A STUDY ON INPUT PARAMETERS AFFECTING METAL REMOVAL RATE AND SURFACE ROUGHNESS IN ELECTROCHEMICAL DISCHARGE MACHINING PROCESS

Parvesh Antil[1], Dr. Sarbjit Singh[2], Dr. A.Manna[3]

[1,2,3]*ME Department, PEC University of Technology, Chandigarh, (India)*

ABSTRACT

In current world, the technology has changed the full state of the manufacturing industries. Electrochemical discharge machining process is an untraditional hybrid machining process typically used to machine electrically non-conductive materials. The research work related to significant factors concerning the processing of such kind of materials has increased. The main aim of this paper is to present a literature survey on the factors which affects the metal removal rate and surface finish in machining of electrically non-conductive materials. The main factors say inductance and powder mixed electrolyte are examined. The conclusion specifies that the controlled usage of inductance lays active outcome on the metal removal rate and machining rate. Electrolyte with contents of powder decreases the surface roughness of the machined surface.

***Keywords*: ECDM, Non-Conductive Materials, Inter Electrode Gap, Metal Removal Rate**

I INTRODUCTION

The untraditional machining processes are becoming popular because of their flexibility and controlled parameters. Electrochemical discharge machining process provides a feasible substitute of traditional machining for processing of electrically nonconductive materials. Electrochemical discharge machining which is hybrid process machining works when the voltage which is supplied to the circuit crosses the critical limit and discharge initiates between the electrode & surrounding electrolyte. With the time, a lot of new parameters have been introduced to enhance the performance of the process. Slots, complex surfaces and micro-holes can be produced in large numbers, in a single work piece with the help of ECDM. These actions are also performed by using traditional machining techniques but the problems generally faced are tool wear, rigidity problem of the tool and heat generation at the tool and work piece interface. Sometimes, it is difficulty to produce complex shapes by using traditional techniques [1]. The influential factors of bubbles reaction are ion translation rate, the electrolyte immersing depth and the concentration of the alkali [2]. The ultra-short pulses and high off-time group pulses are suggested for enhancing the accuracy and surface finish [3]. A number of researches have been conducted on different parameters to check the positive change in the machining speed and metal removal rate. Previously, FEM centered thermal model was used to validate metal removal rate of soda lime glass work piece and alumina work piece which shows MRR increase with increase in duty factor and energy partition for both work pieces. The increase in MRR is found to increase with increase in electrolyte concentration due to ECDM of soda lime glass work piece material. Also, the change in the value of MRR for soda lime glass with concentration is found to be more than that of alumina. As the duty factor and energy partition increases, MRR also increases for both soda lime glass and alumina work piece material [4]. Even though this technology presents several interesting properties like easiness, flexibility and the opportunity to achieve very smooth machined surfaces but it has one severe weakness that is reproducible machining is very rare to achieve. The unstable gas film around the tool electrode is formed in which the necessary electrical discharges for machining take place. Machining on same assembly with same circumstances results in varied distributed patterns and also gas film repetitively fluctuates. By lowering the critical voltage, machining at lower voltage is possible and additional reproducible machining can be achieved by adding liquid soap into the electrolyte but machining time rises [5]. The opportunities of using ECDM technology are studied from several sides.

II BASIC PRINCIPLE AND EXPERIMENTAL MECHANISM

The ECDM process which was introduced in the early 1990s has now emerged as an important untraditional machining process. The processing of work piece starts with the discharge between anode and cathode. The early stage of the process starts in the middle of 20th century but the thought of using it for machining non-conducting materials by revealed by Karafuji and Suda [6]. As the process was getting its edge the numerous researcher starts working in this new field. A supplementary comprehensive investigation of material removal during ECDM and other treatments of ECD were presented by Allesu [7]. As far as the working is concerned it works when the voltage is provided past critical limit to the circuit and discharge initiates between the electrode and adjacent electrolyte. Electrochemical discharge machining process is a joint effect of two processes namely electro-chemical machining (ECM) in which metal is removed by electrochemicalprocess used for machining of extremely hard electrically conductive materials and electrical discharge machining (EDM) in which metal is removed by quick current discharges between two electrodes which are separated by a dielectricliquid and subject to an electric voltage. From the analysis of the effect of ECM, it has been found that the following two types of reactions typically follow in the system [8]:

(i) Electrochemical reactions at the electrode
(ii) Chemical reactions in the electrolyte

The electrochemical reaction occurs at the metal electrolyteboundary layers and the transfer of ions in the electrolyticsolution takes place by dispersion, movement in an electrical field and convection in the flow. The usual types of reaction at the cathode are [9]:

(i) Plating of metal ions

$M^+ + e^- \rightarrow M$

(ii) Evolution of hydrogen gas

$2H^+ + 2e^- \rightarrow H$ (in acidic solution)

$2H_2O + 2e^- \rightarrow 2\,(OH)^- + H_2$ (alkaline sol.)

There will be two types of anodic reaction:

(i) Dissolution of metal ions in the electrolytic solution

$M^{-} \rightarrow M^{+} + e$

(ii) Oxygen gas evolution at the auxiliary electrode surface

$2H_2O \rightarrow O_2 + 4H^{+} + 4e^{-}$ (acidic electrolyte)

$4(OH)^{-} \rightarrow 2H_2O + O_2 + 4e^{-}$ (alkaline electrolyte)

The voltage is supplied beyond critical limit to the circuit and discharge initiates between the electrode & surrounding electrolyte. But in reality the working of this hybrid machining process starts with the action of the gas bubbles which are formed after the reaction of the electrode with electrolyte solution. These bubble acts as a layer between tool and work piece which further help in sparking and removes the metal in the form of erosion. The rate of generation of hydrogen gas bubbles is very high in the vicinity of the tool. The tool is immersed to 2±3 mm below the upper level of the electrolytic solution. The metal removal rate in ECDM is lower because of the larger inter electrode gap. The voltage at which the sparking starts will depend upon the concentration and conductivity of the electrolyte and the tool geometry. The leading mechanism in the process is confined heating of the work-piece by the electrochemical discharges. Material removal is attained by concentrated heating of the work piece surface which in result initially melts and then vaporization takes place. The smoothening effect is given with the help of chemical action. So basically the metal removal rate includes following main steps [10]:

- electrochemical discharges initiates melting and vaporization
- chemical etching at high-temperature
- random thermal stresses and micro cracking
- expanding gases and electrolytic effect gives mechanical blow

III SIGNIFICANCES OF INPUT PARAMETERS

The division and prominence of the cutting or machining of the materials depends on the changed parametric groupings of the machining parameters. Electrolytic concentration, current, voltage, conductivity of the working fluid etc. are some parameters which influence the metal removal rate and work piece surface in ECDM process. Some of the timeworn and some cutting-edge parameters are discussed in the continuing part of the research paper.

3.1 Effect on Metal Removal Rate

Most vital factor in the machining of any material with any process is the amount of metal removed throughout the process. There are a number of factors which affects the metal removal rate in the electrochemical discharge machining process.The controlled usage of parameters is really very important. The range of the parameters puts significant effect on the machined output. The metal removal rate increases with increase in supply voltage, increase in concentration of electrolyte and decrease in inter electrode gap [11]. The electrolytic concentration and voltage has a big role in affecting the MRR. For maximum material to be removed, the parametric combination of 70 V DC supply, 80 g/l electrolyteand at least 180 mm gap between anode and cathode is required [12].The metal removal rate in machining e glass fibre epoxy composite is lower when the gap between tool and anode is higher i.e. nearly 200 mm and the concentration of the electrode is lower i.e. 65 g/l [13]. During machining of glass, inductance affects the machining rate at different levels of electrolyte [14].In metallic contact opening, the regular discharge requires a voltage of the order of 10 V and the duration of the discharge depends on the voltage as well as the energy delivered by the inductance of the circuit. To calculate the theoretical metal removal rate it is necessary that value of L should be recognized which can be calculated as $L = L_o + L_1$. Here L_o is the inherent line inductance and L_1 is the additional inductance [15].In the most positive conditions, the electrical breakdown of the gases occurs when the lowest value of the voltage difference between the electrodes lies in the range of 280-300 V while in electrochemical discharge machining the discharge initiates in the voltage range of 20-40 V which cannot be categories as general electrical breakdown of gas and termed as switching process.The discharge duration satisfies the relationship: $t_d = 1/10\ L\ I_h$ where *L is the* circuit inductance [16]. It was observed earlier that circuit inductance plays an important role in material transfer during the switching of metallic contact [17].The ECDM phenomenon was analyzed as a switching process between the tool and electrolyte. It was found that an extra control parameter can be obtained by introducing an additional inductance in the circuit. It was clear that the machining rate decreases gradually with time and stops after reaching a particular depth. This is due to the transient bubble behavior at the tool-electrolyte interface. Therefore it was decided to opt for the calculation of a representative frequency. A high value of the added inductance (more than 200 mH), caused splashing of the electrolyte during discharge and as a result a decreased MRR was observed. Then it was finalized that the added inductance will be less than 200 mH for attaining better MRR.

3.2 Effect on Surface Roughness

The generation of the quality surface finish in the machining of electrically non-conductive materials in the electrochemical discharge machining process has been a thought-provoking problem. Different researchers have given different results regarding surface quality of the work piece. Manna et al. revealed that during micro drilling of e glass fibre epoxy composite, the surface generated was very deprived. The fibre instead get burnt and caused low quality surface finish. After different experiments it was clear that electrolytic concentration is a dominant parameter. In the ECDM process, the electrolyte plays an operative role in machining of materials. With controlled electrolytic concentration, the better surface of the work piece can be obtained. But during machining of high temperature resistant high strength aluminium oxide ceramics with the use of NaOH electrolyte, the surface obtained after the micro slicing was still irregular[18]. Spark ignition voltage decreases with the addition of conductive particles in the electrolyte. Graphite is commonly used for mixing in the electrolyte because of good thermal and electrical conductivity [19]. Then conductive powder mixed fluid was used to improve machining quality in electrical discharge machining processes. The main reason behind using powder mixed electrolyte is that the powder as a result of discharge energy dispersion, stabilizes the discharge current.The hydrogen film model and single particle charge model can explain the role of the particles in the electrolyte which decreases the spark ignition voltage [20-22]. The spark energy per single discharge pulse decreases due to critical breakdown strength which is reduced by the presence of conductive particles within the hydrogen film. This breakdown is because of local electric field intensification due to attachment on the tool electrode and dynamic particle movements. The dielectric strength of the film is reduced by the presence of conductive particle. In the accepted ECDM process, the locally concentrated spark energy causes irregularity of machined surface due to the micro cracks, local fracture, and breakage of the work piece. By use of the conductive particles (graphite powder), there were evident decreases of micro cracks and fractures on the machined surface of the work piece. The surface becomes fine and smooth at 0.5 and 1.0 wt. % powder concentration. However, when the concentration is above 2.0 wt. %, micro cracks were developed. The use of conductive particle in the electrolyte in electrochemical discharge machining process gives a better surface finish rather than using solo electrolyte concentration.

IV CONCLUDING REMARKS

The subsequent deduction can be drawn with concern to the effects of input parameters on the machining of electrically non-conductive materials:

- This machining process can be used to machine hard and brittle electrically non-conductive materials which are very difficult to machine with the help of traditional machining processes.
- Significant efforts have been made to understand the phenomenon of the metal removal mechanism in the electrochemical discharge machining process. The main factors which are discussed in the paper are inductance and electrolyte with conductive powder contents.
- The controlled usage of inductance and will increase the machining rate and enhances the metal removal rate in a very progressive manner.
- The surface eminence is powerfully increased with the usage of powder contents in electrolyte. Conductive particle mixed electrolyte decreases the micro cracks and fractures on the machined surface of the work piece.

REFERENCES

[1] B. Bhattacharyya, B. Doloi, P.S. Sridhar, Electrochemical micromachining: new possibilities for micro manufacturing, J. Mater. Process. Technol. 113 (2001) 301–305.

[2] W.Y. Peng, Y.S. Liao Study of electrochemical discharge machining technology for slicing non-conductive brittle materials Journal of Materials Processing Technology 149 (2004) 363–369

[3] B. Bhattacharyya, M. Malapati, J. Munda Experimental study on electrochemical micromachining Journal of Materials Processing Technology 169 (2005) 485–492

[4] K.L. Bhondwe, VinodYadava, G. Kathiresan Finite element prediction of material removal rate due to electro-chemical spark machining International Journal of Machine Tools & Manufacture 46 (2006) 1699–1706

[5] R. Wuthrich, L.A. Hof The gas film in spark assisted chemical engraving (SACE)—A key element for micro-machining applications International Journal of Machine Tools & Manufacture 46 (2006) 828–835

[6] H Karafuji, K. Suds, Ann. ClRP 16 (1968) 415

[7] K Allesu, Electrochemical discharge phenomena in manufacturing process, Ph.D. Dissertation, 1lT Kanpur, India, 1988

[8] B. Bhattacharyya, B. Doloi, S. Mitra, S.K. Sorkhel, Experimental analysis on the electrochemical discharge machining (ECDM) system for advanced ceramics, International Conference on Precision Engineering, ICPE, Taipei, Taiwan, 1997, pp. 715±720.

[9] V.K. Jain, P.S. Rao, S.K. Choudhury, and K.P. Rajurkar: "Experimental investigations into travelling wire electrochemical spark machining (TW-ECSM) of composites." Trans. ASME, Journal of Engineering for Industry 113(1991), p. 75.

[10] Micromachining using electrochemical discharge phenomenon: fundamentals and applications of spark assisted chemical engraving/Rolf Wuthrich, ISBN 978-08155-1587-6

[11] A.Manna , KawaljitKhas Micro Machining of Electrically Non Conductive Al_2O_3 Ceramic, Journal of Machining and Forming Technologies, vol. 1 2009, pp 101-112

[12] Alakesh Manna, VivekNarang, A study on micro machining of e-glass-epoxy composite by ECSM process, Int J AdvManufTechnol ((2012) 61:1191-1197

[13] Alakesh Manna, VivekNarang, An Experimental investigation during micro machining of e-glass- fibre epoxy composite on developed by ECSM setup, International Journal of Manufacturing, Materials and Mechanical Engineering,2(2)46-60, june 2012

[14] IndrajitBasak, AmitabhaGhosh, Mechanism of metal removal in electrochemical discharge machining: a theoretical model and experimental verification, Journal of Materials Processing Technology 71 (1997) 350-359

[15] 1. Basak, Electrochemical discharge machining: mechanism and a scheme for enhancing material removal capacity, Ph.D. Dissertation IIT-Kanpur, India, 1992

[16] Holm Ragner, Electrical Contact: Theory and Application, 4thedn., Springer-Verlag, New York, 1967, pp. 276, 278, 338.

[17] J. Warham, Proc. Inst. Electr. Eng. (100) (1953) 163

[18] A. Manna, A. Kundal, Micro machining of electrically non condutiveAl_2O_3 ceramic on developed TW-ECSM Setup, International Journal of Manufacturing , Materials and Mechanical Engineering 1(2), 46-55, June 2011

[19] Y.S. Wong, L.C. Lim, I. Rahuman, W.M. Tee, Near-mirror-finish phenomenon in EDM using powder-mixed dielectric, J. Mater. Process. Technol. 79 (1998) 30–40

[20] V.K. Jain, P.M. Dixit, P.M. Pandey, On the analysis of the electrochemical spark machining process, Int. J. Mach. Tools Manuf. 39 (1999) 165–186.

[21] L. Dascalescu, R. Tobazeon, P. Atten, Behaviour of conducting particles in corona-dominated electric fields, J. Phys. D: Appl. Phys. 28 (1995) 1611–1618

[22] L. Dascalescu, A. Samuila, R. Tobaz´eon, Size of solid contaminants and formation of particle chains: two factors affecting the dielectric strength of insulating gases, J. Electrostatics 40–41 (1997) 419–424.