International Journal of Emerging Technology and Advanced Engineering
Website: www.ijetae.com (ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 6, Issue 8, August 2016)

# Mini Electro Chemical Machining on AISI Steel 304L for Optimization of Metal Removal Rate

Shaik Nilofer[1], P Charan Theja[2]

[1]P.G.Scholar, Advanced Manufacturing Systems, Dept. Mechanical Engineering & SVCE, Tirupati, India
[2]Assistant Professor, Dept. Mechanical Engineering, Sri Venkateswara College of Engineering, Tiruapti, India

***Abstract*—In the present set-up, the Electro Discharge Machining works effectively with the travelling wire methodology. But in Electro Chemical Machining, travelling wire method is not applied. In most cases electrolyte used in ECM was Sodium Chloride (NaCl) because of low cost. Electrochemical machining (ECM) is a method of removing metal particles by an electrochemical process instead of standard machining methods. It gives a new perspective to machining process and being an imitator of new technologies. (MECM).Electrochemical machining is one of the widely used non-traditional machining processes to machine complicated shapes for electrically conducting but difficult-to-machine materials such as super alloys, Ti-alloys, alloy steel, tool steel, stainless steel, etc. Our Project investigates for maximum MRR.**

***Keywords*— Electrolyte Concentration,, Applied voltage, Flow Rate, Electrolyte flow rate.**

## I. INTRODUCTION

In three axis micro ECM, Machining can be done X, Y, Z axis. This is achieved through motors and control units. The experiment setup consist of three motors, all are the permanent magnet D.C Motor type. Three motors, ECM machine and microcontroller unit are used this project. Motor-1 is applied for X-movement, Motor-2 for Y-movement, Motor-3 for up/down (Z)-movement, keypad is used to set the three motors rotation times this is viewed by the LCD display unit. We can change the movement distance by using keypads. The ECM machine is fixed at the up/down movement (Z-axis) with suitable arrangement.

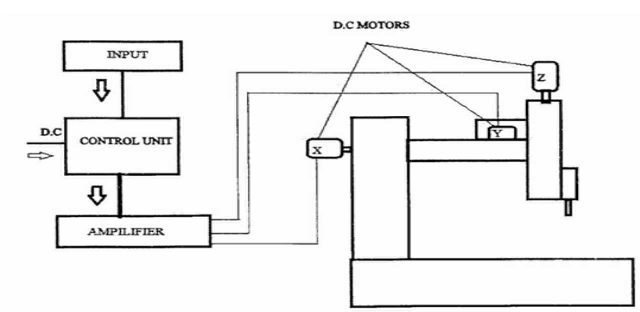



**Fig 1. Schematic Representation of MECM**

Through keypad, input is given to control unit. The control unit controls the input signal and sends it to the particular motor. Due to this, the motor rotates in particular direction. The screw rod is connected to D.C motor shaft. So, screw rod also rotates with the motor shaft. The slide base move with respect to the screw rod. With help of arms, the tool move based on the slide base movement. Likewise, different axis movement is achieved with this principle by control unit.

## II. LITERATURE SURVEY

A lot of contributions have been made on the components of process parameters of different materials by using Electro Chemical Machining and been reviewed. Some of them are discussed below

V.Sathiyamoorthy, T.Sekar, P.Suresh, R.Vijayan, N.Elango [1] (2015) This paper attempts to optimize the predominated machining parameters in Electro Chemical Machining (ECM) of AISI 202 Austenitic stainless steel using Response Surface Methodology (RSM).

M.Kalaimathi, G.Venkatachalam, M.Sivakumar [2] (2014) The Electrochemical Machining (ECM), an advanced manufacturing process, is a natural choice for machining Monel 400 alloys. The present work is carried out to investigate the influence of ECM process parameters, such as applied voltage (V), inter electrode gap (IEG) and electrolyte concentration (EC), on material removal rate (MRR) and surface roughness (Ra) during machining Monel 400 alloys. An aqueous sodium chloride (NaCl) is used as a basic electrolyte in the electrochemical machining of Monel 400 alloys. The experimental strategy is based on a response surface methodology.

Bhawna Bisht, Jyoti Vimal, VedanshChaturvedi [3] (2013) Mild steel and aluminum are used as the work piece material for carrying out the experimentation to optimize the Material Removal Rate and surface roughness. There are four machining parameters i.e. Voltage, Electrolyte flow rate, Tool feed rate and Current. Taguchi orthogonal array is designed with three levels of machining parameters with the help of software Minitab 15. Nine experiments are performed and material removal rate (MRR) and surface roughness is calculated.

Metal removal rate and surface roughness are the most important output parameters, which decide the cutting performance. Taguchi method stresses the importance of studying the response variation using the signal–to–noise (S/N) ratio, resulting in minimization of quality characteristic variation due to uncontrollable parameter.The S/N ratio values are calculated by taking into consideration with the help of software Minitab 15. The MRR and surface roughness values measured from the experiments and their optimum value for maximum material removal rate and minimum surface roughness.

## III. EXPERIMENTAL SETUP

### *A. Work Piece Material*

For carry out of the experiments on the MECM based composites materials are selected as work piece. The properties and applications of this material are given briefly in below.

Specifications of AISI 304L

- Nickel -8 to 12%
- Chromium-18 to 20%
- Manganese-2%
- Silicon-1%
- Carbon-0.03%
- Iron-Remaining

**Fig 2. AISI 304L Work piece Material before Machining**

### *B. Experimental Procedure for Mini ECM*

For carrying out experiments on travelling wire electrochemical machining the following steps are to be taken Putting AISI304L. Firstly clean the machining chamber property with pure distilled water. Prepare the work piece and electrolyte for a particular concentration by mixing NaCl salt with distilled water of known amount the work piece is clamped on the worktable so that the work piece cannot be moved due to wire vibration. A care must be taken so that the top surface of the job remains horizontal and just do not touching with the wire.

Electrolyte is poured in to the machining chamber from reservoir of electrolyte. Upper level of electrolyte must be controlled such that the wire is just immersed in electrolyte but due to manual control the level of electrolyte is to be set. Switch on the main power supply and after that switch on the electrical regulator controller unit. Set the power frequency and motor speed. Set the required speed of wire and ensure that the wire is moved. Now increase the voltage up to a value to experimental plan. During machining a small amount of electrolyte is supplied with pump to machining chamber to make up the voltage of electrolyte. Machining time is noted with the help of stopwatch. Switch of regulator for stopping the wire movement. Switch off the power supply. Remove the work piece from machining chamber and after the work piece is cleaned and dried property before measuring the weight of it. The weight of the job was measured with an electronic weighing machine (accuracy of 1x 10-4), and the average thickness of the cutting zone along the radial direction were measured at magnification of 5x and 10x, respectively, with a measuring microscope (Olympus STM6).

### *C. Design of Experiments-DOE*

To prepare the DOE of the project work by using the Design Expert Software Version 10. The above figure shows about the starting page of the design expert software. Then go through the software and click on the New Design as shown in the above figure.By clicking on the New Design , and then we want to click on the Response Surface. Now we can see some options as shown in the figure, on that we want to choose Central Composite Design. Mention the number of factors as 3,where the 3 factors are applied voltage, electrolyte concentration and flow rate with there maximum and minimum values and also mention the number of experiments as 20.From the Figure we can understand that the responses want to be mentioned. Now mention the responses as 2 where as MRR and Over Cut with their units.

### *D. Surface Response Methodology*

Response Surface Methodology (RSM) is a collection of mathematical and statistical techniques that are useful for modelling and analysis of problems in which the response is influenced by several variables and the main aim is to find the correlation between the response and the variables i.e., it can be used for optimizing the response. In the present study Applied Voltage, Electrolyte Concentration and Flow Rate are chosen as the process parameters and varied at three levels which were shown in Table. In Response surface design, a Central Composite design table with 20 experiments was selected.

International Journal of Emerging Technology and Advanced Engineering
Website: www.ijetae.com (ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 6, Issue 8, August 2016)

Schematic diagram of ECM set-up is shown in Figure. The process parameters, investigation, are EC, V and IEG because of the significant influence on the ECM performances, Their effects on the MRR and R a are tested through the set of the planned experiments based on central composite design (CCD) of RSM.

The factors and their levels in coded and actual values. The levels of each factor were chosen as -1, 0 and 1 in closed form to have a rotatable design. The coded values were obtained from the following equation

$$Xi = \frac{\text{Chosen parameter values} - \text{Central rank of parameters}}{\text{Interval of variation}}$$

Where, X i is the coded values of the variables V, EC and U respectively.

The design requires 20 experiments for the three variables. The design was generated and analyzed using DESIGN EXPERT statistical package.

**TABLE I**
**PROCESSES PARAMETERS & THEIR LEVELS**

| Symbol | Process Parameters | -1 | 0 | 1 |
|---|---|---|---|---|
| X1 | Voltage | 7 | 11 | 15 |
| X2 | Electrolyte Concentration | 140 | 170 | 200 |
| X3 | Flow rate | 4 | 4.7 | 5.4 |

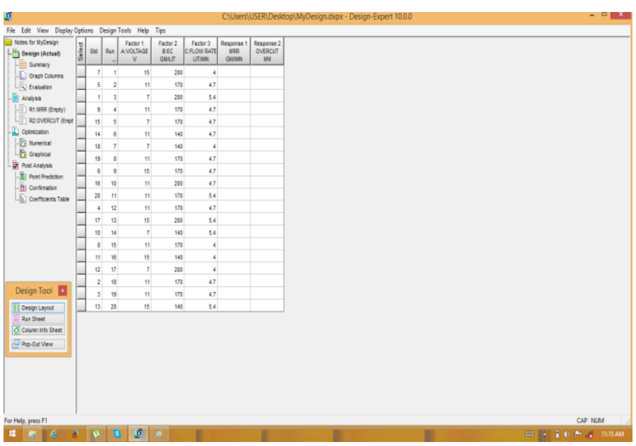


**Fig 3. Preparation of DOE L-20 by using Design Experts Software**

*E. Machining Processes in Mini Electro Chemical Machining*

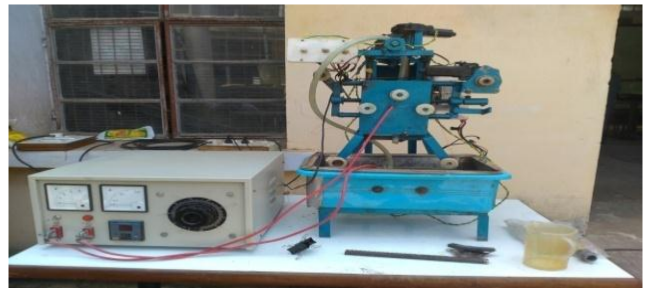


**Fig 4. Mini Electro Chemical Machine.**

There are different steps for the machining process, while doing the machining processes with the input parameters as applied voltage, electrolyte concentration and flow rate with three levels (-1,0,1).

**FiFig 5. Representing the Work piece placed in fixture & Wire is used as cutting tool**

In the machining area the work piece is fitted in a bench wise and the electrolyte concentration is flows on the work piece. Cathode is attach to the copper wire (tool) and anode is attach to the work piece which is shown in the Fig 6.

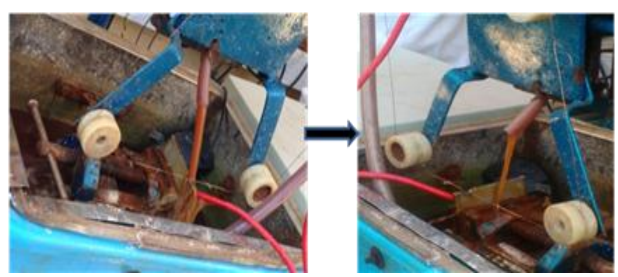


**Fig 6. Representing the Nacl Electrolyte solution is flowing through pipe over working during machining**

By supplying of Electricity, the electrolysis process will be carried out. While the machining process is going on the electrolyte concentration colour will be changed from white to brown because of the particles erode from the work piece and mixed with electrolyte concentration so, the colour will be changed which is shown in the figure. Before machining of the 20 work pieces, we want to measure the weights by the help of the weighing machine.

After the machining process the metal will be removed from the work piece in the small amount as per of DOE. The Figure represent the schematic representation of After Machining Process.


**Fig 7. Representing Work pieces before Machining**

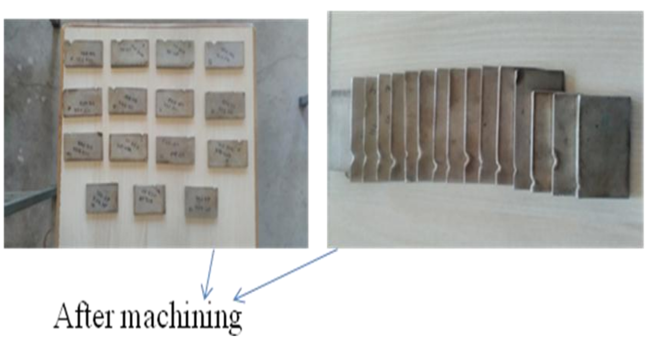



**Fig 8. Representing Work pieces After Machining**

*F. Metal Removal Rate-MRR*

$$MRR = \frac{LW}{MT} \quad \text{----------} \ 1$$

Where, LW= Weight of work piece before machining (BM)-

Weight of work piece after machining (AM)
LW -Loss of weight (grams)
MT- Machining Time (minute)
Here we get MRR in terms of g/min.

The quadratic model is statistically significant for the analysis of MRR. The details of ANOVA for the response surface quadratic model along with the partial sum of squares on MRR are given in the Table 3. The F-value of the source "Model" 7.91 implies that the model is significant. This means that the regression model provides an excellent explanation of the relationship between the factors and the MRR. In this case, V, U*EC, V*EC are significant model terms. The lack of fit "F-value" 3.84 is less than the tabulated value, which means that the developed model is adequate.

The suitable regression model for the response MRR is given below:

$$MRR = -0.03074 + 0.0058*V - 0.00105*EC + 0.0326*U + 0.00007*V^2 - 0.000001*EC^2 - 0.008*U^2 + 0.00005*V*EC - 0.0009*V*U + 0.00038*EC*U$$

## IV. Results & Discussions

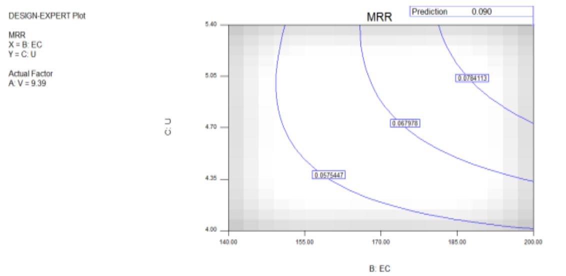
*A. Anova Analysis*

The analysis of variance is performed for the model adequacy checking, which includes a test for the significance of the regression model, model coefficients and lack of fit. ANOVA is mainly carried out to analyze the variation among the groups. This is done by F-test at 95% confidence level. Significance and insignificance are determined by comparing the F-values with standard tabulated values at the corresponding degrees of freedom and 95% confidence level. The values of "Prob> F" less than 0.05 indicates that the model and its terms are significant. The values which are greater than 0.1 indicate that the model terms are not significant.

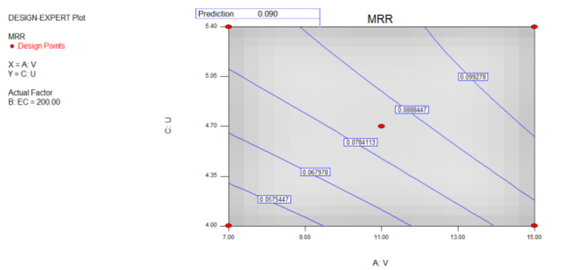
*B. Parameters Influence on MRR*

Based on the mathematical model which is developed through the CCD of the response surface methodology, the effect of the various process parameters' influence on the MRR has been analyzed. The contourplots were drawn for various combinations of influencing parameters. The changes in the intensity of the shade in the plot represent the change in the MRR. Graphs represents the influence of parameters such as EC, V and U on MRR. The increase in the voltage increases the machining current in the Flow Rate (U), thereby increasing the MRR.

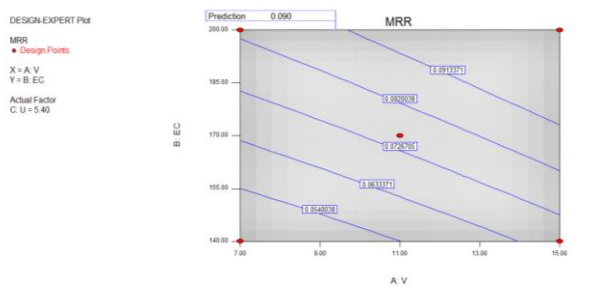
The mobility of ions in the high concentration of electrolyte in the small Flow Rate is disturbed. Therefore, it results in poor MRR. But, the smaller Flow Rate and the moderate concentration allow more ions for ionization, which results in increasing the MRR.




**Graph 1. Effect of Flow rate & Electrolyte Concentration on MRR**




**Graph 2. Effect of Flow rate & Applied Voltage on MRR**




**Graph 3. Effect of Electrolyte Concentration & Applied Voltage on MRR**

### C. *Response Surface Optimization*

In RSM, multiple responses are optimized with the steepest ascent/descent method by the desirability function (DF). DF is one of the most extensively used methods for multi-response optimization. It transforms each response $y_i$ into an individual desirability function $d_i(y_i)$ that varies in the range (0, 1). It increases as the corresponding response value becomes more desirable. Depending upon the nature of the responses ($y_i$), the desirability functions $d_i(y_i)$ will be maximized/minimized, or assigned to a target value.

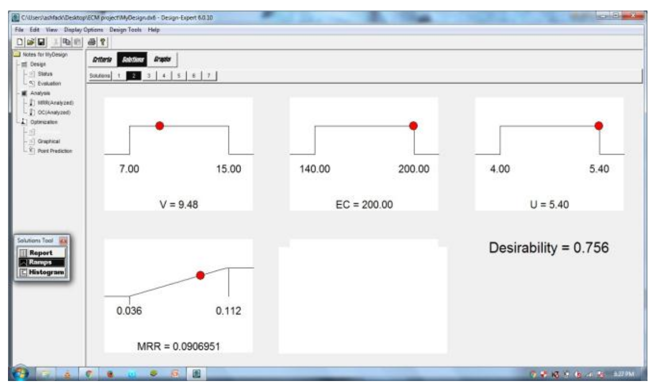
Where, x is the parameters, i.e., V, EC and U

$L_i$ and $U_i$ are lower and upper acceptable bounds of $y_i$, $T_i$ is target values desired for i response, where $L_i < T_i < U_i$ r is the parameter that determines the shape of $d_i(y_i)$. The individual desirability functions are then combined using the geometric mean, which gives the Composite desirability D:

**TABLE II**
**PROCESSES RESPONSES**

| **Variables** | **Goal** | **Lower Bound(Li)** | **Upper Bound(Ui)** |
|---|---|---|---|
| V | In the range | 7 | 15 |
| EC | In the range | 140 | 200 |
| U | In the range | 4 | 5.4 |
| MRR | Maximize | 0.036 | 0.112 |

The best composite desirability (0.756) is established at the following machining conditions. U=5.4liter per minute, V=9.48 V, EC=200 grams per liter, MRR=0.09069 grams per minute.




**Graph 4. Graph represents optimum MRR value for MECM for Given Parameters**

## V. CONCLUSION

An attempt has been made in this work to highlight the influence of ECM process parameters on the machining performances, i.e., MRR, Over Cut AISI 304L. Response surface methodology was employed to analyze the ECM process.

Mathematical models have also been developed based on the RSM approach for correlating the MRR and Over Cut with process parameters. The adequacy of the developed mathematical model has been tested through the analysis of variance (ANOVA). The results of the analysis justify the closeness of the fit of the mathematical model at 95% confidence level. The influence of different process parameters on machining performance criteria are exhibited though contour plots. It is clear from the response contour plot of MRR increase with the increase in the voltage. Electrolyte concentration of 170grams per liter and U 4.7liter per minute provide good MRR From the developed mathematical model, the optimal machining parametric combination, i.e., U=5.40 liter per minute, V=9.48V and EC=200grams per liter was found out to achieve the maximum material removal rate, i.e., 0.09069 grams per minute and minimum.The effective utilization of ECM for AISI 304L for achieving the best material removal rate (MRR) has been attempted in this work.

REFERENCES

[1] V.Sathiyamoorthy, T.Sekar, P.Suresh, R.Vijayan, N.Elango, Optimization of Processing Parameters In Electrochemical Machining of AISI 202 Using Response Surface Methodology Journal of Engineering Science And Technology Vol. 10, No. 6 (2015) 780 - 789 © School of Engineering, Taylor's University.

[2] Ramandeep Singh, Nikhil Gandotra, AyyappanSolaiyappan, Study of Different Work Materials Effect on Surface Roughness in Electrochemical Machining Process IJRET: International Journal Of Research In Engineering And Technology, Eissn: 2319-1163 | Pissn: 2321-7308 (2015).

[3] M.Kalaimathi, G.Venkatachalam, M.Sivakumar, JJMIE: Jordan Journal ofMechanical and Industrial Engineering, Volume 8 Number 5, June, 2014, ISSN 1995-6665.

[4] Pradeepkumar.P ,International Journal of Applied Engineering And Technology ISSN: 2277-212X (Online) An Open Access, online International Journal Available At Http://Www.Cibtech.Org/Jet.Htm 2014 Vol. 4 (1) January-March, Pp.68-71/Pradeep(2014).

[5] P.V.Jadhav, D.S.Bilgi, Sumitsharan, Rachitshrivastava , International Journal of Innovative Research In Science, Engineering and Technology (An ISO 3297: 2007 Certified Organization) Vol. 3, Issue 1, January 2014 Experimental