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ELECTROCHEMICAL DISCHARGE MACHINING –A REVIEW

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ABSTRACT

Electrochemical Discharge Machining is unconventional hybrid machining process which combines the features of electrochemical machining (ECM) and electro discharge machining (EDM). This machining process is able to machine hard and brittle non-conductive materials such as glass, ceramics, refractory bricks, quartz, composite materials and electrically conductive materials such as steel, copper, tungsten etc. Features with high aspect ratio and complicated geometry can be created by Electrochemical Discharge Machining. Electrochemical Discharge Machining (ECDM) find a wide range of applications in advanced industries like Nuclear reactor, Automobiles, Aeronautic, MEMS. This paper reviews various notable works related with the effective parameters of ECDM and optimization of parameters by different optimizing techniques, also gives future scope in the Electrochemical Discharge Machining.

KEYWORDS - ***Electro chemical discharge machining (ECDM), Material removal rate (MRR)***

INTRODUCTION

Electrochemical Discharge Machining (ECDM) is considered as new hybrid technique, comprising the techniques of ECM and EDM to machine conducting and nonconducting materials like silicon, glass, ceramics, composites, etc. Since the actual process involved in ECDM is still not fully understood, quality characteristics of the machined part introduce new challenges in machining complicated shapes. ECDM is considered as non conventional machining to machine electrically conducting and non-conducting materials using the electrochemical discharge phenomenon. If a beyond-critical voltage is applied to an electrochemical cell, discharge initiates between one tool of electrode and surrounding electrolyte which is termed as electrochemical discharge. This discharge energy is used to machine the workpiece.

Process Potential possible uses in the following areas:

• Micro Generation of Hole Array in SU-8 Material (high aspect ratio, polymer, dielectric Photo filterist content) for making micro filter Micro-EDM is required in the process
• Micro-seam welding of copper plates and foil
• Construction of small components
• Heat treatment.

1. LITERATURE SURVEY

The ECSM process has been examined by several groups of investigators. General studies have been passed out and are still continuing with different groups having another research objective.

Kurafuji and Suda et. al. [24]**:** The ECDM process was first reported by Kurafuji and Suda of Japan in 1968, which they termed as electrical discharge drilling. The process was essentially a combination of EDM and ECM. They demonstrated the possibility of drilling micro-holes in glass, and their study was related to the effect of electrolyte chemical composition and tool-electrode materials on the mechanism of material removal.

Cook et al. [25]**:** In the year 1973, Cook et al. Suggested a new name for the process as discharge machining of non-conducting materials, saying that the process described by Kurafuji and Suda is different from EDM and ECM. They applied the process to a broad range of non-conductive materials and further studied the effect of the electrolyte.

McGeough et al. [34]: In 1983 he had studied the effects of pulsed voltage and vibrating tool-electrode and found that the influence of the electrical discharge is the major factor that enhances the metal removal rate as the phase-angle and vibration amplitude increase; however, structural damage was reported on the machined surface.

Tsuchiya et al. [26]: In the year 1985, Tsuchiya et al. termed this process as wire electrochemical discharge machining, and showed that this technique can be used to cut glass and various ceramics. In the 1990's simultaneously several studies were undertaken in this process.

Khairy and McGeough et. al. (1989) [33]: shows that metal removal rate, dimensional tolerance and surface integrity in ECDM are considerably better than pure electro-chemical machining and electro discharge machining processes.

Basak and Ghosh et. al. (1996) [32]: A study about the critical voltage and the current required to initiate the discharge has been reported by Basak and Ghosh . They have developed a theoretical model and compared with the experimental one, it was found that theoretically predicted value to compare quite well with experimental observations with reasonable accuracy. They concluded that the ECDM process involves a number of complex phenomena.

Basak and Ghosh et. al. [27]: In the year 1997, Basak and Ghosh reported that the material removal in the ECDM is the combination of melting and chemical reaction. They developed a simplified model to predict the characteristics of MRR for varying input parameters. The work also claimed enhancement of the capability of the process through modification of the electrolytic circuit.

Gautama and Jain et. al. (1998)[16] : Have studied the effects of machining time and machining rate with a tool-electrode which is rotated at different eccentricities. They had observed increased machined depth with an increase in eccentricity till the machined depth attained an optimum value at eccentricity distance approximately equal to the tool radius. As the eccentricity increases, the side space between tool and work piece gets widened that results in more quantity of fresh electrolyte flow into the machining zone which helps to flush out the debris produced. The study reveals that it is possible to drill a blind hole without any hump with eccentricity less than or equal to the tool radius,. However, with eccentricity marginally higher than the tool radius, a sweeping cut can be obtained. If the eccentricity increases further, a hump will be formed in the middle of the drilled hole , which increases the local concentration of contaminants in the confined space between the walls of the hump and the machined hole. The contaminants causes the conductivity of the electrolyte to decrease which results in reduced machining rate with consequent reduction in machining depth. Similar findings have also been reported by other researchers.

Jain et al. (2002) [23] had proposed use of abrasive tool-electrodes. They had chosen the feed of the tool-electrode such that always the tool will be in contact with the work piece. Thus the machining gap will be of the order of same magnitude as the size of the abrasive particles embedded to tool-electrode. They showed that the material removal (122 mg) achieved with abrasive tool-electrode is nearly 22 % higher than that (100 mg) obtained with conventional tool-electrode at an applied voltage of 70 V.

Kulkarni et al. (2002) [30], made an attempt to identify the underlying mechanism of ECDM through experimental observations by time-varying current in the circuit. They found that when an isolating film of hydrogen gas bubbles covers the cathode tip portion in the electrolyte, a large dynamic resistance gets formed and the current through the circuit becomes almost zero. A high electric field gets generated across the cathode tip and isolated electrolyte causing an arc discharge within the gas layers covering the tip. The electrons flow towards the workpiece kept near the cathode tip. This flow of electron is seen as a current spike of about 20 A or more for a short duration of a few milliseconds. This bombardment of electrons raises the temperature of the workpiece momentarily and then the temperature decreases due to quenching.

Skrabalak et. al. [28]: In 2004, he developed a model to estimate the current of electrochemical dissolution and electro discharge machining in the ECDM process. Based on this model they made an attempt to adapt fuzzy-logic controller for ECDM process.

Mediliyegedara et al. (2004) [37]: reported the ECDM performance in terms of surface finish and material removal rate is affected by many of factors. Relationships between machining performance and these factors are very complex and highly non-linear. Therefore, developing a relationship between these factors and the machining performance is very difficult with conventional method of mathematical modelling.

Wüthrichand Fascio [29]: In 2005, Wüthrichand Fascio published first review on ECDM process after 40 years of its first mention in literature. The work highlighted the electrochemical aspects and indicated some limiting factors and their possible solutions

Yang CT, Song SL, Yan BH, Huang FY (2006) [20]: They reported that an abrasive mixed electrolyte does not promote the chemical etching unless the tool-electrode is provided an appropriate motion (i.e. rotation or vibration). In case of Wire-ECDM, the presence of abrasive particle in the gap of wire-electrode and glass disrupts formation of the gas film around the wire-electrode. As a result the critical voltage increases. With increase in abrasive concentration the MRR is increased due to increase in critical voltage but tends to get saturated at a concentration of 100 g/l in NaOH .

Wüthrich et al. (2006) [14]: have explained that in the needle-shaped tool, the discharges are concentrated at the tip of the tool-electrode. In general, the discharge density is higher for smaller cross-sectional tool electrodes that results in higher material removal rate. This effect is significant at low voltages only in the discharge regime. As soon as tool-electrode reaches the hydrodynamic regime, drilling speed becomes almost independent of the voltage. By further observation in the hydrodynamic regime the difference between the needle-shaped and cylindrical tool is hardly visible.

Cao et al. (2009)[21]: used load-cell based mechanical contact detector to maintain stable gas film over the whole surface of the tool at low voltages, as poor machining results at high voltages. They also demonstrated the potential of ECDM for micro-machining of glass by fabricating 3D micro-structures of around 80 μm in size. Their conclusion show that the use of load-cell and small depth of tool tip immersion reduces the required voltage and the use of pulsed voltage results in hole size reduction and surface quality improvement. They also revealed that the machining gap obtained by KOH electrolyte is smaller than that of NaOH solution.

Liu et al. (2010)[36]: analyzed discharge mechanism while machining reinforced metal matrix composite. They developed a model to predict the maximum field strength position on the bubble surface and the critical voltage required for spark initiation. Their experimental results showed that an increase in electrolyte concentration, current, pulse duration or duty cycle would promote the arcing action. It was further reported that the predicted values were close to with the experimental values. The study also confirmed that the sparking action takes place in the form of an arc.

Yang CK, Wu KL, Jung JC, Lee SM,d, Lin JC, Yan BH. (2010)[39]: According to them the chemical etching can be enhanced by optimizing the electrolyte supply to the machining zone. The continuous supply of electrolyte is very important during drilling deep holes where the flow of the electrolyte to the tool-electrode tip becomes more and more difficult. Smooth supply of electrolyte to the machining zone can be achieved by promoting the flow of the electrolyte by tool-electrode motions (rotation or vibration) or by using appropriate tool-electrode shapes.

Yang et al. (2011) [15]: proposed a possible solution to overcome the difficulty of deep drilling by using a tool electrode with spherical end whose diameter is larger than that of its cylindrical body. Their experimental results showed that the curved surface of the spherical tool electrode reduces the contact area between the electrode and the workpiece, thus facilitating the flow of electrolyte to electrode end.

Jawalkar et al. (2013)[8]: have found MRR increasing and decreasing kind of effect as electrode spacing increased from 50 to 150 mm in three levels while machining optical glass at voltage levels of 60, 70 and 80 V. They reported marginal increase of material removal from 3.5 mg at first level (50 mm) to 3.8 mg at second level (100 mm). This second level was considered as the optimum level. The increase in material removal at optimum electrode spacing is due to availability of adequate space for chemical reactions to occur and disposal of gases without any interference. In the next level (150 mm), the material removal was drastically decreased to 2.8 mg. Thus, it implies that the low voltage is applied, and then attention has to be paid for electrode shape and electrolyte concentration in order to offset the effect of inter-electrode resistance.

Jui et al. (2013) [22]: tried to enhance the limiting depth by using high aspect ratio micro-tools for deep micro hole drilling on glass with low electrolyte concentration and rotation of the tool-electrode. Their results also show that the overcut, tool wear and hole taper were reduced by 22%, 39% and 18% respectively due to use of lower concentration of electrolyte.

Liu et al. [31]: in 2013, developed a grinding-aided electrochemical discharge machining (G-ECDM) process in order to improve the performance of the conventional ECDM in machining particulate reinforced metal matrix composites (MMCs). In G-ECDM process, the functions of electrochemical dissolution, spark erosion, and direct mechanical grinding were combined to act together. A tool-electrode with diamond particles coating was used in the G-ECDM. In ECDM, the mechanism of material removal, including the phenomenon of spark generation, is not fully established. Empirical methods used for estimation of discharge energy results in large prediction error of material removal and are hard to validate experimentally.

Laio et al. (2013) [38]: showed that when the Sodium Dodecyl Sulphate (SDS) surfactant was added to the electrolyte, the current density got increased which resulted in more bubble release, brighter sparks and a more stable pulse current during machining; consequently, enhancement in machining accuracy was reported.

Gupta et al. (2014)[35]: presented a review on the effect of tool-electrode process parameters like tool geometry, tool motion, wettability, feed, temperature and concentration of electrolyte on improvement in accuracy and efficiency in the ECDM process. They have suggested some future scope in this area including tool wear, hybridization, use of magnetic field etc.

Cao et al. (2014) [40]: have used this for their work, in which a sensitive load cell was used to detect the mechanical contact between the tool-electrode and the work piece. As the contact force acting on the load cell due to contact between the tool-electrode and the work piece exceeds a pre-set limit (in their case, it was 8 mN), the load cell produces a voltage signal to withdraw the tool-electrode from the work piece corresponding to the excess load. The voltage produced by load cell is sent to a controller through suitable signal conditioning device which subsequently sends control signal to the tool feeding mechanism. Accordingly, the mechanism withdraws the tool-electrode in order to maintain the constant gap between the tool-electrode and the work piece.

Kulkarni et al. [30]: have proposed a mechanism to study the temperature rise and mechanism of material removal during the ECDM process by measuring the time-varying current. They observed the generation of high electricsss field (107 V/m) across the tool-electrode and electrolyte initiating an arc discharge in the gas film covering the tool tip. They also studied the nature of individual discharge striking the surface, size of the discharge and the distribution of discharge over the surface. They also found that circular zones are created at the discharge-affected region. These circular zones look like as they are created due to solidification of material after melting.

Gautam N, Jain VK [16]: According to them two distinct types of effects are reported with respect to rotational speed of the tool:- (i) Machining efficiency increases at slow rotation (typically less than 25 rpm), and (ii) for rotational speeds of higher than 25 rpm, the efficiency decreases owing to increasing instability of the gas film . However, at high rotating speed of the tool-electrode, machining does take place only at the bottom side of the tool-electrode that reduces the stray erosion at the hole's entrance and exit. As the tool-electrode rotation increases, the tool wear reduces because rotating electrode can avoid the discharge focused on the same point.

Jain et al. [23]: reported that as electrolyte temperature increases the conductivity of electrolyte also increases, which accelerates the electrolysis process. Formation of hydrogen gas bubbles at the cathode increases due to increase in electrolysis process that leads to an enhancement in sparking rate, hence increase in MRR.

Rao et. al. [43]: proposed the single- and multiobjective optimization for the ECM process variables. They considered MRR and radial overcut as the output response variables. The multiobjective optimization problem was converted into a single-objective optimization problem with assigning a prior weight.

CONCLUSION

This paper is review of the relevant literature on materials, processing conditions and effective parameters in ECDM. The review reveals, many researchers have attempted primarily glass as the work material, however, there is hardly any resemblance in the relevant conditions and hence results. On further analysis of the experimental results through design of experiments, it was found that all the selected process parameters were significant. The applied voltage was the most influencing parameter for Material removal rate. Electrolyte concentration is the secondary parameter affecting the Material Removal Rate and Tool wear. From literature review, it is observed that, there is some work done on various work pieces which are difficult to be machined by conventional machining. More work need to done on the optimization of parameters for better performance of Electrochemical Discharge Machining. MRR increases as rise in voltage. So higher the voltage higher was the MRR value upto a limit.

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