Artificial neural network models for the prediction of MRR in Electro-chemical machining

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Abstract

Electro-chemical machining (ECM) uses a set of intricate process to create a negative image of tool on workpiece by high rate anodic dissolution. A Full factorial (DOE) $2^4$ is applied to determining the most important factors which influence MRR of AA6061 (T6). In the present work, experimental data collected are tested with analysis of variance (ANOVA) and Artificial Neural Network (ANN) model has been proposed for the prediction of response. For this purpose, the MATLAB has been used for training and testing of neural network model. The predicted results using ANN specify good agreement between the predicted values and experimental values. Multilayer perceptron model has been constructed with back-propagation algorithm using four process parameters viz. voltage, feed rate, electrolyte concentration and electrode (Cu, Brass) are considered in this study. Finally, ANN model has been found efficient to predict ECM process response for selected process conditions.

Keywords: Electrochemical machining (ECM); Full factorial (DOE); Analysis of variance; Artificial Neural Network.

Nomenclature

ECM Electro-chemical machining
DOE Design of Experiments
V Voltage in Volts
EC Electrolyte Concentration (NaCl)
MRR Material removal rate (mg/min.)
$R^2$ Coefficient of determination
Pred. $R^2$ Predicted $R^2$
Adj. $R^2$ Adjusted $R^2$
ANN Artificial Neural Network

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1. Introduction

Electrochemical machining (ECM) is one of the best processes to machine hard materials of complex geometry. Hard materials show better surface accuracy and integrity when machined by ECM, which makes it most popular and have increased use in industries like automotive, aircraft industries to machine turbine blades [1-4], casting industries to make dies [2] etc. So it is always needed to improve the process capabilities of ECM. Researchers are trying to increase the performance level of ECM by modifying the tool shape [3] rotating the tool [4]. It is the basic requirement of any industry to produce the final product with the least time and at desired level of surface finish. From the economic point of view, maximum MRR is the objective of any process. Alternatively, surface roughness plays an important role for the tribological operation of any component. Proper selection of machining parameters for the best process performance is quite a challenging job. Numerous researchers carried out various investigations for improving the process parameter optimization in ECM. Tiwari et al. [5] to develop a mathematical model for responses i.e., MRR and SR through regression analysis for ECM on EN-19 and ANOVA test is implement to check the suitability of the developed mathematical models. Giribabu et al. [6] multiple linear regression models are build up for MRR, SR and ROC. Optimum machining parameters to maximize Material Removal Rate (MRR), minimize Surface Roughness (SR) and minimize Radial Over Cut (ROC) are found out using genetic algorithms. Patil et al. [7] have presented the study of the work has been undertaken to finding the material removal rate by electrochemical dissolution of an anodic ally polarized work piece with a circular-shaped copper electrode. Babar et al. [8] investigates the effect and parametric optimization of process parameters for Electrochemical machining of Titanium based alloy. The process parameters take into account are electrolyte concentration, applied voltage and feed rate are optimized in concern of material removal rate. Analysis of variance is performed to get contribution of each parameter on the performance characteristics and it was detected that feed rate is the significant process parameter that affects the ECM robustness. Senthilkumar et al. [9] have studied the effect of various process parameters such as electrolyte concentration, voltage, tool feed rate and electrolyte flow rate on MRR and surface roughness (Ra) and developed a mathematical model in terms of machining process parameters for Material Removal Rate (MRR) and surface roughness (Ra) prediction in Electrochemical machining of LM25 Al/10%SiCp composite. Goswami et al. [10] have optimized machining process parameters viz. voltage, tool feed and current with consideration of multiple performance characteristics including MRR and surface roughness for ECM of aluminium and mild steel material using Taguchi technique. Bahre et al. [11] have attempted to model and optimize the pulse electro chemical machining (PECM) process using Response Surface Methodology (RSM). The machining parameters considered in the study are voltage, pulse on time, frequency, feed rate, pressure, multiple responses are MRR and surface roughness (Ra). They have also tried to optimize MRR and Ra prediction model using RSM. Acharya et al. [12] have developed a MRR and surface roughness prediction model in electrochemical machining (ECM) of super alloys using RSM. Rao et al. [13] have found out the optimization machining process parameters for ECM of Al/5%SiC material using Taguchi design considering feed rate, voltage and electrolyte concentration as the process parameters. From Taguchi analysis, they have obtained an optimal combination of process parameters for maximum metal removal rate. Burger et al. [14] have investigated the effects of machining parameters on MRR and surface roughness in ECM/PECM of nickel-base single-crystal alloy (LEK94). Ali et al. [15] have developed a mathematical model and software for simulation, using ultra short (nanoseconds) pulses for generating complex 3-D microstructures of high accuracy. Samanta et al. [16] have used artificial bee colony algorithm for parametric optimization on MRR, over-cut (OC) and heat affected zone (HAZ) in some unconventional machining process including Electrochemical machining, electrochemical discharge machining and electrochemical micro-machining. Chakradhar et al. [17] have examined the optimization of an ECM process performed on EN31 steel considering electrolyte concentration, applied voltage, and feed rate as process parameters. They have optimized them multi response viz., overcut, cylindricity error, surface roughness and MRR using Grey relation analysis. The present study deals with the development of model and its application to optimize ECM process parameters using the full factorial (DOE) which is based on the robust design. Experimentation was executed as per full factorial design of experiments with 16 experimental runs. Each experiment has been performed under the effects of voltage, feed rate, electrolyte concentration and conductive electrode on MRR by artificial neural network (ANN) during electrochemical machining of AA6061. Based on this analysis, process parameters are optimized. ANOVA is implemented to
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