Comparative Study of the Output Responses Obtained by Machining with Different Tools

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Abstract: Electrochemical machining (ECM) is widely used in manufacturing industry due to its many superior properties like no tool wear, good surface finish. Any conducting material can be machined with high dimensional accuracy and intricate designs can be easily carved on difficult to machine materials irrespective of their hardness. The magnetic properties and hardness etc. of the substrate material remain unchanged after machining with ECM due to lesser temperature generation during machining. The main challenge for using this method is that the specific energy requirement for the process is very large (about 150 times that required for conventional processes). Hence optimization techniques are necessary to get the best set of parameters in order to enhance the quality of machining. In the present work AISI D2 steel is machined with three different types of tools, copper, brass and graphite. Comparative study of the output responses obtained by machining with different tools was done to examine the advantage provided by individual tool material on the performance characteristics. Design of experiments was carried out using Response surface methodology combined with utility concept to convert the multi response system into an equivalent single response objective function by giving equal weight age to all the responses. Finally the responses were optimized by the nature inspired optimization technique Harmonic search algorithm as it takes lesser time and fewer calculations to optimize the responses. It was found that graphite tool gives the highest value of MRR and lowest value of overcut as compared to copper and brass tool while surface roughness obtained by machining with brass tool was found to be minimum.
Keywords: Electrochemical machining; Copper; Brass; Graphite; Response surface method; AISI D2 steel; Utility concept; Harmonic search algorithm..

I. INTRODUCTION

Electrochemical machining (ECM) is a non-conventional anodic dissolution process in which material removal takes place at atomic level by electrochemical action. The material removal rate depends only on the atomic weight and valence of the work material and not on the mechanical or physical properties of it. So any electrically conductive material can be easily machined irrespective of their hardness, strength or even thermal properties. ECM propounds many advantages over other machining processes however there are several disadvantages also. Advantages: there is no hydrogen embrittlement of the products because hydrogen evolves at cathode while metal removal takes place due to anodic dissolution at the anode; no effect on ductility, yield strength, ultimate strength and micro hardness of the machined components. Limitations: specific energy requirement for the process is very large (about 150 times that required for conventional processes). Not suitable for electrically non-conducting materials and jobs with very small dimensions; expensive machines; difficulty in handling and containing of the electrolyte. Applications: Owing to its innovative nature and numerous material and machining benefits it has very wide cross industry applications. In aerospace industry, ECM is used in the manufacturing of turbine blades and blisks in jet engines and gas turbines, gears, nozzles, manifolds, diffusers etc., in automotive industry, turbochargers, gears, fuel systems, break systems, oil flow features, pistons, shafts, vehicle logos etc., in biomedical industry artificial implants (e.g. hip implants), surgical blades, saws etc., in chemical industry micro reactors, micro heat exchangers etc.

II. LITERATUERE SURVEY

Rajurkar et al. (2022) focused their study on the minimization of MRR such that exact amount of localized machining can be obtained to minimize the machining allowance. They found that the use of passivation electrolyte and pulse current minimizes generation of sludge hence improves the accuracy.

Kumar et al. (2021) discussed a case study on Al-Si alloy employing an approach which is based on Taguchi combined with utility based method. The authors developed a model to predict the optimal settings of the process parameters such that optimal quality characteristics can be obtained. For obtaining different sets of optimal parameters, different weights can be assigned to different responses.

Bhattacharyya and Munda (2019) developed an electrochemical micro-machining (EMM) experimental set-up to carry out research so that EMM process parameters can be adequately controlled. He found that value of voltage in between 6-10 V provides a significant amount of MRR with reasonable accuracy. He also found that lesser value of electrolytic concentration with moderate pulse on time and high voltage gives good dimensional accuracy lesser overcut and moderate MRR. Micro sparks are undesirable as it results in inaccuracy.

Datta and Mahapatra (2017) applied Taguchi, Principal Component Analysis (PCA) and utility theory to optimize various correlated surface quality features of a mild steel product manufactured by straight turning operation. PCA is applied to convert correlated responses into independent quality indices and utility concept is used to convert multi responses into single response such that the problem is solved by Taguchi method. They explored the comprehensive procedure and mathematical expressions for the above optimization methods and concluded the robustness and flexibility of the proposed optimization techniques.

Erdal and Saka (2015) utilized Harmonic search method for the optimization of design of grillage system. presented a new method particle swarm optimization (PSO) to find out best combination of process parameters of ECM process. They formulated expressions for three objective functions to be maximized namely dimensional accuracy, MRR and tool life under the constraints of passivity of electrolyte, choking and maximum temperature to be allowed. The responses obtained from single objective and multi-objective are compared and it was found that those obtained from the multi-objective optimization are better.

Rao et al. (2014) They also compared the performance of PSO with other non-conventional optimization methods and found that less no of trails are required to predict the optimum operating parameters.

Routara et al. (2010) studied utility concept and combined it with Taguchi method for a case study in CNC end milling of leaded brass and found out the optimum process parameters which fulfils the multi objective and simultaneously satisfy multiple requirements of surface quality. A multi-objective optimization problem cannot be solved by conventional Taguchi method so utility theory is coupled with it to convert it into single-objective optimization problem.

Ayachi et al. (2009) determined the arrangement of containers such that due delivery dates to customers can met and handling cost of containers can be reduced. To overcome with the problem they applied harmonic search method. This method was compared with the previously applied genetic algorithms and found good results.

Chakradhar and Gopal (2008) Considered the effect of process parameters such as applied voltage, tool feed rate, electrolyte concentration for ECM on EN-31 steel and optimized them using grey relational analysis. Multi objective optimization is applied to consider surface roughness, MRR, overcut, cylindricity error simultaneously and it was observed that the most significant process parameter was feed rate. Grey relation analysis was used to convert the above four responses into single Grey relational grade as the response to simplify the procedure.

Samanta and Chakraborty (2007) applied artificial bee colony (ABC) algorithm to find out the optimal combinations of different operating parameters for three nontraditional machining processes, i.e. ECM, EDM, and ECMM. Both the single and multi-objective optimization problems for the considered NTM processes are solved using this algorithm. The results obtained while applying the ABC algorithm for parametric optimization of these three NTM processes are compared with those derived by the past researchers, which prove the applicability and suitability of the ABC algorithm in enhancing the performance measures of the considered NTM processes

III. PROBLEM IDENTIFICATION

1. The main challenge for using this method is that the specific energy requirement for the Process is very large.

2. The material removal rate depends only on the atomic weight and valence of the work material and not on the mechanical or physical properties of it.

3. Multi objective optimization is applied to consider surface roughness, MRR, overcut, cylindricity error

simultaneously and it was observed that the most significant process parameter was feed rate.

IV. RESEARCH OBJECTIVES

The aim of the present work can be summarized as given below:

1. Comparative study of the output responses obtained by machining with different tools to examine the advantage provided by individual tool material on the performance characteristics.

2. Effect of feed rate, electrolytic concentration and voltage on MRR, surface roughness and overcut of AISI D2 steel.

3. To combine utility method with Response surface method.

4. According to Harmonic search method to find which set of process parameters will give the optimal result for response variables.

V. METHODOLOGY

All the experimental work was done on electrochemical machine. The machining setup consists of three main parts:

- Machining Cell

- Control Panel

- Electrolyte Circulation system

In this component the main machining work is being carried out. This is made by assembling various precision machined component parts. There is arrangement for up and down movement of tool which is servo motorized, a glass window through which machining process can be seen from outside, vice for fixing the job which can move in horizontal and vertical direction, arrangement for incoming and outgoing of electrolyte. All the parts which is inside the machining chamber are exposed to electrolyte which is generally salt and acids so proper selection of material, coating etc. are necessary to make it corrosion resistant. The technical data are as follows:

- Tool area- 122.72mm2

- Cross head stroke- 150mm

- Tool feed motor- DC servo type

Control panel is used to control all the process parameters of machining. Voltage (V), current (I), feed rate (F), duration of time, all are adjusted through the switch buttons provided in the control panel. Technical specification of the control panel is as follows:

- Electrical Out Put Rating - 0-300 A. DC at any voltage from 0 - 20 V.

- Efficiency - Better than 80% at partial & full load condition.

- Protections - Over load, Short circuit, single phasing.

- Operation Modes - Manual/Automatic.

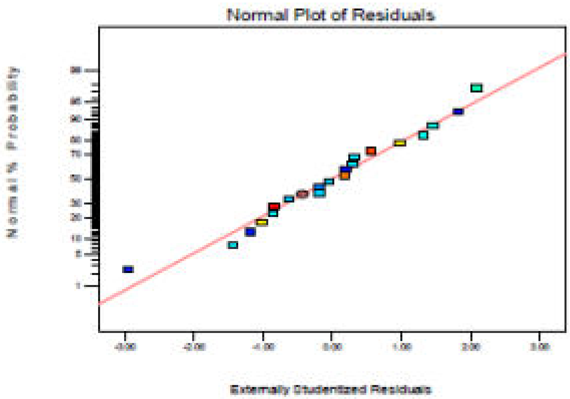
- Timer - 0 - 99.9 min. • Tool Feed - 0.2 to 2 mm / min.

- Z Axis motion Control - Manual Forward and reverse, auto forward /reverse through micro controller.

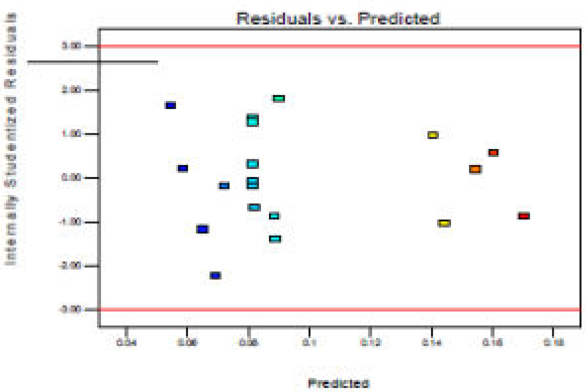
The electrolyte tank consists of three chambers separated through filtering meshes; the capacity of the tank is 90 liters. Filtered electrolyte is pumped to the machining zone and used electrolyte goes to the chamber which is farthest away from the pump and after two filtrations it is again circulated for machining.

VI. RESULTS AND ANALYSIS

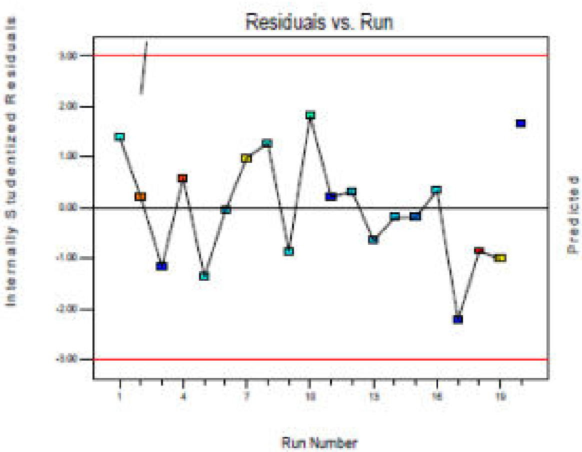
It is clear that the model is significant as its F-value is 108.90. In this case A, B, B^2 are significant model terms. Here the value of Predicted R-Squared of 0.9324 is in reasonable agreement with the Adjusted R-Squared of 0.9808 and close to 1.0 which suggests that the variation in the observed value can be explained by the chosen model satisfactorily. The value of Adequate precision is 32.82 is good as it measures the S/N ratio.



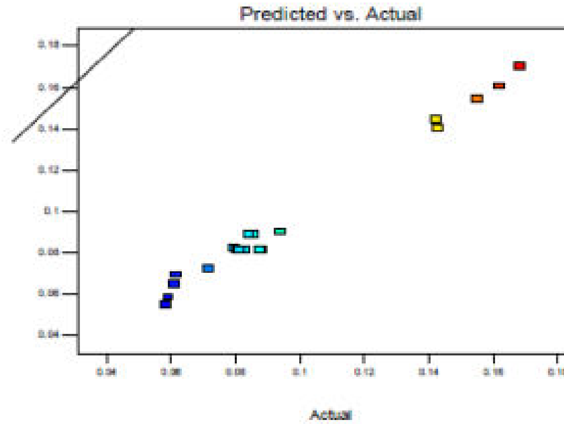
(A) Normal Plots for Residuals



(B) Residuals Vs Predicted



(C) Residuals Vs Run No.



(D) Predicted Vs Actual

VII. CONCLUSIONS

Maximum material removal rate and minimum radial overcut was obtained by using graphite as the tool material. Best surface finish of the machined surface was obtained by using brass tool. Optimization of the output responses obtained by machining with graphite tool using Harmonic search method yielded the optimal parametric combination as f=0.3mm/min, V=14V, C=15g/l. The output responses obtained under this combination was found to be MRR= 0.1428 g/min, Surface roughness = 12.4963µm, Radial overcut= 0.423mm. The optimal parametric combination obtained for brass tool by applying Harmonic search method was f=0.3mm/min, V=14V, C=15g/l. The output responses corresponding to the optimal set of combination is MRR= 0.0981 g/min, Surface roughness = 10.3017µm, Radial overcut= 0.403mm. The same technique of optimization was applied to the output responses obtained for copper tool and the optimal parametric combination was found to be f=0.3mm/min, V=14V, C=15g/l. The corresponding responses were MRR = 0.1622 g/min, overcut = 0.213 mm, surface roughness = 14.426µm.

The present work indicated that highest MRR and least overcut were obtained with graphite tool whereas machining with brass tool resulted in best surface finish. Therefore, graphite tool is recommended in those practical applications where material removal rate needs to be high and dimensional accuracy of the final product is a vital requirement. Similarly, electrochemical machining with brass tool is recommended in the applications where the machined surface needs to have a good surface finish. The current research work was carried out using different tool materials, brine solution as electrolyte and AISI D2 tool steel to study the effect of each tool material during the machining process. Still there is a need to study the effect of more variations in the machining conditions to enhance the performance characteristics.

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