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OPTIMIZED PARAMETE FOR ELECTRO CHEMICAL MICRO MACHINING –A STUDY REVIEW

Vikram Singh[1]
[1]Asst. Professor,
Dept. of Mechanical Engineering,
Aryabhatta college of engineering & Research center,
Ajmer

Pankaj Jain[2]
[2]Asst. Professor,
Dept. of Mechanical Engineering,
Aryabhatta college of engineering & Research center,
Ajmer

Kuldeep[3]
[3]Asst. Professor,
Dept. of Mechanical Engineering,
Aryabhatta college of engineering & Research center,
Ajmer

ABSTRACT

Electro chemical micro machining (ECMM) is an advanced form of machining process for the machining of the electrically conductive materials. Electro chemical micro machining has one of the alternatives to the conventional method for the machining of hard materials and complex shape without any residual stress and also machined to the work piece without any tool wear. ECMM has extensive used in aerospace, automotive, medical, electronic, textile and petroleum industries. The study of material removal rate (MRR) is the most important in ECMM in micro levels. In this present study, an experimental setup is used to machine a set of holes with and without the masking of work piece and 3D micro structure channel also machined on aluminum strip by using patterning. The machining of micro holes is done b using tool with micro tip diameter (Micro diameter of copper wire used as a tool and aluminum sheet used as a work material). The solution of water and Sodium nitrate (NaNO3) used as an electrolyte. The Taguchi method orthogonal arrays L16 are used to optimize the machining parameter and their levels. The machining parameters are used as voltage, flow rate, electrolyte concentration. Also, a micro tool is fabricated for electrochemical micro machining. Electrochemical micro machining is used to produce different complex shapes on work piece by using mask patterning.

KEYWORDS - *Taguchi method, Electrochemical micro Machining (ECMM), Material removal rate (MRR), electrode.*

1. INTRODUCTION

Electrochemical machining is used for removing the material by electrochemical process. The electrochemical machining first patent in 1929s by Gusseff after that this processes were introduce advanced in late 1995s and early 1960s in aerospace, heavy industries for milling, shaping and finishing operation of large parts.[1]

Electrochemical machining process is used for the working of extremely hard material, high strength and heat resistant material that are difficult to machine with the complicated shapes using conventional method. It contains the ability to cut complex shapes in electrically conductive hard material such as super alloys, stain less steel, tool steel etc. The machining rate does not depend on the work material hardness. It can be machine internal and external geometry with higher accuracy produce to the component. Material removal rate is higher

possible in ECM, with no thermal stress or mechanical stress transfers to the work piece [2].

In ECM process work piece is connected with positive terminal (anode) and tool is connected with the negative terminal (cathode). Electrolyte flows between the tool and work piece which helps to flush away the removed materials and NaNO3 and NaCl is used as a electrolyte. A low voltage and high amperage current passes through the electrolyte medium which flows between electrode anode and cathode. The mechanism of material removal is the anodic dissolution according to Faraday's laws of electrolysis. This process is widely used in aerospace, automotive, surgical component forging die and electronic industries [3].

The gap between the tool and work piece is called IEG (inter electrode gap). ECM process provide better surface quality, higher MRR, damage free surface, longer tool life, no stress and burrs [4].

2. INVESTIGATION OF ELECTRO CHEMICAL MICRO MACHINING PROCESS

2.1 PARAMETERS ON AL- SI, CP - GR COMPOSITES USING TAGUCHI METHODOLOGY

B. Babu et al.[1] examines the effect of process parameters like paper machining Frequency at the rate of voltage, electrolyte concentration, over-cut and material removal (MRR). It discusses a method to customize paper machining Parameters on drilling of al-CICP-G metal matrix composites using EMM. Taguchi Analysis of L_{27} orthogonal array and diversity is planned to effect this Machining parameters like machining voltage, electrolyte concentration, frequency over Cut and MRR.

2.2 OVERVIEW BASED ON EMM & ECM

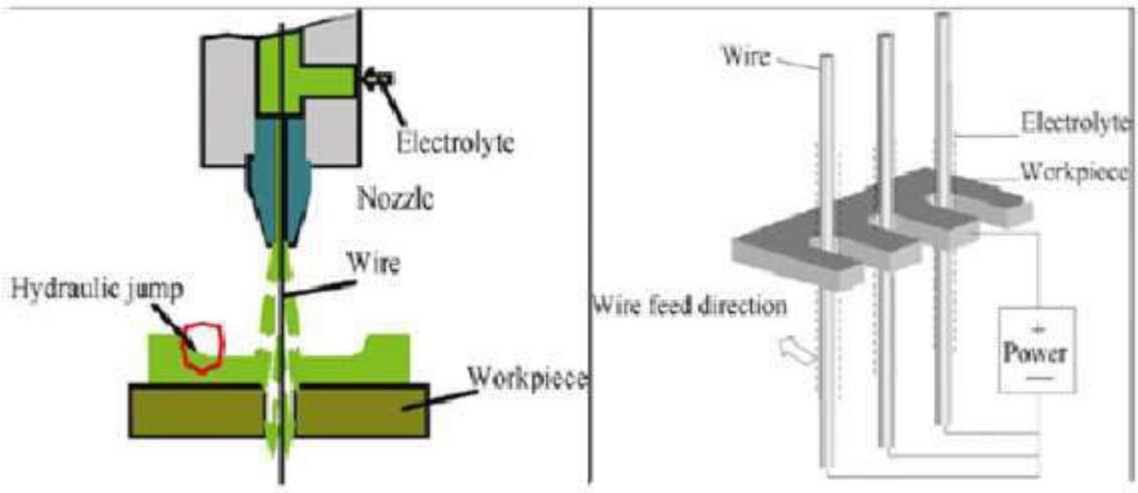
B. Bhattacharyya et al. [5] successful develop an EMM setup for carrying out in depth independent research for achieving satisfactory control of electrochemical machining process parameters to meet the micromachining requirements. The developed EMM setup mainly consists of various sub-components and systems, e.g., mechanical machining unit, micro tooling system, electrical power and controlling system and controlled electrolyte flow system, etc. All these system components are integrated in such a way that the developed EMM system setup will be capable of performing basic and fundamental research in the area of EMM fulfilling the requirements of micromachining objectives. F. Klocke et al. [11] is 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. [12] 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. These processes are also being attempted at the nano-scale.

2.3 OVERVIEW BASED ON OPTIMIZATION TECHNIQUE

Bhawana Bisht et al. [2] carried out the experimentation to optimize the material removal rate and surface roughness. Experiment conducted on mild steel and aluminium. 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". The S/N ratio15 values are calculated by taking into consideration with the help of software Minitab 15. There are four machining parameters are used as voltage, electrolyte flow rate, tool feed rate and current. In this process, a low voltage (5-15V) is applied across two electrodes with a small gap (0.2- 0.5mm) and with a current of (20-100A). Taguchi orthogonal array is designed with three levels of machining parameters. The MRR and surface roughness values measured value for maximum material removal rate and minimum surface roughness respectively. Kanhu Charan et al. [3] in optimize 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/cm2.

Electrolytes NaCl+H2O flow through the gap with a velocity of 20-30 m/s. In machining the process of modeling and optimization are challenging task to meet the requirements in order to produce good quality of products. EN19 tool steel material used as the workpiece for experiments. After evaluating MFNN and LSSVM model and MNFF model for training and testing datasets were accomplished that LSSVM more powerful machine learning tool and predict MRR and successfully compared to other models. R. Goswamil et al. [9] in this paper taguchi method with three parameter and level is applied to find optimum process parameters for Electrochemical machining (ECM). The parameters used as voltage, tool feed and current. Nine set of experiment conducted by L9 orthogonal array. With the help of Signal to Noise we find out the optimum results for the ECM. Analysis of various parameters on the basis of experiment results, analysis of variance (ANOVA), F-test and SN ratio. Presented in this paper, the optimal machining parameters for maximum material removal rate and minimum surface roughness in the ECM operations have been determined. D. Chandrakar and A.Vanu Gopal [13] investigate the effect of parametric optimization of process parameters for electrochemical machining of EN-31 steel using grey relation analysis.

Electrolyte concentration feed rate and applied voltage are optimized with consideration of multiple performance characteristic including MRR, over cut, Cylindricity error and surface roughness. Low voltage (5-25V) is applied across two electrodes with a small gap size (0.2mm16 0.5mm) and with a high current density around 2000 A/cm3. NaCl and NaNO3 are used as electrolyte. It was observed that feed rate is the significant process parameter that affects the ECM robustness. The experimental results for the optimal setting show that there is considerable improvement into the process. This technique converts the multi response variable to a single response grey relational grade and therefore, simplifies the optimization procedure.



Electrolyte flow status and diagram of multi wire ECM [13]

Rama Rao and Padmanabhan [14] 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 find that the metal removal rate increase with voltage, feed rate and electrolyte concentration in electrochemical machining. Validation with the optimal levels of machining parameters was carried out in order to demonstrate the effectiveness of taguchi optimization method. C. Senthikumara et al. [15] shows the influence of input parameters on the characteristic of Electrochemical machining process such as material removal rate and surface and surface roughness. The electrolyte used for experimentation was fresh aqueous solution of sodium nitrate (NaNO3) with varying electrolyte concentration and workpiece was used LM25AL/10%SiCp composite. Variation of MRR with voltage and tool feed rate presented. The Electrolyte concentration has most considerable factor for surface roughness rather than other parameters. Experiments have been carried out to constitute on between process parameters and response in ECM process using Response Surface Methodology. The developed experimental relationships predict the machining conditions within the experimental domain. They used plots curve for study the effect of process parameters with their interactions. Lijo Paul and Somashekhar S. Hiremath [16] is study about the effect of process parameters of ECDM on Material removal rate on borosilicate glass. The design of experiment (DOE) is used for experimental design table for the conduction of experiments. In this Response surface modeling (RSM) is used for optimization of process parameters. Electro discharge machining (EDM) and Electro chemical Machine (ECM) are introduced for machining of conducting material. But for the non-conducting materials a hybrid process combining the features of many conventional and non-conventional machining processes is required. Electro chemical Discharge machining (ECDM) is one such non-conventional hybrid machine. Borosilicate glass of 0.5 mm thickness is used for conducting nine set of experiments design based on taguchi L9 orthogonal array, to study micro-holes using tungsten carbide tool. Suresh H. Surekar [17] is conducted the experimental process to optimize parameters which affecting to material removal rate of HasTelloy c-276. Three parameters are used during experiments feed rate, electrolyte flow rate and voltage. Taguchi L9 orthogonal array is used for setting of parameter during the experimental runs. Aqueous solution of sodium nitrate (NANO3) is used as an electrolyte. In this higher material removal rate is obtained at high feed rate 1mm/min, minimum electrolyte flow rate 150 L/hr and high voltage 916 V. In this paper observed that feed rate is the more affecting parameter to the material removal rate.

2.3 OVERVIEW BASED ON ELECTROLYTE USED IN ECM PROCESS

Qu Ningsong et al. [6] in this paper Titanium and its alloys used with the axial electrolyte flushing is presented to WECM for removing electrolysis products and renewing electrolyte. The optimal combination level of the machining parameter are electrolyte 2.5%NaCl+2.5%NaNO3, 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. 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 improves by multi wire electrochemical machining.

Dayanand S.Bilgi et al. [18] is investigated the hole quality and inter electrode gap during pulse current electrochemical deep hole drilling of nickel-based super alloy. Input parameter are voltage, tool feed rate, duty cycle, pulse on time and bare tip length of tool & radial overcut, MRRg and linear MRRl are used as response. For the optimizing of process parameter DOE is used. Optimum parameters determined from the experiments, is used for efficient drill high-deep holes of high aspect ratio in nickel based super alloys.

R.Thanigaivelana et al. [19] is 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 (NaNO3) and Acidified sodium nitrate (0.05mole of H2SO4 +NaNO3) of varying concentration. The power supply with constant pulse frequency of 50 Hz is considered for the experiments. The machining variables are voltage, pulse on time and electrolyte concentration. The performance of acidified sodium nitrate and sodium nitrate on EMM are compared. It is concluded that machining rate and overcut are significantly improved using acidified sodium nitrate as an electrolyte.

2.4 OVERVIEW BASED ON 3-D PROFILE CUTTING ON ECM

Hong Shik Shin et al. [20] in order to minimize the side gap, ultra short voltage pulses were applied between the tool electrode and the workpiece. Changes in the side gap according to the applied pulse voltage, pulse on-time and pulse period were investigated, and the optimal pulse condition for stable machining was obtained. By this method, micro features such as micro grooves and gears were fabricated into stainless steel plates. Platinum electrodes were used as a reference electrode (RE) and a counter electrode (CE). Sulfuric acid is used as electrolyte. Tungsten wire with a 10 μm diameter (Nilaco, Corp.) was used as a tool electrode. The average tool feed rate was 0.1 μm s^{-1}, voltage of 6 - 6.5 V and the current density during machining is in the range of 0.82 – 0.96 A mm^{-2}. It is useful to concentrate on the reaction current in the machining area which increases the machining rate.

B. H. Kim et al. [22] investigate the micro machining of stainless steel by micro ECM. To prevent taper, a disk-type electrode was introduced. To improve productivity, multiple electrodes were applied and multiple structures were machined simultaneously. Using a platinum wire electrode with 10 pm diameter, various 3D features were machined on stainless steel plate. The machining gap can be reduced to a few pm by using ultra short pulse. The change of the machining gap was investigated according to pulse condition and machining time

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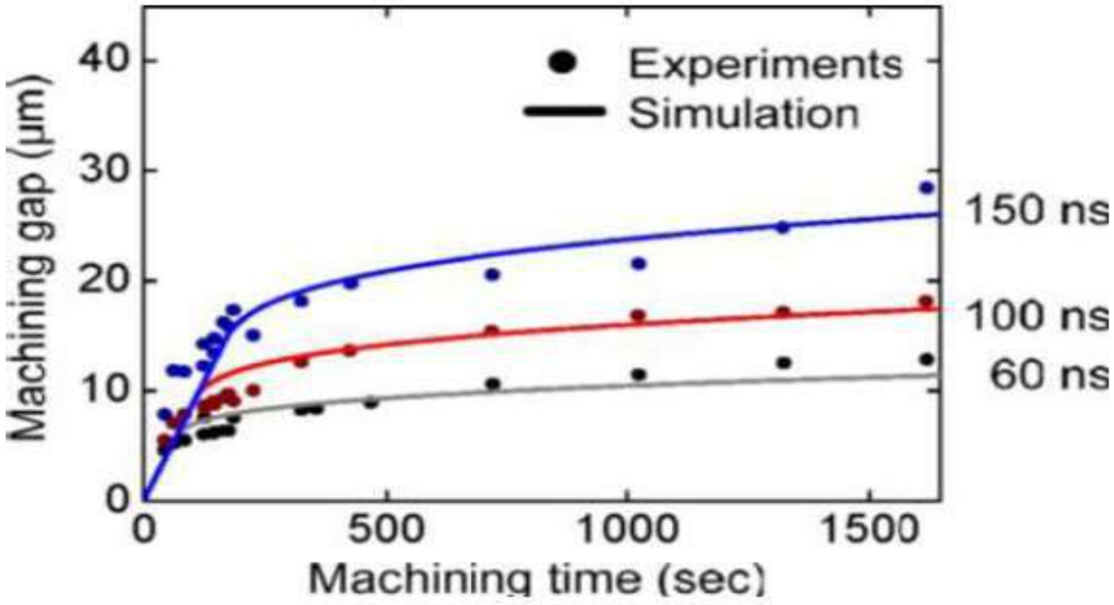

Graph for machining time and machining gap

2.5 OVERVIEW BASED ON MASKING USED ON ECM PROCESS

E. Rosset and D. Landolt [23] is worked on electrochemical micro machining through photo resist masks of SS304 and Phynox using a jet cell and a neutral NaNO3 electrolyte. It concluded that the EMM is most suitable for the shaping of highly corrosion resistant alloys which are not properly machined chemically. The main difficulty of EMM results find that the irregular attack of differently spaced anodes. It is compare the results obtained by EMM with those of chemical milling. For this a 500 um thick SS304 plate was chemically etched in an FeCl3 salt spray under industrial conditions then the profile is elliptical and slightly asymmetric. The reproducibility of the undercut in chemical etching was approximately 3% compared

to 19% in EMM with the jet cathode and 6% in EMM with the magnetic cathode. D. Zhu et al. [24] proposes a method of electrochemical micromachining of micro hole or dimple

array, in which a patterned insulation plate coated with metal film as cathode is closely attached to workpiece plate. When voltage is applied across the workpiece and cathode film over which the electrolyte flows at high speed, hole or dimple array will be produced. The proposed technology offers unique advantages such as short lead time and low cost. The effect of process parameters on the microstructure shape is demonstrated numerically and experimentally. Arrays of holes or dimples of several hundred micrometers diameter have been produced. R. V. Sheno and M. Datta [25] develop mathematical model to predict shape evolution in through-mask electrochemical micromachining (EMM). Boundary element method is used to solve the Laplace equation for electric potential with appropriate boundary conditions that describe the metal dissolution process under ohmic control. The influence of mask wall angle on shape of the evolving cavity, current distribution within the cavity and etch factor have been determined. For mask wall angles less than 90°, the etch factor increased due to the shadowing effect of the mask, whereas the etch factor decreased for mask wall angles greater than 90°. The influence of mask wall angle has been found to diminish with increasing metal film thickness.

Shuangqing Qian et al. [26] concluded that the various techniques are employed to produce micro-dimples on the surface of friction pair. In this study, a modified through mask electrochemical micromachining (TMEMM), in which the insulation layer was directly attached to the cathode, was developed to produce micro dimples on the hard chrome-coated surface. By controlling machining parameters, micro-dimples array with hundreds of micrometers in diameter and several micrometers in depth, were produced. Compared with the traditional TMEMM, the modified method can both reduce cost and improve machining efficiency. Friction experiments show that the friction coefficient of the surface with appropriate micro-dimples array is obviously lower than that with no dimples.

2.6 OVERVIEW BASED ON PULSE CURRENT USED ECM

Rolf Schuster et al. [27] give the application of ultra short voltage pulses between a tool electrode and a workpiece in an electrochemical environment. It allows the three-dimensional machining of conducting materials with sub micrometer precision. The principle is based on the Unit time constant for double-layer charging, which varies linearly with the local separation between the electrodes. During nanosecond pulses, the electrochemical reactions are conned to electrode regions in close proximity. This technique was used for local etching of copper and silicon as well as for local copper deposition.

B. Bhattacharyya and J. Munda [28] is investigated the influence of electrochemical process parameters such as machining voltage, electrolyte concentration, pulse on time and frequency of pulsed power supply on the material removal rate (MRR). A machining voltage range of 6 to 10V gives an considerable amount of MRR at moderate accuracy. According to this investigation, The most effective zone of pulse on time and electrolyte concentration considered as 10–15 ms and 15–20 g/l respectively, which gives an considerable amount of MRR as well as lesser overcut. It is observed, lower value of electrolyte concentration with higher machining voltage and moderate value of pulse on time will produce a more accurate shape with fewer overcuts at moderate MRR. Micro-sparks occurs during micromachining operation causes uncontrolled material removal which results in improper shape and low accuracy.

Shi Hyoung Ryu [29] describes micro electrochemical machining of stainless steel in an environmentally friendly electrolyte of citric acid. Electrochemical dissolution region is minimized by applying a few hundred nanosecond duration pulses between the tungsten SPM tip and the work material. Electrochemical machining (ECM) characteristics tool feed and pulse amplitude, pulse frequency, and tool electrode baseline potential are investigated through a series of experiments. Micro holes of 60μm in diameter with the depth of 50μm and 90μm in diameter with the depth of 100μm are perforated using citric acid electrolyte. Square and circular micro cavities are also fabricated by electrochemical milling. This research may contribute to the development of safe and eco-friendly micro manufacturing technology.

D.Bahrea et al. [30] **is** investigated the pulse Electrochemical Machining (PECM) for the machining of lamellar cast iron. The machining was done for a fixed time interval of 120 s, and initial working gap of 30 μm. The MRR was determined by measuring the mass loss on a precision balance and the surface roughness (Ra) measuring with a profilometer MarSurf XR The MRR characteristics determined by using systematic design of experiments techniques. L. Yong and H. Ruiqin [31] investigate the electro machining process of tapered holes for fuel jet nozzles. The influences of machining voltage, pulse duration, pulse duty ratio and electrode feeding speed to hole diameter are investigated experimentally.

3. CONCLUSION AND RESEARCH OBJECTIVES

Based on the above literature review it seen that only few work has been done related to stationary tool on ECMM, so this research are one step ahead for ECMM. The goal of this thesis is to optimize the factor affecting to the responses by using taguchi method. The factors are used as voltage, electrolyte concentration and flow rate. Responses are used as MRR and Taper for without masking work experiment as well as MRR and overcut responses are used for with masking work experiment. Aluminium is used as a work and copper used as a tool.

The objective of this thesis can be enumerated as below:

- Conduct an experimental study to optimize the factor affecting to the responses. MRR and Taper responses used for without masking work and responses for with masking work used as MRR and Overcut.
- Determine the set of experiment through L16 orthogonal array.
- Optimize the parameter through taguchi method.
- Fabrication of strength circular micro electrode of copper.
- Generate different profiles application by patterning used ECMM.

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