte concentration, voltage and tool tip geometry on material removal rate and condition of machined surface. In ECDM process gap is controlled with automatic feed mechanism by a low speed motor. The KOH electrolyte gives a smaller machining gas than a NaOH solution which results in the increases of Material Removal Rate.

The empirical mathematical model, showing the influence of the process parameters on the electrode tool wear, MRR and the shape accuracy of the machined hole.The EDM and ECDM process are similar regarding the formation of craters on the work piece, along the re-casting effects which caused by the sparking actions . The process parameters were applied voltage, electrolyte concentration and the inter-electrode gap and the effective parameters were minimum radial overcut (ROC) and minimum heat affected zone (HAZ). Hybrid machining processes (HMPs) are developed to enhance the material removal rate (MRR) increases the capabilities of the constituent process.

In the present review paper, the various Input parameters with their effect on Material Removal Rate, Surface Finish (SF) and Tool Wear Rate (TWR) have been discussed. The optimized value of their parameter by various optimization techniques has been summarized.

II. ECDM PROCESS

The working principle in ECDM process involves the combination of thermal and chemical mechanisms electrically. The two electrodes are immersed in the electrolyte solution which helps in the formation of hydrogen gas and vapour bubbles. The cathode (tool) is chosen with a much smaller surface than the anode (auxiliary electrode). When the D.C voltage supply is applied, electrolysis happens and an insulating layer of gas bubbles are formed at the tool electrode (cathode) and oxygen bubbles at the counter electrode (anode).

When the voltage is increased, the density of sparks increases and more and more bubbles grow, forming a bubbles layer around the electrodes. The non-conducting workpiece is placed at the sparking area and tool always touches the workpiece which is controlled by the fixture.

The spark generation results in the material removal from the non -counting material. The various parameters of ECDM for a workpiece and tool combination and their effect on MRR, SF, and TWR have been listed in TABLE 1.

Table 1: The Input Parameters and their Effect on MMR, SF and TWR during ECDM

SN	WORKPIECE MATERIAL	INPUT PARAMETER	TOOL MATERIAL	RANGE	OUTPUT PARAMETERS			REPORTED BY
					MRR	SF	TWR	
1.	Glass(Pyrex)	Voltage Elec.con Pulse	-	Voltage:20-45V Elec.con:5-40(wt %) Pulse:0-80(µs)	Increases with DC voltage, Elec.temp depending upon the work piece material.	-	Increases with voltage	Facio and Wuthrich [9]
2.	Glass(Pyrex)	Voltage Elec.con	Stainless Steel, Tungsten carbide and Tungsten	Voltage: less than 30V Elec.con:20-40(wt %)	Increases with use of KOH as electrolyte	Surface roughness up to 39.73 to 45.95 to91.22 mm	Least tool wear in tungsten carbide electrode	Cheng-kung [6]
3.	3D-micro-structures of glass(Pyrex glass)	Electrolyte concen.,Pulse on/off ratio, Applied voltage ,feed rate in drilling process	Tungsten carbide used as cathode	Electrolyte(KOH): 30%wtg Pulse voltage:30V Pulse ratio;1ms/1ms	-	Poor surface finish when voltage is high	-	Xuan Doan cao Hyun [10]
4.	Quartz	Open voltage, Gap voltage, Peak current, Duty floor, Rotational ,speed	Auxiliary electrode(graphite)	Open voltage(v):150 Gap voltage(V):100 Peak current(A):3 Duty Factor:50	High material removal rate is achieved	Spherical electrode have advantage in enhancing the shape accuracy of the micro-through hole	Cylindrical electrode shows tool wear marks	Cheng-yang-Jung [11]
5.	Pyrex Glass composed mainly SiO_2(83 %), B_2O_3(10 %), Al_2O_3 (3 %)	Applied Voltage, Electrolyte concen, Rotational speed	Anode Auxiliary electrode(graphite) Cathode (Tungsten carbide)	Applied Voltage(V):30-45, Electrolyte conce.:6M(KOH), Rotational speed:500rpm	High material removal rate is achieved	Smooth surface finish	-	Chih-cheng-chao-chung [12]

6.	Optical glass and Quartz bars	Applied voltage Electrolyte concen.	-	Applied voltage (V):45-90, Electrolyte concen: 5M,	MRR can be obtained using the duty factor0.53,f=200 Hz,MRR= $0.06mm^3/min$	Less surface roughness and better transparency (Ra)=3.5µm	-	W.Y Peng and Y.S Liao [13]
7.	Borosilicate Glass	Applied Voltage, Peak Current Electrolyte Conc. ,Graphite conc.	-	Applied Voltage(V):35, Peak Current(A):1.1 Electrolyte Conc.(wgt%):30 ,Graphite powdercon.:.5-2wgt%	MRR improved using rotational tool	Surface roughness Ra=1.44µm	-	Min-Seop Han, Byung-Kwon Min , Sang Jo Lee [14]
8.	Quartz	Applied Voltage, duty factor, Surfactant, Electrolyte concen.	Tungsten Electrode	Applied Voltage(V):50-70, duty factor:0.75, Electrolyte concen.:6M(KOH)	Lower surfactant gives low machining	Better surface Quality but little oversized holes are drilled with higher engraving speed	-	Y.S Laio L.C Wu,W. Y Peng [15]
9.	Silicon nitride ceramics	Applied Voltage, Electrolyte. Concen. Inter-electrode Gap	Stainless Steel	Applied Voltage(V):50-70, Electrolyte Concen.(wgt):10-30 Inter-electrode Gap(mm):20-40	Effective MMR on the combination of 80V and 25%NaOH	-	-	Bhattacharya [4]
10.	Metal matrix composite Aluminum alloy,20 %Sic	Current Voltage Pulse duration	Cylindrical steel tool	Current:0.5-5(A) Voltage:20-120(V) Pulse duration:4-400(µs)	Increase in MRR.	Surface finish is poor	-	Lui [8]
Legend : MRR = Material removal rate, MR = Material removal, TWR = Tool wear rate,TW = Tool wear, M/c = Machining, Dia = diameter, V = Voltage, Vc = Critical Voltage, g/l = grams/litre, A = Ampere, Hz =Hertz, Elec. Con. = Electrolyte concentration, mm = millimeter, SR = Surface roughness, mN = 10-3 Newton, µRa =Roughness average in microns, Rw =Energy partition, MMC = Metal matrix composite, SiC = Silicon carbide, , S= seconds.								

III. OPTIMIZATION OF PARAMETERS OF ECDM

The selection of optimum range of parameters is very necessary for better performance of ECDM. The approach adopted by design of experiment through the taguchi orthogonal array is very popular for solving optimization problems in manufacturing engineering. The ANOVA is also been used successfully in process optimization. It is difficult to solve the third order models hence, based on the second order polynomial equations, some mathematical models correlated the ECDM process parameters while machining nitride ceramic. The optimized value of influencing parameters with applied optimization techniques has been listed in TABLE 2.

Table 2: Optimization Techniques and Influencing Input Parameters of ECDM

S.NO	OPTIMIZATIONTECHNIQUE	INPUT PARAMETERS	LEVELS	RESPONSE PARAMETERS	OPTIMUM VALUES OF INPUT PARAMETERS	INFLUENCING PARAMETERS	REPORTED BY
1.	Taguchi's standard L-4 Orthogonal array and ANOVA	Applied voltage, Electrolyte concentration, work feed rate	Two	Material Removal, Tool Wear	Applied voltage(80V) Electrolyte Conc.(50g/l) Work feed rate(6mm/min)	Applied voltage 94.078%	Jawalkar [3]
2.	Standard Orthogonal array(L9) and ANOVA	Applied voltage, Electrolyte concentration, Inter Electrode Gap	Three	Material Removal Rate, Signal to noise Ratio	Applied voltage(60V) Electrolyte Conc.(20g/l) Inter Electrode Gap(20mm)	Applied voltage 51.77%	Harugade [2]
3.	Taguchi Orthogonal arrayL9	Applied voltage, Electrolyte concentration, Inter Electrode Gap	Three	Material Removal Rate, Tool wear rate	Applied voltage(60V), Electrolyte concentration(30 %), Inter Electrode Gap(0.3mm)	Inter Electrode Gap 47.05%	Sathisha [16]
4.	Genetic Algorithm	Applied voltage, Electrolyte concentration, Inter Electrode Gap	Five	Radial overcut, Heat effect zone	Radial overcut minimum at Applied voltage(50V), Electrolyte concentration(20 g/l), Inter Electrode Gap(20mm)	-	Ruben [17]
5.	Taguchi Method L16(4^5) Orthogonal array and ANOVA	Applied voltage, Electrolyte concentration, Electrolyte flow, Bare tool tip length	Four	Material removal rate, Average depth of radial overcut	Applied voltage(20V), Electrolyte concentration(75 g/l), Electrolyte flow(150l/hr), Bare tool tip(1.5mm) length(	Applied voltage 53.88 %	Chigal[5]
6.	Standard Orthogonal Array L9	Applied voltage, Electrolyte concentration, Inter Electrode Gap	Three	Material Removal Rate, Signal to noise Ratio	Applied voltage(50V), Electrolyte concentration(15 %), Inter Electrode Gap(30mm)	Applied voltage 62.76%	B. Doloi and Bhattacharya [18]
7.	TLBO(Teaching Learning Based Optimization)	Applied voltage, Electrolyte concentration, Inter Electrode Gap	-	Material Removal Rate, Radial overcut, Heat effect zone	Applied voltage(50V), Electrolyte concentration(30 %), Inter Electrode Gap(20mm)	Applied voltage	RV Rao [19]

ANOVA= Analysis of variance,g/l= gram/litre,l/hr=litre/hour

CONCLUSION

This paper is review on the effective parameters in the processing of ECDM. The following facts can be concluded. MMC", International Journal of Machine Tool and Manufacturing, ScienceDirect vol 50, pp 86-96, September 2010.

1. It was found in the researches that applied voltage is the most influential parameter for Material removal rate.
2. Electrolyte concentration the secondary parameter affecting the MRR and Tool wear.
3. The optimization techniques are required to kwown the optimized value of parameter for better performance of ECDM.
4. The ECDM has capability to provide better results but selection and optimization of parameters is necessary.

*<u>**Methodology**</u> for further work will be based on usage of different types of abrasives in ECDM, some of these are as follows:

a) Silicon carbide
b) Alumina

Parameters to be analysed:

a) Optimum concentration of abrasive
b) Suitable abrasive under given conditions eg. Material of the work job.

REFERENCES

[1]. V.K Jain, "Advance Machining Processes", Allied Publishers Private Limited, 2010

[2]. M.L Harugade,M.V Kavade,N.V Hargude, "An Experimental Investigation of Effect Of Electrolyte Solution On Material Removal Rate in ECDM",International Journal of Engineering Research & Technology (IJERT) ,ScienceDirect vol 2 ,January 2013.

[3]. C.S Jawalkar, Apurbba Kumar Sharma, Pradeep Kumar, "Micromachining with ECDM: Research Potentials and Experimental Investigations", World Academy of Science, Engineering and Technology, ScienceDirect vol.61, pp.90-95, 2012.

[4]. B.Bhattacharya, B.N Doloi and S.K Sorkhel,. "Parametric analysis on electrochemical discharge machining of silicon nitride ceramics",ScienceDirect vol 28,873-881, May 2006.

[5]. Gaurav Chigal, Prof.Gaurav Saini, Prof.Doordanshi Singh, " A study on Machining of Al 6061/Sic (10%) Composite by Electrochemical Discharge Machining (ECDM) Process", International Journal of Engineering Research & Technology (IJERT), ScienceDirect vol 2. Jaurary2013.

[6]. Cheng-Kuang Yang, Chih-Ping Cheng, A.Chao-Chuang Mai, Acheng wang jung-chau hung and N.Biing-Hwa Yan, " Effect of surface roughness of tool electrode materials in ECDM Performance". International Journal of Machine tool & Manufacture ScienceDirect vol150, pp1088-1096, September 2010.

[7]. M. Coteaţă, L. Slătineanu, O. Dodun and C. Ciofu "Electrochemical discharge machining of small diameter holes". International Journal of Material Forming. ScienceDirect Vol.1, pp.1327-1330, 2008

[8]. Liu J. W., Yue T. M, Guo Z. N., "An analysis of the discharge mechanism in ECDM of particulate reinforced

[9]. Fascio V., Wuthrich R., Bleuler. H., "Spark assisted chemical engraving in the light of electrochemistry", Electrochemical Acta, 49, ScienceDirect 3997-4003, 2004.

[10]. Xuan Doan Cao, Bo Hyun Kim, Chong Nam Chu, "Micro-structuring of glass with features less than 100μm by electrochemical discharge machining",ScienceDirect vol 33 ,459–465, (2009).

[11]. Cheng-Kuang Yang, Kun-Ling Wu, Jung-Chou Hung, Shin-Min Lee, Jui-Che Lin, Biing-Hwa Yan, "Enhancement of ECDM efficiency and accuracy by spherical tool electrode", ScienceDirect vol 51,528–535, 2011.

[12]. Chih-Ping Cheng, Kun-Ling Wu, Chao-Chuang Mai, Cheng-Kuang Yang,Yu-Shan Hsu, Biing-Hwa Yan, "Study of gas film quality in electrochemical discharge machining", ScienceDirect vol 50 ,689–697, April (2010).

[13]. W.Y. Peng,Y.S. Liao, "Study of electrochemical discharge machining technology for slicing non-conductive brittle materials", 149 ,363–369, 2004

[14]. Min-Seop Han, Byung-Kwon Min, Sang Jo Lee, "Improvement of surface integrity of electro-chemical discharge machining process using powder-mixed electrolyte", ScienceDirect vol 191, 224–227, (2007).

[15]. Y.S. Laio, L.C. Wu, W.Y. Peng, " A study to improve drilling quality of electrochemical discharge machining (ECDM) process". vol. 6, pp609 – 614, 2013

[16]. Sathisha.N, Somashekhar.S.H, "Optimization of ECDM process Parameters using Taguchi Robust Design and Utility Concept", International Journal of Engineering Trends in Engineering and Development,, ScienceDirect vol 2 March 2013.

[17]. Ruben Phipon and B.B Pradhan, "Optimization of Electrochemical discharge machining process using genetic Algorithm",IOSR Journal of Engineering(IOSRJEN) , ScienceDirect vol 2 pp106-115 September 2012

[18]. B. Doloi, B. Bhattacharyya and S. K. Sorkhel, "Electrochemical Discharge Machining of Non-Conducting Ceramics", Defence Science Journal, ScienceDirect Vol 49, No 4, pp. 33 1-338, DESIDOC, August 1999,

[19]. R V Rao, V D Kalyankar, " Parameters optimization of advanced machining processes using TLBO algorithm", EPPM, Singapore, Science Direct pp 20-21 Sep 2011

[20]. Gaurav Kumar Sharma, Audhesh Narayan, "Thermal Modeling and Finite Element Analysis of Electro-chemical Spark Machining(ECSM) ", Proceedings of the National Conference on Trends and Advances in Mechanical Engineering, YMCA University of Science & Technology, Faridabad, Haryana, pp 19-20, Oct 2012.