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Survey on ECM, PECM and Ultrasonic Assisted PECM

Shardul Sunil Bargale
Student, Department of Mechanical Engineering, MIT College of Engineering, Pune, India

***Abstract*: This paper deals with overview of electrochemical machining process along with its principles. It is also focused on the literature survey to discuss various advantages, disadvantages and applications of ECM, PECM and Ultrasonic assisted PECM. Electrochemical and Pulse electro chemical machining processes have gained importance as major electro-machining processes with unique capabilities. These machining process offer a better alternative or sometimes the only alternative in generating accurate 3-D complex shaped macro, micro and Nano features and components of difficult–to-machine materials. Technological advances reported in ultrasonic assisted pulse electrochemical process, which reflect the state of the art in academic and industrial research and applications, are briefly reviewed in this paper.**

***Keywords*: ECM, Pulse electro chemical machining,Ultrasonic Vibration, ECMM, UAPECM, CFD, Material Removal Rate**

1. Introduction

Electro chemical machining (ECM) is an electrolytic material removal process involving a negatively charged tool (cathode), a conductive fluid (electrolyte), and a conductive work piece (anode). The advance machining processes are commonly used for the materials which are hard and difficult to cut by conventional machining processes. One of the most commonly used advance machining processes is pulse electro chemical machining process. In pulse electro chemical machining process, the tool and work piece don't have any physical contact, resulting no tool wear. Conductive liquid is employed as the electrolyte in the process, which carries the current from the work piece to tool, remove the work piece material and generate the sludge. The electrolyte carriers the sludge out of machining zone.

A. *Principal of ECM*

ECM is the controlled removal of metal by anodic dissolution in an electrolytic cell in which the work piece is the anode and the tool is cathode [1]. Electrochemical machining is developed on the principle of Faradays and Ohm. In this process, an electrolyte cell is formed by the anode (work-piece) and the cathode (tool) in the midst of a following electrolyte. The metal is removed by the controlled dissolution of the anode according to the well-known Faradays law of electrolysis. Fig1. Shows two electrodes which are placed closely with a gap of about 0.5 mm and immersed in an electrolyte which is a solution of sodium chloride (common salt).

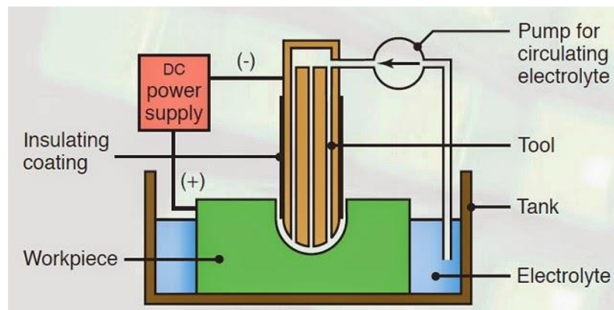

Fig. 1. Schematic for electrochemical machining process

The high current densities promote rapid generation of metal hydroxides and gas bubble in the small spacing between the electrodes. These become a barrier to the electrolyzing current after a few seconds. To maintain a continuous high density current, these products of machining must be continuously removed. This is achieved by circulating the electrolyte at a high velocity through the gap between the electrodes. It is also to be noted that the machining gap size increases as the metal is removed. The larger gap leads to a decrease in the metal removal rate.

Therefore to maintain a constant gap between the tool and work-piece, the cathode (tool) should be advanced towards the anode (work) at the same rate at which the metal is removed.

B. *Precision electro-chemical machining*

Precision Electro-Chemical Machining (PECM) was developed from ECM through two key developments: the minimization of the machining gap (through which the electrolyte solution flows) and the necessary exchange of the electrolyte itself [2]. On one hand, the gap for PECM has to be particularly narrow to achieve a decent reproduction. At the same time, an overlaid mechanical, oscillatory movement ensures that the electrolyte is properly replaced and renewed. To further ensure that the current flows easily during the tool movement, a pulsed, freely programmable power source is employed. That is why precision electro-chemical machining makes for such an effective and precise removal of the material. Precision electrochemical machining (PECM) is a nonconventional machining process that can help deliver complex and precise comp00onents quickly and accurately. It uses electrodes and a pulsed direct current to dissolve practically any electrically conductive metal, including highly tempered steel, rolling bearing steel and alloys [3]. This flexible technology allows metals to be machined into highly complex geometrical shapes

C. How the PECM process works

- PECM drives the cathode into the work piece while maintaining a tiny gap (up to 10µm) throughout the complete cycle time. The oscillating motion is required to ensure the electrolyte flushing exchange.
- The DC pulse occurs only at the smallest gap.
- The quality of the cathode and the gap conditions are controlled to ensure desired results.
- Both oscillating and non-oscillating modes are available to ensure the highest productivity.
- Bipolar DC pulsing is incorporated into the process that cleans the cathode during and after the machining cycle to maintain constant operating conditions.
- A fully controlled process that includes an integrated quality control system.
- A precise machining control system that includes adjustment of the cathode movement and DC pulsing to allow the smallest gap sizes, highest repeatability, accuracy in the front gap, and a quality surface finish in the side gap.
- The operator interface provides a clear representation of the process stages which reduces the complexity of operation.
- Standardized power generators, electrolyte tank control, and regulated relevant electrolyte parameters work in unison to precisely control constant gap conditions.

D. Issues with PECM

One primary issue in pulse electrochemical micromachining is using pulses of electrical current to control precise machining resolution as well as the uniform electrolyte flow inside inter electrode gap between two electrodes. Periodical replacement of electrolyte flush away generated heat and gas bubbles which interrupt stable electrochemical reaction with uniform ionic charging in electrolyte. Though PECM require precise control of electrical parameters, such as pulse time, duty factor, applied current/voltage and total machining time, quantitative analysis of these parameter, especially pulse time, has not been introduced.

E. Overview on ECMM

The fabrication of microstructures by ECM process is known as electrochemical micromachining. (ECMM) ECMM is the key technology for the, electronics, optics, biomedical, automotive, avionics and ultra-precision machinery industries [4]. The ECMM appears to be very promising as a future micromachining technique, since it offers several advantages such as higher machining rate, better precision, control and capability to machine wide range of materials. The ECMM process produces a stress free surface using precise process control along with higher Material Removal Rate (MRR). Hard metals can be shaped with ECM and ECMM process using electrolysis principle. In this process, the MRR is not affected by the hardness of the work piece. The ECMM is still in its initial stages of development and a lot of research needs to be done to improve MRR, surface quality and accuracy by optimizing the various process parameters [5].

F. The influence of the ultrasonic field on the ECM and PECM process (UAPECM)

The use of ultrasound energy in a series of industrial applications is related to the characteristic features of ultrasonic waves: relatively small wave-length, very high acceleration, leading, focusing and spreading facilities, as well as the specific interaction with the propagation/working environment [6]. The most important ultrasonic propagation effect in liquid media is known as ultrasonic cavitation.

G. UAPECM is performed by two methods.

- By direct vibration either by means of tool or by work-piece.
- By indirect vibration by means of electrolyte bath.

In direct vibration method, if vibration given to work-piece its frequency will get changed with respect to frequent material removal. Hence vibration is given to tool in order to maintain its natural frequency [7]. In order to comply with various safety and industry standards a tool has to be designed and optimized through FEM on ANSYS and CFD analysis.

H. The use of UA-PECM for several advantages

- Higher dimensional precision
- No tool wear
- No residual stress in the work-piece
- Higher productivity

2. Literature review

An exhaustive literature survey has been carried out on electrochemical machining. The research and studies on ECM started a long back on 1969. A few of this research works is presented in this Paper. Based on this important review papers, scope and objective of the present study is established. Various research papers, books and websites were studied to ascertain the state of art of electrochemical machining which are briefed below:

Anil Kumar Mehar [8] carried out work to show the process characteristics of ECM and how it is affected by the process parameters. His work shows a study of the intervening variables in electrochemical machining (ECM) of mild steel (C=0.08%, Mn=0.35%, P=0.014%, S=0.018%, Si=0.017%, Fe= rest). The material removal rate (MRR) was studied. Two parameters were changed during the experiments: feed rate and voltage. Sodium chloride solution was taken as electrolyte (100gm/lt). The results show that feed rate was the main parameter affecting the MRR.

Alexandru Hedes et al. [9] experimented with the ultrasonic assistance of an electrochemical process. They presented and discussed some experimental investigations obtained on a laboratory prototype, at two ultrasonic frequencies. The results, expressed in the evolution of current, voltage and electrolyte temperature during the process, prove the favorable effect of the ultrasonic field in electrochemical passivation in order to improve the performance of the electrochemical machining process.

The recent developments and future trends of EMM were highlighted in the research titled "Advancement in electrochemical micro machining" by Bhattacharyya B [10]. It suggests that micro-ECM (ECMM) method can be effectively used for high precision machining operations such as removal of burrs, making patterns in foils, and 3D micro-machining. The research suggests that for utilizing ECMM in micro fabrication, improvement in micro tool design and development, monitoring and control of the inter electrode gap (IEG), control of material removal and accuracy, power supply, and elimination of micro-sparks generation in IEG, and selection of electrolyte is required.

Cheng-Kuang Yang et al. [11] Experiment were carried out on the quartz for micro hole drilling by varying the tool material and keeping other process parameters like tool electrode diameter, machining depth, electrolyte and its concentration and rotational speed of tool constant. So this study shows that selection of proper tool material is very important in case of micro machining.

S. Jawalkar et al. [12] presented review on different materials and machining conditions in ECM along with some most influencing parameters of the process. The obtained results showed that applied voltage was the most influencing parameter in both MRR and TWR studies.

Xuan Doan Cao et al. [13] studied the effect of voltage, electrolyte, electrolyte conc. pulse on/off time ratio, feed rate and rotational speed in drilling and milling processes in ECM.

Chih-Ping Cheng et al. [14] demonstrated the relationship between gas film quality and machining characteristics under different process parameters including applied voltage, tool Rotating speed, electrolyte conc. machining depth and tool geometry while drilling micro holes in Pyrex glass by analyzing current signals and dimensions of machined micro hole obtained. Current serves as key determinant for varying the process parameters to achieve better efficiency and accuracy's.

L. Harugade et al. [15] three process parameters were selected at three different levels such as applied voltage, electrolyte conc. and inter electrode gap. The obtained results evidence that applied voltage was found to be most influencing parameter for MRR and KOH shows the better removal rate than other proposed electrolyte solutions used in an experiment

V. K. Jain et al. [16] they have concluded that with the use of reverse polarity quartz cuts at faster rate as compared to direct polarity but it produces adverse effect such as higher overcut, higher tool wear and higher surface roughness.

Mohammad Reza Razfar et al. [17] Different types of longitudinal oscillation to the cathode electrode were applied while drilling of glass and the effects of vibration parameters including amplitude, frequency and waveform on machining speed and machining depth were examined.

Cheng-kaung yang et al. [18] the comparison between machining by conventional cylindrical tool electrode and the proposed spherical tool electrode was made to focus on the impact of Tool electrode shape on initial machining status, discharge frequency and machining performance.

Baoyangjiang et al. [19] presented works on process modelling of ECM with respect to spark generation and material removal rate. From the experiment it is seen that there is problem of tool wear associated with use of tapered tool electrode.

Sumit K. Jui et al. [20] the results obtained from test were rotation of the tool electrode improves the circularity of machined hole along with high aspect ratio and lower surface roughness.

3. Conclusion

- It is evident from the literature survey that only a few researchers have studied the parameters influencing the MRR & Surface finish. Further studies are required to commercialize the technology.
- The machining rate as well as overcut increases with the increase in machining voltage and electrolyte concentration.
- Voltage and electrolyte concentration were the most significant factor that influences the
- Further experimental studies, especially on tool design for structural analysis can be carried out in order to understand the surface finish and material structural change in the machined zone.

A. More research is recommended to accurately monitor the purity, temperature and velocity of electrolyte.

Based on the literature reviews and conclusions, the author aims to Identify and research on

- The most suitable tool material for tool design
- Modeling of the copper tool using Pro-E Creo-2 design modeler.
- Preparation of drawing of copper tool for actual manufacturing.
- FEA analysis of copper tool using ANSYS 17.0 software
- Manufacture the copper tool for set frequency of 20 KHz.

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