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Experimental Investigation of ECMM Parameters through Micro Hole Drilling using RSM

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***Abstract*— . ECMM is an advanced version of ECM. It is a non-conventional machining process. Electrochemical micro-machining (ECMM) appears to be very promising as a future micromachining technique since in many areas of applications, it offers several advantages, which include higher machining rate, better precision and control, short lead time and a wide range of materials that can be machined and fabrication of microhole. In the micro ECM process, it is not easy to decide the optimal machining parameters for improving the output quality because this process is complex. The optimization of process parameters is essential for the realization of a higher productivity, which is the preliminary basis for survival in today's dynamic market conditions. Optimal quality of the workpiece in ECMM can be generated through combinational control of various process parameters [1]. In this paper we have taken three input parameter Voltage, Concentration and Inter electrode Gap (IEG) to optimize material removal rate (MRR). Response surface methodology is used as an optimization tool to design the set of experiments and to find the optimum values. The electrolyte used is $NaNO_3$ (Sodium Nitrate), and workpiece used is aluminum with the copper electrode as the tool.**

***Index Terms*— *Response surface methodology (R*SM), MRR, ECMM, IEG.**

I. INTRODUCTION

In the Electrochemical machining, process metal is removed by the electrochemical process. It is generally used for hard material, high strength and heat resistant material that are difficult to machine with the complicated shapes using traditional method. The demand for micro-products and components has been rapidly increasing in the electronics, optics, medicine, biotechnology, automotive, communications, and avionics industries [2].The workpieces are shaped in ECMM with the range of dimensions are 1 to 999 μm and part production has a lot of applications in industries with the high surface finish. The fabrication of microstructures by ECM is known as Micro ECM. Alternately, it can be thought of as a material removal process maintaining micron range tolerances. Electrochemical micromachining is the key technology for the semiconductor, electro-communication, optics, medicine, biotechnology; automotive, avionics, and ultra-precision machinery industries.

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II. LITERATURE REVIEW & RESEARCH GAP

S.Dharmalingam et al. investigate the influence of the process parameters like machining voltage, electrolyte concentration, frequency on the overcut and Material Removal Rate (MRR) using Electrochemical Micro Machining (EMM).. They applied Taguchi methodology and grey relational analysis. This paper discussed a methodology for the optimization of the machining parameters on drilling of Al - 6% Gr Metal Matrix composites Based on the analysis, optimum levels of parameters were determined and the same to validate through the confirmation test. The confirmation results reveal that, there is considerable improvement in Material Removal Rate, Overcut, Grey relational grade are improved by 08.33 %, 41.17 % and 81.77 % respectively [3].

Ali Mehrvar et al. applied differential evolution algorithm to look for the optimum solution. Four parameters, i.e. voltage, tool feed rate, electrolyte flow rate, and electrolyte concentration; and two machining criteria, i.e. material removal rate and surface roughness (Ra) was considered as input variables and responses, respectively. They developed comprehensive mathematical models using response surface methodology through experimentation based on the central composite design plan. Then, differential evolution algorithm has been utilized for optimizing the process parameters; both single- and multi-objective optimizations were considered, and optimal Pareto front was determined. Finally, optimization result of a trade-off design point in the Pareto front of Ra and material removal rate was also verified experimentally [4].

Rahul Shrivastava et al experimented to develop a comprehensive mathematical model for correlating the interactive and higher order influences of various machining parameters on the dominant machining criteria i.e. the material removal rate (MRR), surface roughness (SR) and overcut (OC) phenomenon through Response Surface Method (RSM) method. They found out the material removal rate, surface roughness and overcut by electrochemical dissolution of an anodically polarized workpiece (AISI304 stainless steel) with a copper electrode of hexagonal cross-section. It was observed that concentration is the most significant factor for the response of material removal rate and in case of surface roughness voltage is the most significant factor. For response of overcut, the voltage is the most significant factor [5].

III. Experimental Set-up

Schematic diagram of ECM set-up is shown in Figure 1. The set up consists of a chamber of dimension 25*37 cm^2 which is used for performing the experiments. The applied voltage varied through power supply which can supply maximum voltage of 30V and current supply is maximum up to 2 A. The tool material is a copper wire of the diameter of 0.16 mm. The electrolyte flow is controlled by the submersible pump. The work material is made of aluminum pieces of the dimension having 3.9*3.5 cm^2 and 1 mm thickness each approximately. The downward movement of the tool material is carried out by stepper motor of step 1.8 degree each movement.

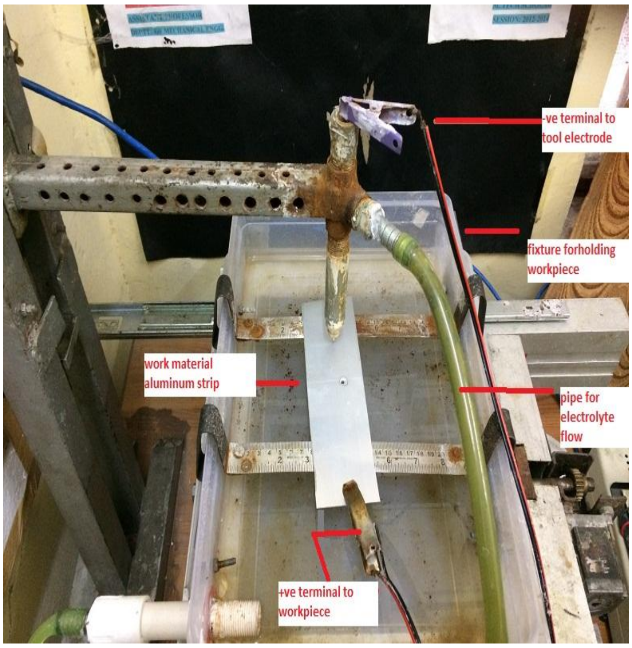

Fig. 1 Schematic Diagram of ECMM

Table 1 Equipment Details

S. No.	Equipment	Specification
1	Workpiece	Aluminum Strip
2	Tool	Copper
3.	Stepper Motor	1.8 degree, 200 steps
4.	Voltage Regulator	Range- 0-30 V
5.	Micro controller	Forwarded feed
6.	Electrolyte solution	$NaNO_3$(% wt)

IV. Design of Experiment (DOE)

We have designed experimental parameters using RSM in minitab 17 software. RSM is a powerful way for building the relationship between input parameters and responses that are useful for the modeling and analysis of the problems. We have obtained a total of 15 sets of experiments for getting desired result. The MRR is obtained using below formula

MRR=(Initial Weight of Specimen-Final Weight of Specimen) ÷ Machining Time

Table 2 ECMM Parameters & Levels

Parameter	Low	Medium	High
Voltage	15	20	25
Concentration	100	125	150
IEG	0.5	1.0	1.5

Table 3 Run Order for Experimentation

Run Order	Voltage	Conc.	IEG	MRR
1	25	150	1.0	1.50258
2	20	125	1.0	1.23432
3	25	125	1.5	1.29858
4	20	100	1.5	0.88910
5	20	125	1.0	1.25432
6	20	150	0.5	1.44748
7	25	100	1.0	0.89433
8	15	125	1.5	0.78433
9	15	100	1.0	0.81432
10	15	125	0.5	0.86543
11	15	150	1.0	1.13433
12	25	125	0.5	1.27432
13	20	125	1.0	1.26432
14	20	150	1.5	1.38258
15	20	100	0.5	0.98433

V. Results and Discussions

Mathematical modeling is done using RSM. The important response parameter is MRR whereas voltage, concentration and IEG is considered as an input variable. The material removal rate is calculated in terms of the input variable. In this design regression equation is obtained, using quadratic term, it has 95% confidence level. Following regression equation is obtained having 96.33% R seq. value:

MRR= -1.88+0.1795*Voltage+0.0062*Conc+0.08* IEG - 0.00570*Voltage*Voltage- 0.000036* Conc.*Conc. - 0.212* IEG*IEG+ 0.000576* Voltage*Conc.+ 0.0105 * Voltage*IEG+ 0.00061* Conc.*IEG

4.1Effect of voltage on MRR:

Experimental investigation revealed that the MRR increases with increase in voltage. As voltage increases current supply increases which consequently increases material removal rate. As voltage further increased due to formation of hydrogen bubbles, the MRR becomes constant.

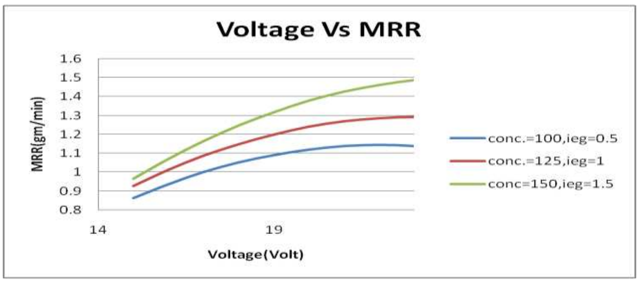

Fig. 2 Voltage v/s MRR

4.2 Effect of electrolyte concentration on MRR:

In Fig. 3, it is investigated that MRR increases with increasing electrolyte concentration. As increased concentration increases amount of negative ions, which increases rate of electrochemical reaction with metallic ions, consequently MRR increases.

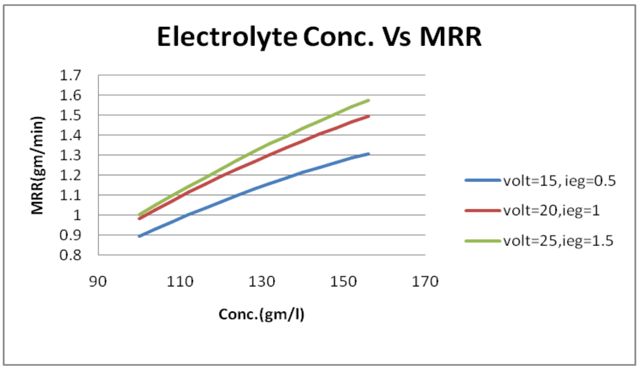

Fig. 3 Electrolyte Conc. v/s MRR

4.3 Effect of IEG on MRR:

In Fig 4 it is investigated that as IEG increases MRR first increases and then decreases, as increase in the inter-electrode gap above optimum value lowers the flow of electric current.

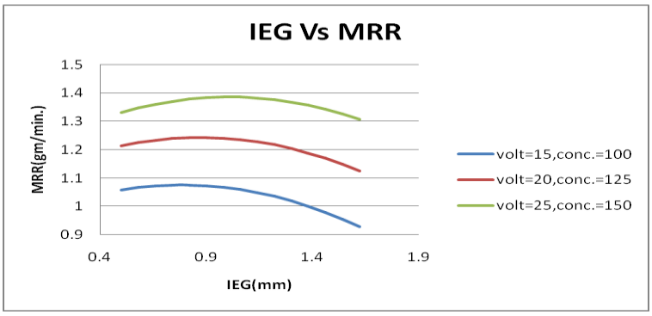

Fig. 4 IEG v/s MRR

4.4 Surface Plot: The Fig. 5 Showing Variation of MRR with IEG and Electrolyte Concentration.

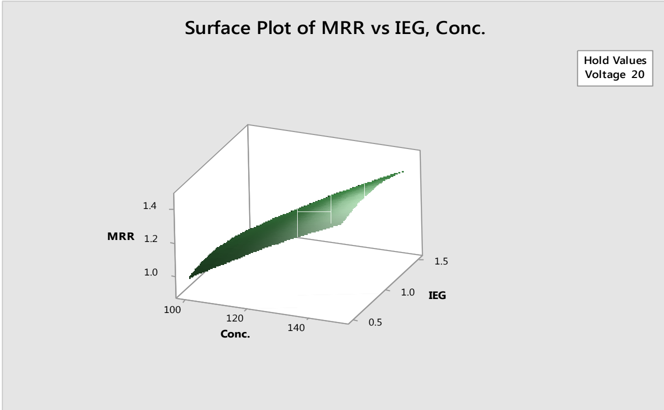

Fig. 5 MRR v/s IEG, Electrolyte Concentration..

4.5 Surface Plot: Fig. 6 Showing Variation of MRR with IEG and Voltage.

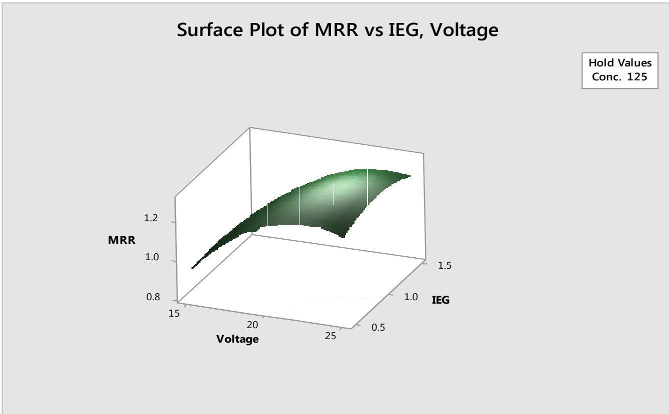

Fig. 6 MRR v/s IEG, Voltage

4.6 Surface Plot: The Graph Showing Variation of MRR with Electrolyte Concentration and Voltage.

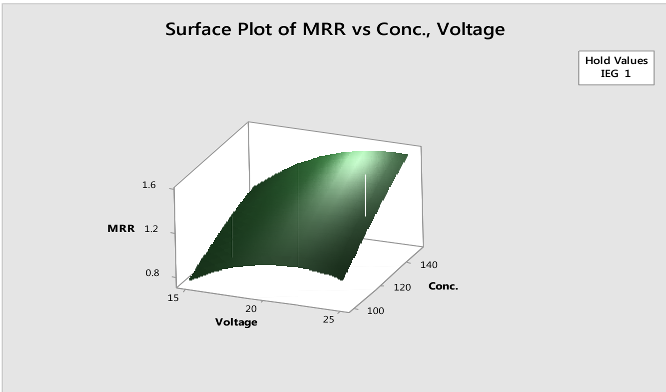

Fig. 7 MRR v/s Electrolyte Concentration , Voltage

4.7 Workpiece Images After Machining

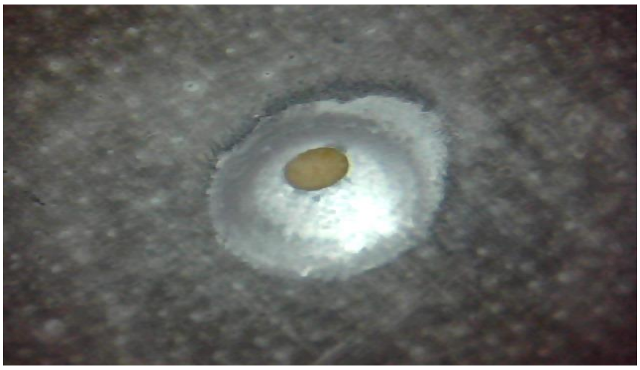

Fig 8 Workpiece Image After Machining

Fig 9 Workpiece Image After Machining

VI Conclusion

In present study, experiments of ECMM are carried out on aluminum strip. We obtain optimum values of all three parameters using response surface methodology. Optimum value of applied voltage is 24.29V, electrolyte concentration is 150 gm/l and inter electrode gap is 1.02 mm gives maximum MRR is 0.1568 gm/min.

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List of Publications.

S.No	Title	Journal	ISSN/ISBN
1	Anode shape prediction in Through-mask-ECMM using FEM	International Journal of Machining Science & Technology (Francis & Taylor)	LMST-2014-0010.R
2	Analysis of Abrasive Jet Micro Machining by Taguchi Technique	Int. J. of Engg. Trends and Technology (IJETT)	Vol. 49, No. 6 pp.358-362 ISSN 2231-5381
3	Parametric Optimization of Abrasive Jet Micromachining through Genetic Algorithm	Int. J. of Innovative Research in Science, Engineering,and Technology	Vol.6, Issue 7 pp. 15127-15133
4	Study of Anode Shape Prediction in Through Mask Electrochemical Micro Machining	Int. J. of Engg. Trends and Technology (IJETT)	Vol. 46, No. 6 pp.320-326 ISSN 2231-5381
5	Experimental Study of Anode Shape Prediction in Through MaskElectrochemical Micro Machining	ICCASP/ICMMD-2016. Advances in Intelligent Systems Research.	ICCASP/ICMMD-2016. Advances in Intelligent Systems Research. Vol. 137, Pp. 220-228.
6	Process analysis and application of microfabrication using patterning by electrochemical electrolysis process	Int. conference of advances in material & product design(AMPD2015)	NIT Surat
7	Parametric optimization of ECMM for Masking Aluminum by Taguchi Method	Int. conference of advances in material and product design(AMPD2015)	NIT Surat
8	Fabrication and Parametric Optimization of AJMM Setup by Taguchi Robust Design Method	6th Int. & 27th All India Manufacturing Technology, Design, and Research Conference (AIMTDR2016)	College of Engg.,PuneMaharashtra,
9	Experimental investigation of Erosion Behaviour of theGlass surface in Abrasive Jet Micromachining setup	proceeding in Int. Conference on Emerging Trends in Engineering Innovations & Tech.	NIT Hamirpur
10	Application of Artificial Neural Network (ANN) for Analysis of Abrasive Jet Machining	Proceeding in4th Int. *Conference* on Industrial Engg.(ICIE-2017)	SVNIT Surat
11	Experimental Investigation Of AFM by using Response Surface Methodology and Parametric Optimization by Genetic Algorithm	Proceeding in 4th Int. *Conference* on Industrial Engg.(ICIE-2017)	SVNIT Surat
12	Optimization Of Electrochemical Discharge Machining Process Parameters Using Genetic Algorithm	Proceeding in 4th Int. *Conference* on Industrial Engg. (ICIE2017)	SVNIT Surat
13	A Review On ECSM	Proceeding in 4thInt. *Conference* on Industrial Engg.(ICIE-2017)	SVNIT Surat
14	Analysis of Abrasive Flow Machining by Taguchi Technique	Proceeding in Int. Conference on Emerging Trends in Engg. Innovations	NIT Hamirpur
15	Parametric Optimization of Electrochemical Spark Micromachining For micro-hole fabrication	Proceeding in 4th Int. *Conference* on Industrial Engg.(ICIE-2017)	SVNIT Surat
16	Survey of quality and management tool	NCREAT, Ajmer	GEC Ajmer
17	Implementation of quality circle	NCREAT, Ajmer	GEC Ajmer
18	Poka-Yoka a Tool for Mistake Proofing	NCREAT, Ajmer	GEC Ajmer
19	ECMM-An Advanced Manufacturing Process for Microfabrication	National Convention for Mechanical Engineers	IE Jaipur
20	Electrochemical Discharge Micro Machining: A Review	National Conference on Emerging Trend in Civil and Mechanical Engg. (NCETCME2017)	Aryabhatta College of Engg.Ajmer

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