IJCSE International Journal of Computer Sciences and Engineering Open Access
Review Paper Volume-5, Special Issue-2, Dec 2017 E-ISSN: 2347-2693

Electrochemical and Discharge Micro Machining: A Review

P.K Goyal[1], Kamal Singh[2], Sunil Kumar Bhati[3], Dilip Gehlot[4]

[1*]Govt. Engg. College Ajmer
[2]Govt. Engg. College Ajmer
[3]Govt. Women's Engg. College Ajmer
[4]Govt. Engg. College Ajmer

Available online at: www.ijcseonline.org

Abstract: Electrochemical micromachining is an advanced machining process that used for cutting complex shapes, 3-D profiles which is difficult for conventional machining**.** In the present work, reviews are conduct based on ECMM experimental investigations. The effect of ECMM process parameter on material removal rate (MRR), overcut (OC), kerf shape**.** Various optimization tools like Taguchi, Response surface methodology (RSM), as well as prediction tools like artificial neural network (ANN), finite element method (FEM), are implemented. ECMM offers several advantages including higher machining rate and better surface finish than another conventional machining process.

Keywords: ECMM, 3-D profile, ANN

INTRODUCTION

ECMM is one of the most potential non-traditional machining processes used for machining difficult to machine materials. The main application of ECMM is to produce blind complex cavities, curved surfaces, through cutting and large through cavities with excellent surface quality. ECMM is based on the principle of electrolysis. In this process, electricity is conducted in the metal by the free electrons but in an electrolyte, the conduction of electricity is achieved through the movement of ions. Many researchers have work on this process. Some of the reviews of their research are as follows.

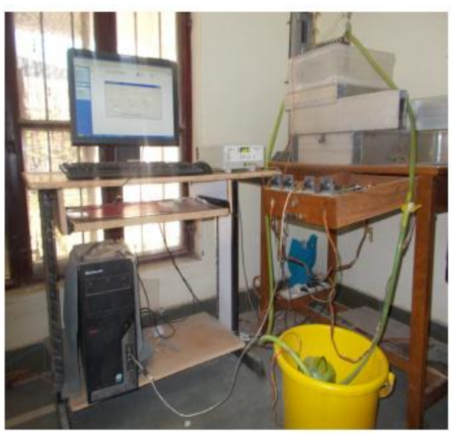

Fig.1: Electro-Chemical Micro Machining setup

ELECTROCHEMICAL MICROMACHINING BASED OVERVIEW

Datta and Harris [1] In this paper developed high-speed ECMM process for molybdenum mask fabrication and compared it to a conventional chemical etching process using ferricyanide solution. They concluded that metal removal rate in ECMM is of magnitude higher than that in chemical etching.

Dayanand Bilgi et al. [2] In this paper electrochemical deep hole drilling of the nickel-based superalloy done. The results have been confirmed for the profile of the drilled hole and MRR_1 obtained experimentally. In all the experiments, the mixture of NaCl and HCl are used as an electrolyte and through hole of 26mm depth and diameters ranging from 2.0205mm to 3.279mm were drilled.

F. Klocke et al. [3] In this study investigated the machinability of selected modern titanium and nickel-based alloys for aero engine components. In ECM the experimental results of feed rate as a function of current density for an ECM sinking operation with a cylindrical tool electrode and external flushing are compared to the theoretical dissolution behavior according to Faraday's law of electrolysis. Furthermore, surface properties were examined in terms of SEM and EDX analysis of the rim zone.

K.P. Rajurkara et al. [4] Recent advancements in various aspects of electrochemical and electro-discharge machining that reflect the state of the art in these processes are presented in this paper.

Bhawana Bisht et al. [5] carried out the experimentation to optimize the material removal rate and surface roughness. An experiment conducted on mild steel and aluminum. The metal removal rate was considered as the quality characteristics with the concepts of "The larger the better" and surface roughness was considered with the concepts of "The smaller the better". **Kanhu Charan et al. [6]** in optimizing the surface roughness and MRR by the Taguchi technique. Experiment result of MRR and Surface Roughness was predicted by the Multi-Layer Feed Natural Network (MFNN) and Least square support vector machine (LSSVM). In this process, a low voltage (5-25V) is applied across two electrodes with a small gap size (0.1mm-0.5mm) and with a high current density around 2000 A/cm^2**.** Electrolytes NaCl+H_2O flow through the gap with a velocity of 20-30 m/s. EN19 tool steel material used as the workpiece for experiments.

From the Fig.2 SEM micrograph, it may be observed that a lower value of electrolyte concentration with higher machining voltage and moderate value of pulse on time will produce a more accurate shape with less overcut at moderate MRR.

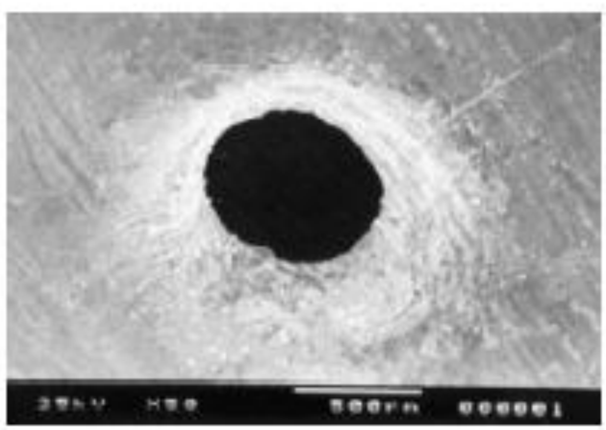

Fig.2: shows an SEM micrograph of micro-hole machined by ECM

R. Goswami et al. [7] in this paper Taguchi method with three parameters and the level is applied to find optimum process parameters for Electrochemical machining (ECM). The parameters used as voltage, tool feed, and current.

D. Chandrasekaran A.Vanu Gopal [8] investigate the effect of parametric optimization of process parameters for electrochemical machining of EN-31 steel using grey relation analysis.

Rama Rao and Padmanabhan [9] in this paper application of Taguchi method is used for the optimization of process parameters. Taguchi parameter design can successfully verify the optimal cutting parameters V= 20V, feed rate = 0.3 mm/rev and concentration = 30 g/l. It is noted that the metal removal rate increase with voltage, feed rate and electrolyte concentration in electrochemical machining.

C. Senthilkumar et al. [10] shown an influence of input parameters on ECMM characteristics such as MRR and surface roughness. The electrolyte used for experimentation was afresh aqueous solution of sodium nitrate ($NaNO_3$) with varying electrolyte concentration and workpiece was used LM25AL/10%SiCp composite.

M. Datta and D. Landolt [11] studied the effect of electrolytes like chloride, chlorate and nitrate solutions used in ECM. They concluded that electrolyte flow conditions play an important role in the obtained surface finish. They also studied the effect of pulsating current on high rate trans-passive dissolution of Ni.

Bhattacharyya et. al. [12] The electrolyte concentrations commonly used range from around 30 g/L to 35 g/L and a pH of around 7 that can enhance the dissolution of metal without affecting the micro tool. By using an electrolyte with a lower concentration, the inter-electrode gap could be reduced resulting in improved accuracy shown in fig.3.

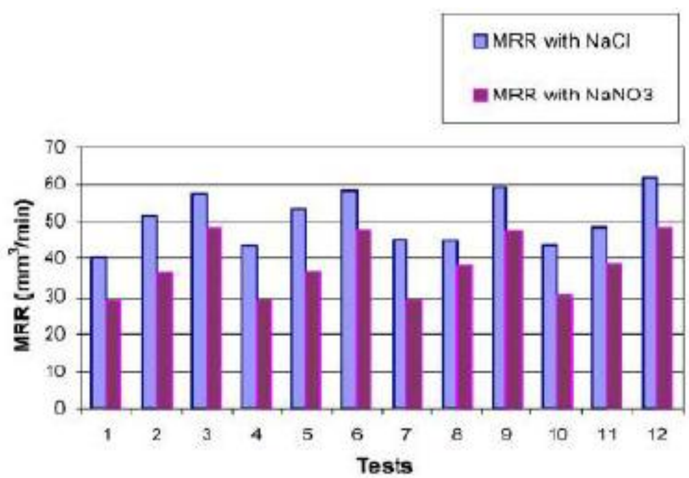

Fig.3: MRR for different electrolyte [12]

Qu Ningsong et al. [13] The optimal combination level of the machining parameter is electrolyte 2.5%NaCl+2.5%$NaNO_3$, 5 mm nozzle workpiece distance, 87 m/s electrolyte flow rate, 18V working voltage and 1.8 mm/min wire feed rate, machining voltage, electrolyte concentration etc. The experimental result shows that WECM with axial electrolyte flushing is a promising issue in the fabrication of titanium alloys. The machining productivity of wire electrochemical machining could be improved by multi-wire electrochemical machining.

R.Thanigaivelana et al. [14] this paper describes the Electrochemical Micromachining (EMM) of stainless steel with acidified sodium nitrate. All Experiments of EMM done on a stainless plate by using

160 μm thick conical tip shape tool electrode. The electrolyte is used as Sodium nitrate ($NaNO_3$) and Acidified sodium nitrate (0.05mole of H_2SO_4 +$NaNO_3$) of varying concentration.

Rajurkar et al. (2004) [15] used pulse electrochemical micromachining process for generating complex shapes and possibly 3-D micro components of high accuracy.

B. H. Kim [16] Micro Electrochemical Machining presented. 0.1 M sulfuric acid was used as an electrolyte and 3D microstructures were machined on 50 um thick stainless steel plate by micro ECM. To prevent taper, a disk-type electrode was introduced.

E. Rosset and D. Landolt [17] is worked on electrochemical micromachining through photoresist masks of SS304 and Phynox using a jet cell and a neutral $NaNO_3$ electrolyte. For this a 500 mm thick SS304 plate was chemically etched in a $FeCl_3$ salt spray under industrial conditions then the profile is elliptical and slightly asymmetric.

Suresh H. Surekar [18] is conducted the experimental process to optimize parameters which affecting to the material removal rate of Hastelloy c-276. Three parameters are used in experiments feed rate, electrolyte flow rate and voltage. In this paper observed that feed rate is the more affecting parameter to the material removal rate.

Jain and Jain [19], studied that, the optimization of ECM process parameters like applied voltage, electrolyte flow velocity, and tool feed rate, were optimized through single objective GA.

Asokan et al [20] propose a practical method of optimizing cutting parameters for ECM based on multiple regression models and Artificial Neuron Network (ANN) model are presented in this paper. Current, voltage, flow rate, and gap have been considered as machining parameters. The geometry, condition, and accuracy of the machined surface depend on the electrolyte salt type concentration, machining gap, pulse power supply setting, flow velocity, and flow profile.

H.Hocheng et al [21] The authors discuss the influences of machining time, electrolyte Concentration, voltage, the interelectrode gap the amount of material removal and diameter of hole shown Fig 4. The material removal increases with increasing electrical voltage, the molar concentration of the electrolyte, machining time and reduced initial gap.

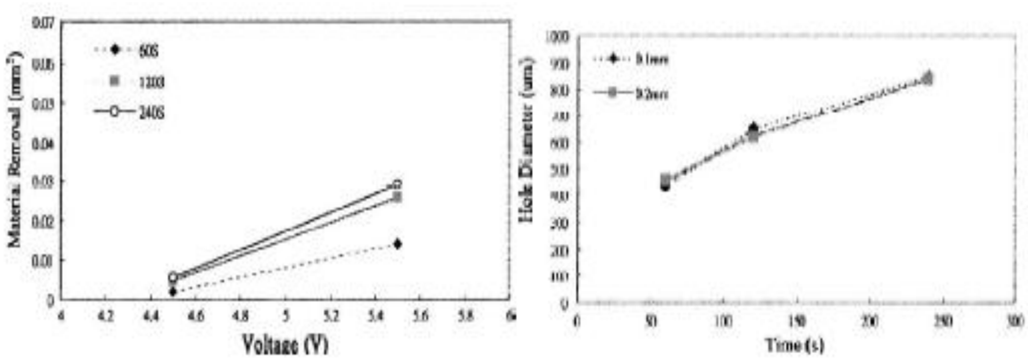

Fig.4: Variation in MRR and Hole diameter for different parameters

In Fig.5 the produced diameter must be investigated for effective control of the final dimension at various machining conditions, which is a major concern of manufacturing engineer. The effect of machining time on the cavity size is shown Fig 6. The hole is obviously enlarged by machining time since the material removal takes place continuously.Fig. 6 shows a computational model is proposed to predict the erosion profile during ECM process in use of a simple flat-end electrode at voltage = 6V, electrolyte Consistency= 2.5M, gap = 0.25 mm, diameter of the electrode = 0.3 mm. The simulation agrees with the experimental results.

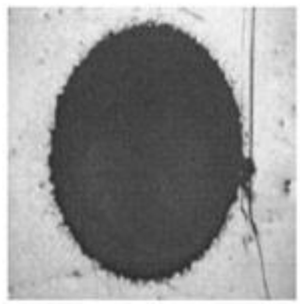

Fig.4: Micrograph of machined hole top: 240,5M,0.1mm

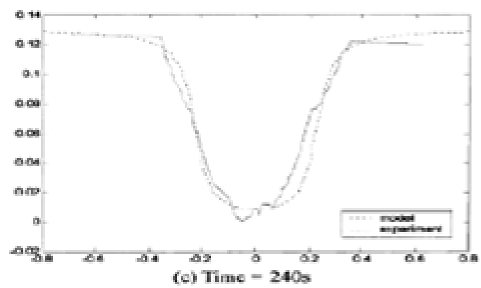

Fig.5: Predicted and experimental erosion profile

The authors also discuss the influences of machining time, electrolyte concentration, voltage, the interelectrode gap on the amount of material removal and diameter of the hole.

Mount et al [22] lay emphasis on analyzing the current transients during ECMM. The set up allows calculating the current at different time interval. This help in determining important parameter in ECMM. Using finite difference process simulation, it has been shown that these parameters can be used in the simulation of nonplanar configurations applicable to practical ECM.

Cheng-Kuang Yang et al [23] proposes the use of tool electrode with a spherical end instead of cylindrical tool electrode in ECMM. It was found that by using the spherical tool tip electrode machining time is reduced by 83% and hole diameter also decreases by 65%.

Chan-Hee Jo et al. [24] presented this paper, in which the application of micro electrochemical machining (ECMM) for the micromachining of internal features is investigated. Fig. 6 shows the relationship between the pulse on-time and the machining gap. The figure shows that the machining gap increases as the pulse on-time increases. Consequently, an increase in the machining gap offers the possibility of making a reverse-tapered hole by controlling the pulse duration. However, when the pulse on time was longer than specific duration (160 ns for this experiment), the machined surface was rough.

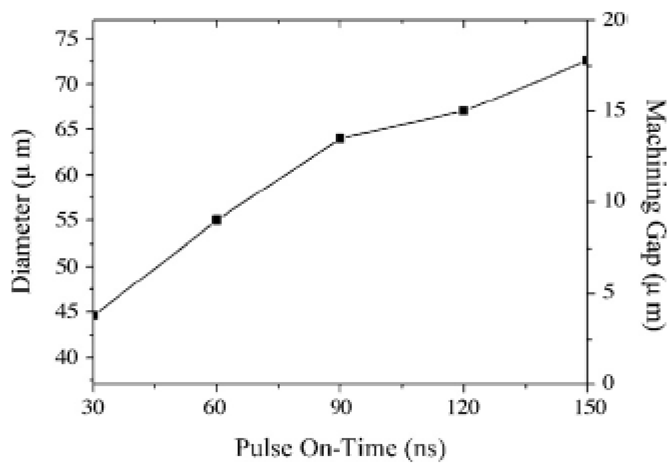

Fig.6: Machining gap and diameter variation with pulse on time [26]

V.K. Jain & V.N. Nand [25] presented a paper on the side wall generated during electrochemical drilling (ECD) of a cylindrical hole is tapered. From the analysis of the results, it was found that bare bit tool or coated tool generate less taper as compared to the taper produced by the bare tool.
V. K. Jain et al [26] presented a paper, in which models SBFET-II (one-dimensional analysis) and SBFET-22 (two-dimensional analysis), based on finite element technique, have been proposed.
H. Hocheng and P. S. Pa [27] This paper review in Electrochemical drilling slow relative rotary motion between the electrodes help in producing holes of the better profile.
Min-Seop Han et al [28] in this paper suggested the use of power-mixed electrolyte in electrochemical discharge machining. Powders used in the electrolyte are conductive particles.Graphite powder is generally mixed with the electrolyte is termed as powder mix electrolyte.

CONCLUSION

Recent advancements in various aspects of electrochemical and electro-discharge machining that reflect the state of the art in these processes are presented in this paper. ECM and EDM technologies have been successfully adapted to produce macro, micro-components with complex features and high aspect ratios for biomedical and other applications.

Following conclusion can be drawn in this review paper. Machining performance can be evaluated by considering MRR, overcut as a response which effects with various process parameter like voltage inter-electrode gape, machining time etc.

The 3D profile can easily cut through ECMM and crater shape prediction by FEM and ANN.

REFERENCES

[1]. Datta, M., Harris, D., "Electrochemical micromachining: An environmentally friendly, high-speed processing technology." ElectrochimicaActa., 42: 3007-3013. (1997).

[2]. Suresh H. Surekar, Sudhir G. Bhatwadekar, and Dayanand S. Bilgi, "Analysis of electrochemical machining process parameters affecting material removal rate ofHastelloy c-276", International Journal of Advanced Research in Engineering andTechnology (IJARET), ISSN 0976 – 6480(Print), ISSN 0976 – 6499(Online) Volume 5,Issue 1,January (2014), pp. 18-23.

[3]. F. Klocke, M. Zeis, A. Klink and D. Veselovac, "Experimental research on the electrochemical machining of modern titanium and nickel-based alloys for aero engine components", Available online at www.sciencedirect.com, Procedia CIRP 6 (2013) 368–372.

[4]. K.P. Rajurkar, M. M. Sundaram, and A. P. Malshe, "Review of Electrochemical and Electro-discharge Machining", Available online at www.sciencedirect.com Procedia CIRP 6 (2013) 13 – 26.

[5]. Bhawna Bisht, Jyoti Vimal, and Vedansh Chaturvedi, "Parametric Optimization of Electrochemical Machining Using Signal-To-Noise (S/N) Ratio", International Journal of Modern Engineering Research (IJMER) www.ijmer.com Vol.3, Issue.4, Jul - Aug. 2013 pp- 1999-2006 ISSN: 2249-6645.

[6]. Kanhu Charan Nayak and Rajesh Kumar Tripathy, "Taguchi integrated Least Square Support Vector Machine an alternative to Artificial Neural Network analysis of Electrochemical machining process", IOSR Journal of Mechanical and Civil Engineering (IOSRJMCE) ISSN: 2278-1684 Volume 1, Issue 3 (July-Aug 2012), PP 01-10.

[7]. R.Goswami, R. Chouhan, and V. Chaturvedi, "The implementation of Taguchi approach On ECM process parameters for mild steel and aluminum", International Journal of Research in Engineering & Applied Sciences, IJREAS Volume 3, and Issue 2 (February 2013) http://www.euroasiapub.org ISSN: 2249-3905.

[8]. D.Chakradhar and A. Venu Gopal, "Multi-Objective Optimization of Electrochemical machining of EN31 steel by Grey Relational Analysis", International Journal of Modeling and Optimization, Vol. 1, No. 2, June 2011.

[9]. Rama Rao. S and Padmanabhan. G, "Application of Taguchi methods and ANOVA in optimization of process parameters for metal removal rate in electrochemical machining of Al/5%SiC composites", International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622 www.ijera.com Vol. 2, Issue 3, May-Jun 2012,pp. 192-197.

[10]. C. Senthil Kumar, G. Ganesan, and R. Karthikeyan, "Influence of Input Parameters on Characteristics of Electrochemical Machining Process", International Journal of Applied Science and Engineering (2013). 11, 1: 13-24.

[11]. M. Datta and D. Landolt, "On the role of mass transport in high rate dissolution of iron and nickel in ECM electrolytes i. chloride solutions, vol. 25, pp. 1255–1262, 1980

[12]. Bhattacharyya, B.; Malapati, M.; and Munda, J. (2005). "Experimental study on electrochemical micro machining." Journal of Materials Processing Technology (v169,n3), pp485-492.

[13]. Qu Ningsong, Fang Xiaolong, Li Wei, Zeng Yongbin and Zhu Di, "Wire electrochemical machining with axial electrolyte flushing for titanium alloy", Chinese journal of Aeronautics, 2013, 26(1): 224–229.

[14]. R.Thanigaivelan, RM.Arunachalam, B.Karthikeyan, and P.Loganathan, "Electrochemical Micromachining of stainless steel with acidified sodium nitrate electrolyte", Available online at www.sciencedirect.com Procedia CIRP 6 (2013) 351 – 355.

[15]. K.P. Rajurkar, M. M. Sundaram, and A. P. Malshe, "Review of Electrochemical and Electro-discharge Machining", Available online at www.sciencedirect.com Procedia CIRP 6 (2013) 13 – 26.

[16]. Chan-Hee Jo, Bo Hyun Kim& Chong Nam Chu,"Micro electrochemical machining for Complex internal micro-features", CIRPAnnals-Manufacturing Technology 58 (2009) 181–184.

[17]. E. Rosset, M. Datta & D. Landolt,"Electrochemical dissolution of stainless steels inflow channel cells with and without photoresist masks", Journal of Applied Electrochemistry 20 (1990) 69-76.

[18]. Suresh H. Surekar, Sudhir G. Bhatwadekar, and Dayanand S. Bilgi, "Analysis of electrochemical machining process parameters affecting material removal rate of Hastelloy c-276", International Journal of Advanced Research in Engineering andTechnology (IJARET), ISSN 0976 – 6480(Print), ISSN 0976 – 6499(Online) Volume 5,Issue 1,January (2014), pp. 18-23.

[19]. N. K. Jain and V. K. Jain, "Optimization of Electro-Chemical Machining Process Parameters using Genetic Algorithms", Journals of Machining Science and Technology, 2007, pp.235–258.

[20]. P. Asokan, R. Ravi Kumar, R. Jeyapaul& M. Santhi,"Development of multi-objective optimization models for electrochemical machining process", Int. Journal of Advanced Manufacturing Technology(2008) 39:55–63.

[21]. H. Hocheng, Y.H. Sun, S.C. Lin & P.S. Kao", A material removal analysis of electrochemical machining using flat-end cathode", Journal of Materials Processing Technology 140 (2003) 264–268.

[22]. A.R. Mount, D. Clifton, P. Howarth& A. Sherlock,"An integrated strategy for materials characterization and process simulation in electrochemical machining", Journalof materials Processing Technology 138 (2003) 449–454.

[23]. Cheng-Kuang Yang, Kun-LingWu, Jung-ChouHung, Shin-MinLee&Jui-CheLin, Biing- HwaYan,"Enhancement of ECDM efficiency and accuracy by spherical tool electrode", International Journal of Machine Tools & Manufacture 51 (2011) 528–535.
[24]. Chan-Hee Jo, Bo Hyun Kim& Chong Nam Chu,"Micro electrochemical machining for complex internal micro-features",CIRPAnnals-Manufacturing Technology 58 (2009) 181–184.
[25]. V.K. Jain and V.N. Nand,"Analysis of taper produced inside zone during ECD",January1986 VOL 8 NO 1.
[26]. V. K. Jain, P. G. Yogendra and S. Murugan,"Prediction of Anode Profile in ECBD and ECD Operations",Int. Math.ToolsManufact.Vol. 'No. I. p. 113-.134, 1987
[27]. H. Hocheng& P. S. Pa, "A review of electrode design for electrochemical drilling and electropolishing of holes", current topics in electrochemistry vol 12 2007.
[28]. Min-Seop Han, Byung-Kwon Min & Sang Jo Lee,"Improvement of surface integrity of electro-chemical discharge machining process using powder-mixed electrolyte",Journal of Materials Processing Technology 191 (2007) 224–227.