Scopus

Documents

Hasan, M.M.[a] , Saleh, T.[a] , Sophian, A.[a] , Rahman, M.A.[b c] , Huang, T.[d] , Mohamed Ali, M.S.[e]

Experimental modeling techniques in electrical discharge machining (EDM): A review
(2023) *International Journal of Advanced Manufacturing Technology*, 127 (5-6), pp. 2125-2150. Cited 8 times.

DOI: 10.1007/s00170-023-11603-x

[a] Autonomous Systems and Robotics Research Unit (ASRRU), Department of Mechatronics Engineering, Kulliyyah of Engineering, International Islamic University Malaysia, Kuala Lumpur, 53100, Malaysia
[b] Department of Mechanical and Production Engineering, Ahsanullah University of Science and Technology, Dhaka, 1208, Bangladesh
[c] Department of Mechanical Engineering, McMaster Manufacturing Research Institute (MMRI), McMaster University, Hamilton, ON L8S4L7, Canada
[d] College of Science and Engineering, James Cook University, Smithfield Cairns, QLD 4878, Australia
[e] Faculty of Electrical Engineering, Universiti Teknologi Malaysia, Johor, Johor Bahru, 81310 UTM, Malaysia

Abstract
Electrical discharge machining (EDM) is a widely used non-conventional machining technique in manufacturing industries, capable of accurately machining electrically conductive materials of any hardness and strength. However, to achieve low production costs and minimal machining time, a comprehensive understanding of the EDM system is necessary. Due to the stochastic nature of the process and the numerous variables involved, it can be challenging to develop an analytical model of EDM through theoretical and numerical simulations alone. This paper conducts an extensive review of the various experimental (or empirical) modeling techniques used by researchers over the past two decades, including a geographic and temporal analysis of these approaches. The major methods employed to describe the EDM process include regression, response surface methodology (RSM), fuzzy inference systems (FIS), artificial neural networks (ANN), and adaptive neuro-fuzzy inference systems (ANFIS). Additionally, the optimization methods used in conjunction with these methods are also discussed. Although RSM is the most commonly used empirical modeling technique, recent years have seen an increase in the use of ANN for providing the most accurate predictions of EDM process responses. The review of the literature shows that most of the investigations on experimental EDM modeling were conducted in Asia.

Author Keywords
ANFIS; ANN; EDM; Experimental modeling; Fuzzy; Optimization; Regression; RSM

Index Keywords
Conductive materials, Costs, Electric discharge machining, Electric discharges, Fuzzy inference, Fuzzy neural networks, Fuzzy systems, Stochastic systems; Adaptive neuro-fuzzy inference, Adaptive neuro-fuzzy inference system, Electrical discharge machining, Experimental modelling, Fuzzy, Modelling techniques, Neuro-fuzzy inference systems, Optimisations, Regression, Response-surface methodology; Stochastic models

References

- Meshram, D.B., Puri, Y.M.
Review of research work in die sinking EDM for machining curved hole
(2017) *J Braz Soc Mech Sci Eng*, 39, pp. 2593-2605.

- Webzell, S.
(2001) *The first step into EDM in machinery*,
Findlay Publications Ltd, Kent, UK

- Ho, K.H., Newman, S.T.
State of the art electrical discharge machining (EDM)
(2003) *Int J Mach Tools Manuf*, 43, pp. 1287-1300.

- Jameson, E.C.
Electrical discharge machining
(2001) *Society of Manufacturing Engineers (SME), Michigan*,

- McGeough, J.A.
(1988) *Advanced methods of machining*,

Chapman and Hall, London, UK

- Lonardo, P.M., Bruzzone, A.A.
Effect of flushing and electrode material on die sinking EDM
(1999) *CIRP Ann Manuf Technol*, 48, pp. 123-126.

- Panda, R.C., Sharada, A., Samanta, L.D.
A review on electrical discharge machining and its characterization
(2021) *Mater Today Proc*,

- Jahan, M.P., Rahman, M., Wong, Y.S.
Micro-electrical discharge machining (Micro-EDM): processes, varieties, and applications
(2014) *Comp Mater Process*, 11, pp. 333-371.

- Pham, D.T., Dimov, S.S., Bigot, S.
Micro-EDM - recent developments and research issues
(2004) *J Mater Process Technol*, 149, pp. 50-57.

- Mollik, M.S., Saleh, T., Bin Md Nor, K.A., Ali, M.S.M.
A machine learning-based classification model to identify the effectiveness of vibration for μEDM
(2022) *Alex Eng J*, 61, pp. 6979-6989.

- Jahan, M.P., Rahman, M., Wong, Y.S.
Study on the nano-powder-mixed sinking and milling micro-EDM of WC-Co
(2011) *Int J Adv Manuf Technol*, 53, pp. 167-180.

- Zhang, Z., Zhang, Y., Ming, W.
A review on magnetic field assisted electrical discharge machining
(2021) *J Manuf Process*, 64, pp. 694-722.

- Muthuramalingam, T., Mohan, B.
A review on influence of electrical process parameters in EDM process
(2015) *Arch Civ Mech Eng*, 15, pp. 87-94.

- Raju, L., Hiremath, S.S.
A state-of-the-art review on micro electro-discharge machining
(2016) *Procedia Technol*, 25, pp. 1281-1288.

- Tariq Jilani, S., Pandey, P.C.
Analysis and modelling of edm parameters
(1982) *Precis Eng*, 4, pp. 215-221.

- DiBitonto, D.D., Eubank, P.T., Patel, M.R., Barrufet, M.A.
Theoretical models of the electrical discharge machining process. I. A simple cathode erosion model
(1989) *J Appl Phys*, 66, pp. 4095-4103.

- Eubank, P.T., Patel, M.R., Barrufet, M.A., Bozkurt, B.
Theoretical models of the electrical discharge machining process. III. the variable mass, cylindrical plasma model
(1993) *J Appl Phys*, 73, pp. 7900-7909.

- Joshi, S.N., Pande, S.S.
Development of an intelligent process model for EDM
(2009) *Int J Adv Manuf Technol*, 45, pp. 300-317.

- Izquierdo, B., Sánchez, J.A., Plaza, S.
A numerical model of the EDM process considering the effect of multiple discharges
(2009) *Int J Mach Tools Manuf*, 49, pp. 220-229.

- Bańkowski, D., Młynarczyk, P.
Influence of EDM process parameters on the surface finish of alnico alloys
(2022) *Materials*, 15.
(,),.,., https://doi.org/10.3390/ma15207277

- Zhang, Y., Zhang, G., Zhang, Z.
Effect of assisted transverse magnetic field on distortion behavior of thin-walled components in WEDM process
(2022) *Chin J Aeronaut*, 35, pp. 291-307.

- Ostertagová, E.
(2012) *Modelling using polynomial regression. Procedia Eng*, 48, pp. 500-506.

- Çogun, C., Akaslan, S.
The effect of machining parameters on tool electrode edge wear and machining performance in electric discharge machining (EDM)
(2002) *46 KSME Int J*, 16, pp. 46-59.

- Keskin, Y., Halkaci, H.S., Kizil, M.
An experimental study for determination of the effects of machining parameters on surface roughness in electrical discharge machining (EDM)
(2006) *Int J Adv Manuf Technol*, 28, pp. 1118-1121.

- Azadi Moghaddam, M., Kolahan, F.
Optimization of EDM process parameters using statistical analysis and simulated annealing algorithm
(2015) *Int J Eng Trans A*, 28, pp. 157-166.

- Kuriachen, B., Mathew, J.
Spark radius modeling of resistance-capacitance pulse discharge in micro-electric discharge machining of Ti-6Al-4V: an experimental study
(2016) *Int J Adv Manuf Technol*, 85, pp. 1983-1993.

- Dang, X.P.
Constrained multi-objective optimization of EDM process parameters using kriging model and particle swarm algorithm
(2018) *Mater Manuf Processes*, 33, pp. 397-404.

- Dey, K., Kalita, K., Chakraborty, S.
A comparative analysis on metamodel-based predictive modeling of electrical discharge machining processes
(2022) *Int J Interact Des Manuf*,

- Ay, M., Çaydaş, U., Hasçalik, A.
Optimization of micro-EDM drilling of inconel 718 superalloy
(2013) *Int J Adv Manuf Technol*, 66, pp. 1015-1023.

- Torres, A., Puertas, I., Luis, C.J.
Modelling of surface finish, electrode wear and material removal rate in electrical discharge machining of hard-to-machine alloys
(2014) *Precis Eng*, 40, pp. 33-45.

- Laxman, J., Raj, K.G.
Mathematical modeling and analysis of EDM process parameters based on Taguchi design of experiments
(2015) *J Phys Conf Ser*, 662.
(,),.,., https://doi.org/10.1088/1742-6596/662/1/012025

- Mausam, K., Kumar Singh, P., Sharma, K., Gupta, R.C.
Investigation of process parameter of EDM using genetic algorithm (GA) approach

for carbon fiber based two phase epoxy composites
(2016) *Mater Today Proc*, 3, pp. 4102-4108.

- Selvarajan, L., Manohar, M., Udhayakumar, A., Dhinakaran, P.
Modelling and experimental investigation of process parameters in EDM of Si3N4-TiN composites using GRA-RSM
(2017) *J Mech Sci Technol*, 31, pp. 111-122.

- Salcedo, A.T., Arbizu, I.P., Luis Pérez, C.J.
Analytical modelling of energy density and optimization of the EDM machining parameters of inconel 600
(2017) *Metals (Basel)*, 7.

- Niamat, M., Sarfraz, S., Shehab, E.
Experimental characterization of electrical discharge machining of aluminum 6061 T6 alloy using different dielectrics
(2019) *Arab J Sci Eng*, 44, pp. 8043-8052.

- Meslameni, W., Kamoun, T., Hbaieb, M.
Experimental modeling of EDM process using the experimental design method
(2019) *Int J Appl Res Technol*, 2, pp. 39-47.

- Kalyon, A.
Optimization of Machining Parameters in Sinking Electrical Discharge Machine of Caldie Plastic Mold Tool Steel,

- Gaikwad, M.U., Krishnamoorthy, A., Jatti, V.S.
Implementation of Jaya algorithm for process parameter optimization during EDM processing of NiTi 60alloy
(2021) *Mater Today Proc*, 47, pp. 5701-5708.

- Meshram, D.B., Gohil, V., Puri, Y.M., Ambade, S.
Implementation of multi-objective Jaya optimization for performance improvement in machining curve hole in P20 mold steel by sinking EDM
(2022) *World J Eng*, 19, pp. 381-394.

- Tajdeen, A., Wasim Khan, M., Kamal Basha, K.
Experimental investigation and optimization of EDM process parameters on EN31 steel using genetic algorithm
(2022) *Mater Today Proc*, 64, pp. 821-827.

- Maji, K., Pratihar, D.K.
Modeling of electrical discharge machining process using conventional regression analysis and genetic algorithms
(2011) *J Mater Eng Perform*, 20, pp. 1121-1127.

- Ming, W., Zhang, G., Li, H.
A hybrid process model for EDM based on finite-element method and Gaussian process regression
(2014) *Int J Adv Manuf Technol*, 74, pp. 1197-1211.

- Mohanty, C.P., Mahapatra, S.S., Singh, M.R.
An intelligent approach to optimize the EDM process parameters using utility concept and QPSO algorithm
(2017) *Eng Sci Technol Int J*, 20, pp. 552-562.

- Box, G.E.P., Wilson, K.B.
On the experimental attainment of optimum conditions
(1951) *J Roy Stat Soc: Ser B (Methodol)*, 13, pp. 1-45.

- Box, G.E.P., Draper, N.R.
(2007) *Response surfaces, mixtures, and ridge analyses*, 2, John Wiley & Sons Inc, New Jersey

- Kung, K.Y., Horng, J.T., Chiang, K.T.
Material removal rate and electrode wear ratio study on the powder mixed electrical discharge machining of cobalt-bonded tungsten carbide
(2007) *Int J Adv Manuf Technol*, 40, pp. 95-104.

- Sohani, M.S., Gaitonde, V.N., Siddeswarappa, B., Deshpande, A.S.
Investigations into the effect of tool shapes with size factor consideration in sink electrical discharge machining (EDM) process
(2009) *Int J Adv Manuf Technol*, 45, pp. 1131-1145.

- Hosseini Kalajahi, M., Rash Ahmadi, S., Nadimi Bavil Oliaei, S.
Experimental and finite element analysis of EDM process and investigation of material removal rate by response surface methodology
(2013) *Int J Adv Manuf Technol*, 69, pp. 687-704.

- Mohanty, C.P., Mahapatra, S.S., Singh, M.R.
A particle swarm approach for multi-objective optimization of electrical discharge machining process
(2014) *J Intell Manuf*, 27, pp. 1171-1190.

- Singh, N.K., Singh, Y.
Experimental investigation and modeling of surface finish in argon-assisted electrical discharge machining using dimensional analysis
(2019) *Arab J Sci Eng*, 44, pp. 5839-5850.

- Phate, M., Toney, S., Phate, V.
Modelling and investigating the impact of EDM parameters on surface roughness in EDM of Al/Cu/Ni Alloy
(2020) *Aust J Mech Eng*, pp. 1-14.

- Papazoglou, E.L., Karmiris-Obratański, P., Leszczyńska-Madej, B., Markopoulos, A.P.
A study on electrical discharge machining of titanium grade2 with experimental and theoretical analysis
(2021) *Sci Rep*, 11, p. 8971.

- Lin, Y.C., Tsao, C.C., Hsu, C.Y.
Evaluation of the characteristics of the microelectrical discharge machining process using response surface methodology based on the central composite design
(2012) *Int J Adv Manuf Technol*, 62, pp. 1013-1021.

- Assarzadeh, S., Ghoreishi, M.
A dual response surface-desirability approach to process modeling and optimization of Al2O3 powder-mixed electrical discharge machining (PMEDM) parameters
(2013) *Int J Adv Manuf Technol*, 64, pp. 1459-1477.

- Gopalakannan, S., Senthilvelan, T.
Optimization of machining parameters for EDM operations based on central composite design and desirability approach
(2014) *J Mech Sci Technol*, 28, pp. 1045-1053.

- Senthil Kumar, R., Suresh, P.
Experimental study on electrical discharge machining of Inconel using RSM and NSGA optimization technique
(2019) *J Braz Soc Mech Sci Eng*, 41.
(,),.,., https://doi.org/10.1007/s40430-018-1526-5

- Raza, M.H., Wasim, A., Ali, M.A.
Investigating the effects of different electrodes on Al6061-SiC-7.5 wt% during electric discharge machining
(2018) *Int J Adv Manuf Technol*, 99, pp. 3017-3034.

- Singh, N., Bharti, P.S.
Multi-Objective parametric optimization during micro-EDM drilling of Ti-6Al-4 V using teaching learning based optimization algorithm
(2022) *Mater Today Proc*, 62, pp. 262-269.

- Agarwal, N., Irshad, M., Raj Singh, M., Singh, G.
Optimization of material removal rate of Ti-6Al-4V using Rao-1 algorithm
(2022) *Mater Today Proc*, 62, pp. 6722-6726.

- Aruri, D., Kolli, M., Kosaraju, S., Sai Kumar, G.
RSM-TOPSIS multi optimization of EDM factors for rotary stir casting hybrid (Al7075/B4C/Gr) composites
(2022) *Int J Interact Des Manuf*,

- Tiwary, A.P., Pradhan, B.B., Bhattacharyya, B.
Study on the influence of micro-EDM process parameters during machining of Ti–6Al–4V superalloy
(2015) *Int J Adv Manuf Technol*, 76, pp. 151-160.

- Balasubramanian, P., Senthilvelan, T.
Optimization of machining parameters in EDM process using cast and sintered copper electrodes
(2014) *Proc Mater Sci*, 6, pp. 1292-1302.

- Kuriachen, B., Mathew, J.
Modeling and multi-response prediction of micro edm drilling on inconeL 718
(2014) *All India Manufacturing Technology, Design and Research Conference*,
IIT Guwahati, Assam, India

- Perveen, A., Jahan, M.P.
Application of box Behnken design to model crater size generated during micro-EDM of NI-X alloy
(2018) *Int J Mech Eng Robot Res*, 7, pp. 229-234.

- Singh, N., Routara, B.C., Das, D.
Study of machining characteristics of Inconel 601 in EDM using RSM
(2018) *Mater Today Proc*, 5, pp. 3438-3449.

- Naik, S., Das, S.R., Dhupal, D.
Experimental investigation, predictive modeling, parametric optimization and cost analysis in electrical discharge machining of Al-SiC metal matrix composite
(2021) *SILICON*, 13, pp. 1017-1040.

- Ibrahim, A.F., Singal, A.H., Noori, D.A.A.K.
Investigation of material removal rate and surface roughness during electrical discharge machining on Al (6061)-5%SiC-10%B4C HYBRID COMPOSITE
(2022) *Metallurgical Mater Eng*, 28, pp. 47-60.

- Hegab, H.A., Gadallah, M.H., Esawi, A.K.
Modeling and optimization of electrical discharge machining (EDM) using statistical design
(2015) *Manuf Rev (Les Ulis)*, 2.

- Hiremath, S.S., Raju, L.
Investigation on machining copper plates with NiP coated tools using tailor-made

micro-electro discharge machine
(2017) *Adv Mater Process Technol*, 3, pp. 522-538.

- Mondal, N., Nishant, C., Mandal, M.
Comparative study on EDM process parameters optimization using BBO and ACO algorithms
(2022) *Mater Today Proc*, 62, pp. 6601-6605.

- Sharif, S., Safiei, W., Mansor, A.F.
Experimental study of electrical discharge machine (die sinking) on stainless steel 316L using design of experiment
(2015) *Procedia Manuf*, 2, pp. 147-152.

- Zadeh, L.A.
Fuzzy sets
(1965) *Inf Control*, 8, pp. 338-353.

- Mamdani, E.H.
Application of fuzzy algorithms for control of simple dynamic plant
(1974) *Proc Inst Electr Eng*, 121, pp. 1585-1588.

- Takagi, T., Sugeno, M.
Fuzzy Identification of systems and its applications to modeling and control
(1985) *IEEE Trans Syst Man Cybern*, SMC-15, pp. 116-132.
(,),.,:., https://doi.org/10.1109/TSMC.1985.6313399

- Shabgard, M.R., Badamchizadeh, M.A., Ranjbary, G., Amini, K.
Fuzzy approach to select machining parameters in electrical discharge machining (EDM) and ultrasonic-assisted EDM processes
(2013) *J Manuf Syst*, 32, p. 32.

- Belloufi, A., Mezoudj, M., Abdelkrim, M.
Experimental and predictive study by multi-output fuzzy model of electrical discharge machining performances
(2020) *Int J Adv Manuf Technol*, 109, pp. 2065-2093.

- Rodic, D., Gostimirovic, M., Kovac, P.
Comparison of fuzzy logic and neural network for modelling surface roughness in EDM
(2014) *Int J Recent Adv Mech Eng*, 3, pp. 69-78.

- Majumder, A.
Process parameter optimization during EDM of AISI 316 LN stainless steel by using fuzzy based multi-objective PSO
(2013) *J Mech Sci Technol*, 27, pp. 2143-2151.

- Payal, H., Maheshwari, S., Bharti, P.S., Sharma, S.K.
Multi-objective optimisation of electrical discharge machining for Inconel 825 using Taguchi-fuzzy approach
(2019) *Int J Inf Technol (Singapore)*, 11, pp. 97-105.

- Rodic, D., Gostimirovic, M., Madic, M.
Fuzzy model-based optimal energy control during the electrical discharge machining
(2020) *Neural Comput Appl*, 32, pp. 17011-17026.

- Kumar, A., Vivekananda, K., Ram Prasad, A.V.S.
Experimental investigation and parametric optimization during EDM of titanium grade 9 using MOORA-fuzzy integrated multi-objective Genetic algorithm
(2022) *Mater Today Proc*, 62, pp. 4473-4479.

- Tiwary, A.P., Pradhan, B.B., Bhattacharyya, B.
Application of multi-criteria decision making methods for selection of micro-EDM process parameters
(2014) *Adv Manuf*, 2, pp. 251-258.

- Dewangan, S., Gangopadhyay, S., Biswas, C.K.
Study of surface integrity and dimensional accuracy in EDM using fuzzy TOPSIS and sensitivity analysis
(2015) *Measurement (Lond)*, 63, pp. 364-376.

- Dewangan, S., Gangopadhyay, S., Biswas, C.K.
Multi-response optimization of surface integrity characteristics of EDM process using grey-fuzzy logic-based hybrid approach
(2015) *Eng Sci Technol Int J*, 18, pp. 361-368.

- Deserio, F.L.A.C., Facchini, L.M., Mummolo, F.G.
ANN modelling to optimize manufacturing process
(2018) *Advanced Applications for Artificial Neural Networks*, pp. 201-225.

- Laurene, F.
(1994) *Fundamentals of neural networks - Architectures, Algorithms, and Applications*,
Prentice-Hall, NJ

- Rumelhart, D.E., Hinton, G.E., Williams, R.J.
Learning representations by back-propagating errors
(1986) *Nature*, 323, pp. 533-536.
1986 323:6088

- Paul, W.
(1974) *Beyond regression: new tools for prediction and analysis in the behavioral sciences*,
Harvard University, PhD

- Wuest, T., Weimer, D., Irgens, C., Thoben, K.D.
Machine learning in manufacturing: advantages, challenges, and applications
(2016) *Prod Manuf Res*, 4, pp. 23-45.

- Somashekhar, K.P., Ramachandran, N., Mathew, J.
Optimization of material removal rate in micro-EDM using artificial neural network and genetic algorithms
(2010) *Mater Manuf Processes*, 25, pp. 467-475.

- Teimouri, R., Baseri, H.
Improvement of dry EDM process characteristics using artificial soft computing methodologies
(2012) *Prod Eng Res Devel*, 6, pp. 493-504.

- Maity, K., Mishra, H.
ANN modelling and elitist teaching learning approach for multi-objective optimization of μ -EDM
(2016) *J Intell Manuf*, 29, pp. 1599-1616.

- Singh, N.K., Singh, Y., Kumar, S., Upadhyay, R.
Integration of GA and neuro-fuzzy approaches for the predictive analysis of gas-assisted EDM responses
(2019) *SN Appl Sci*, 2.

- Singh, N.K., Singh, Y., Kumar, S., Sharma, A.
Comparative study of statistical and soft computing-based predictive models for material removal rate and surface roughness during helium-assisted EDM of D3 die

steel
(2019) *SN Appl Sci*, 1.

- Dey, K., Kalita, K., Chakraborty, S.
Prediction performance analysis of neural network models for an electrical discharge turning process
(2022) *Int J Interact Design Manuf (IJIDeM)*,

- Singh, S.K., Mali, H.S., Unune, D.R.
Application of generalized regression neural network and Gaussian process regression for modelling hybrid micro-electric discharge machining: a comparative study
(2022) *Processes*, 10, p. 755.

- Assarzadeh, S., Ghoreishi, M.
Neural-network-based modeling and optimization of the electro-discharge machining process
(2008) *Int J Adv Manuf Technol*, 39, pp. 488-500.

- Markopoulos, A.P., Manolakos, D.E., Vaxevanidis, N.M.
Artificial neural network models for the prediction of surface roughness in electrical discharge machining
(2008) *J Intell Manuf*, 19, pp. 283-292.

- Rahman Khan, M.A., Rahman, M.M., Kadirgama, K.
Neural network modeling and analysis for surface characteristics in electrical discharge machining
(2014) *Procedia Eng*, 90, pp. 631-636.

- Quarto, M., D'Urso, G., Giardini, C.
A comparison between finite element model (FEM) simulation and an integrated artificial neural network (ANN)-particle swarm optimization (PSO) approach to forecast performances of micro electro discharge machining (micro-EDM) drilling
(2021) *Micromachines (Basel)*, 12.

- Quarto, M., D'Urso, G., Giardini, C.
Micro-EDM optimization through particle swarm algorithm and artificial neural network
(2022) *Precis Eng*, 73, pp. 63-70.

- Bharti, P.S., Maheshwari, S., Sharma, C.
Multi-objective optimization of electric-discharge machining process using controlled elitist NSGA-II
(2012) *J Mech Sci Technol*, 26, pp. 1875-1883.

- Kumar, S., Kumar, S., Sharma, R.
Artificial neural network based modeling to predict micro-hardness during EDM of cryo-treated titanium alloys
(2022) *Mater Today Proc*, 56, pp. 2938-2944.

- Pradhan, B.B., Bhattacharyya, B.
Modelling of micro-electrodischarge machining during machining of titanium alloy Ti-6Al-4V using response surface methodology and artificial neural network algorithm
(2009) *Proc Inst Mech Eng B J Eng Manuf*, 223, pp. 683-693.

- Andromeda, T., Yahya, A., Hisham, N.
Predicting material removal rate of electrical discharge machining (EDM) using artificial neural network for high Igap current
(2011) *ECCE 2011 - International Conference on Electrical, Control and Computer Engineering*, pp. 259-262.

- Tzeng, C.J., Chen, R.Y.
Optimization of electric discharge machining process using the response surface methodology and genetic algorithm approach
(2013) *Int J Precis Eng Manuf*, 14, pp. 709-717.

- Kumar, S., Batish, A., Singh, R., Singh, T.P.
A hybrid Taguchi-artificial neural network approach to predict surface roughness during electric discharge machining of titanium alloys
(2014) *J Mech Sci Technol*, 28, pp. 2831-2844.

- Sarıkaya, M., Yılmaz, V.
Optimization and predictive modeling using S/N, RSM, RA and ANNs for micro-electrical discharge drilling of AISI 304 stainless steel
(2018) *Neural Comput Appl*, 30, pp. 1503-1517.

- Varol Ozkavak, H., Sofu, M.M., Duman, B., Bacak, S.
Estimating surface roughness for different EDM processing parameters on Inconel 718 using GEP and ANN
(2021) *CIRP J Manuf Sci Technol*, 33, pp. 306-314.

- Kanake, V., Ahuja, B.B.
Prediction of tool wear length in micro-EDM process using an artificial neural network
(2022) *Mater Today Proc*, 63, pp. 107-112.

- Rouniyar, A.K., Shandilya, P.
Soft computing techniques for modelling and multi-objective optimization of magnetic field assisted powder mixed EDM process
(2022) *Neural Comput Appl*,

- Pourasl, H.H., Javidani, M., Khojastehnezhad, V.M., Vatankhah Barenji, R.
The performance prediction of electrical discharge machining of AISI D6 tool steel using ANN and ANFIS techniques: a comparative study
(2022) *Crystals (Basel)*, 12, p. 343.

- Joshi, S.N., Pande, S.S.
Intelligent process modeling and optimization of die-sinking electric discharge machining
(2011) *Appl Soft Comput J*, 11, pp. 2743-2755.

- Penmetsa, R.V., Ilanko, A.K., Rajesh, S., Chekuri, R.B.R.
Experimental study and machining parameter optimization on powder-mixed EDM of Nimonic 901 using feed-forward backpropagation neural networks
(2022) *Int J Adv Manuf Technol*,

- Krishna Mohana Rao, G., Rangajanardhaa, G., Hanumantha Rao, D., Sreenivasa Rao, M.
Development of hybrid model and optimization of surface roughness in electric discharge machining using artificial neural networks and genetic algorithm
(2009) *J Mater Process Technol*, 209, pp. 1512-1520.

- Mandal, D., Pal, S.K., Saha, P.
Modeling of electrical discharge machining process using back propagation neural network and multi-objective optimization using non-dominating sorting genetic algorithm-II
(2007) *J Mater Process Technol*, 186, pp. 154-162.

- Saffaran, A., Azadi Moghaddam, M., Kolahan, F.
Optimization of backpropagation neural network-based models in EDM process using particle swarm optimization and simulated annealing algorithms

(2020) *J Braz Soc Mech Sci Eng*, 42.
(,),.,., https://doi.org/10.1007/s40430-019-2149-1

- Machno, M., Matras, A., Szkoda, M.
Modelling and analysis of the effect of EDM-drilling parameters on the machining performance of Inconel 718 using the RSM and ANNs methods
(2022) *Materials*, 15.
(,),.,., https://doi.org/10.3390/ma15031152

- Ong, P., Chong, C.H., bin Rahim, M.Z.
Intelligent approach for process modelling and optimization on electrical discharge machining of polycrystalline diamond
(2018) *J Intell Manuf*, 31, pp. 227-247.

- Jang, J.S.R.
ANFIS: adaptive-network-based fuzzy inference system
(1993) *IEEE Trans Syst Man Cybern*, 23, pp. 665-685.

- Jang, J.S.R.
(1991) *Fuzzy Modeling Using Generalized Neural Networks and Kalman Filter Algorithm*, 2, pp. 762-767.

- Salleh, M.N.M., Talpur, N., Hussain, K.
Adaptive neuro-fuzzy inference system: Overview, strengths, limitations, and solutions
(2017) *Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, 10387, pp. 527-535.

- Pradhan, M.K., Biswas, C.K.
Neuro-fuzzy and neural network-based prediction of various responses in electrical discharge machining of AISID2 steel "NF and NN based prediction of responses in EDM of D2 steel
(2010) *Int J Adv Manuf Technol*, 50, pp. 591-610.

- Prabhu, S., Uma, M., Vinayagam, B.K.
Adaptive neuro-fuzzy interference system modelling of carbon nanotube-based electrical discharge machining process
(2013) *J Braz Soc Mech Sci Eng*, 35, pp. 505-516.

- Al-Ghamdi, K., Taylan, O.
A comparative study on modelling material removal rate by ANFIS and polynomial methods in electrical discharge machining process
(2015) *Comput Ind Eng*, 79, pp. 27-41.

- Singh, J., Sharma, R.K.
Implementation of Taguchi method with hybrid decision making tools for prediction of surface characteristics for powder-mixed EDM of WC
(2016) *Perspect Sci (Neth)*, 8, pp. 455-458.

- Goyal, A., Sharma, D., Bhowmick, A., Pathak, V.K.
Experimental investigation for minimizing circularity and surface roughness under nano graphene mixed dielectric EDM exercising fuzzy-ANFIS approach
(2022) *Int J Interact Des Manuf*, 16, pp. 1135-1154.

- Aghdeab, S.H., Shwaish, R.R.
Application of ANFIS for prediction micro holes in EDM
(2017) *Al-Nahrain J Eng Sci*, 20, pp. 544-549.

- Prabhu, S., Sundararaj, O.N.R.
Adaptive neuro-fuzzy interference system modelling of EDM process using CNT

infused copper electrode
(2017) *Int J Intell Eng Syst*, 10, pp. 102-116.

- Rodic, D., Gostimirovic, M., Sekulic, M.
Application of ANFIS for modeling and predicting the EDM surface roughness
(2020) *2020 19Th International Symposium INFOTEH-JAHORINA, INFOTEH 2020 - Proceedings*,

- Suganthi, X.H., Natarajan, U., Sathiyamurthy, S., Chidambaram, K.
Prediction of quality responses in micro-EDM process using an adaptive neuro-fuzzy inference system (ANFIS) model
(2013) *Int J Adv Manuf Technol*, 68, pp. 339-347.

- Bhiradi, I., Raju, L., Hiremath, S.S.
Adaptive neuro-fuzzy inference system (ANFIS): modelling, analysis, and optimisation of process parameters in the micro-EDM process
(2020) *Adv Mater Process Technol*, 6, pp. 133-145.

- Sharma, D., Bhowmick, A., Goyal, A.
Enhancing EDM performance characteristics of Inconel 625 superalloy using response surface methodology and ANFIS integrated approach
(2022) *CIRP J Manuf Sci Technol*, 37, pp. 155-173.

- bin Wan Azhar, W.A., Saleh, T., Razib, M.A.B.M.
Application of CANFIS for modelling and predicting multiple output performances for different materials in μEDM
(2022) *CIRP J Manuf Sci Technol*, 37, pp. 528-546.

- Garai, G.
Application of genetic algorithm in numerous scientific fields
(2022) *Genetic Algorithms*,
(,),.,., https://doi.org/10.5772/INTECHOPEN.105740

- Goldberg, D.E.
(1989) *Genetic algorithms in search, optimization, and machine learning*,
13, Addison-Wesley Professional

- Yılmaz, Ö.F., Durmuşoğlu, M.B.
Evolutionary algorithms for multi-objective scheduling in a hybrid manufacturing system
(2018) *Handbook of Research on Applied Optimization Methodologies in Manufacturing Systems*, pp. 162-187.

- Mitra, K.
Genetic algorithms in polymeric material production, design, processing and other applications: a review
(2013) *Int Mater Rev*, 53, pp. 275-297.

- Yusoff, Y., Zain, A.M.
Experimental study of genetic algorithm optimization on WC/Co material machining
(2016) *J Adv Res Mater Sci*, 21, pp. 14-26.

- Abidi, M.H., Al-Ahmari, A.M., Umer, U., Rasheed, M.S.
Multi-objective optimization of micro-electrical discharge machining of nickel-titanium-based shape memory alloy using MOGA-II
(2018) *Measurement (Lond)*, 125, pp. 336-349.

- Gostimirovic, M., Pucovsky, V., Sekulic, M.
Evolutionary multi-objective optimization of energy efficiency in electrical discharge machining
(2018) *J Mech Sci Technol*, 32, pp. 4775-4785.

- Kumar, K., Singh, V., Katyal, P., Sharma, N.
EDM μ-drilling in Ti-6Al-7Nb: experimental investigation and optimization using NSGA-II
(2019) *Int J Adv Manuf Technol*, 104, pp. 2727-2738.

- Singh, R., Singh, R.P., Trehan, R.
Machine learning algorithms based advanced optimization of EDM parameters: an experimental investigation into shape memory alloys
(2022) *Sensors International*, 3.
(,),., https://doi.org/10.1016/j.sintl.2022.100179

- Zhang, L., Jia, Z., Wang, F., Liu, W.
A hybrid model using supporting vector machine and multi-objective genetic algorithm for processing parameters optimization in micro-EDM
(2010) *Int J Adv Manuf Technol*, 51, pp. 575-586.

- Harrington, E.C., Jr.
The desirability function
(1965) *Ind Qua Control*, 21, pp. 494-498.

- Derringer, G., Suich, R.
Simultaneous optimization of several response variables
(1980) *J Qual Technol*, 12, pp. 214-219.

- Fuller, D., Scherer, W.
Desirability function: Underlying assumptions and application implications
(1998) *Proceedings of the IEEE International Conference on Systems, Man and Cybernetics*, pp. 4016-4021.

- Mehfuz, R., Ali, M.Y.
Investigation of machining parameters for the multiple-response optimization of micro electrodischarge milling
(2009) *Int J Adv Manuf Technol*, 43, pp. 264-275.

- Sengottuvel, P., Satishkumar, S., Dinakaran, D.
Optimization of multiple characteristics of EDM parameters based on desirability approach and fuzzy modeling
(2013) *Procedia Eng*, 64, pp. 1069-1078.

- Dikshit, M.K., Anand, J., Narayan, D., Jindal, S.
Machining characteristics and optimization of process parameters in die-sinking EDM of Inconel 625
(2019) *J Braz Soc Mec Sci Eng*, 41.

- Sahu, A.K., Mahapatra, S.S.
Prediction and optimization of performance measures in electrical discharge machining using rapid prototyping tool electrodes
(2021) *J Intell Manuf*, 32, pp. 2125-2145.

- Singh, A.P., Singh, D.K.
Multi response optimization for micro-EDM machining of AISI D2 die steel using RSM and neural network
(2020) *Mater Today Proc*, 43, pp. 1449-1455.

- Kennedy, J., Eberhart, R.
Particle swarm optimization
(1995) *Proceedings of ICNN'95 - International Conference on Neural Networks*, 4, pp. 1942-1948.

- Bharathi Raja, S., Baskar, N.
  Application of particle swarm optimization technique for achieving desired milled surface roughness in minimum machining time
  (2012) *Expert Syst Appl*, 39, pp. 5982-5989.

- Grimaldi, E.A., Grimaccia, F., Mussetta, M., Zich, R.E.
  PSO as an effective learning algorithm for neural network applications
  (2004) *ICCEA 2004 - 2004 3Rd International Conference on Computational Electromagnetics and Its Applications, Proceedings*, pp. 557-560.

- Vilović, I., Burum, N., Brailo, M.
  (2013) *Microstrip Antenna Design Using Neural Networks Optimized by PSO*,

- Cheng, R., Jin, Y.
  A social learning particle swarm optimization algorithm for scalable optimization
  (2015) *Inf Sci (N Y)*, 291, pp. 43-60.

- Aich, U., Banerjee, S.
  Modeling of EDM responses by support vector machine regression with parameters selected by particle swarm optimization
  (2014) *Appl Math Model*, 38, pp. 2800-2818.

- Majumder, A., Das, P.K., Majumder, A., Debnath, M.
  An approach to optimize the EDM process parameters using desirability-based multi-objective PSO
  (2014) *Prod Manuf Res*, 2, pp. 228-240.

- Mohanty, S., Mishra, A., Nanda, B.K., Routara, B.C.
  Multi-objective parametric optimization of nano powder mixed electrical discharge machining of AlSiCp using response surface methodology and particle swarm optimization
  (2018) *Alex Eng J*, 57, pp. 609-619.

- Prakash, C., Singh, S., Singh, M.
  Multi-objective optimization of MWCNT mixed electric discharge machining of Al–30SiCp MMC using particle swarm optimization
  (2018) *Futuristic Composites, Materials Horizons: From Nature to Nanomaterials*, pp. 145-164.

- Nas, E., Gökkaya, H., Akıncıoğlu, S., Akıncıoğlu, G.
  Surface Roughness Optimization of EDM Process of Hastelloy C22 Super Alloy
  (2017) *1St International Conference of Advanced Materials and Manufacturing Technologies*,
  Safranbolu, Karabük, Turkey

- Nas, E., Akıncıoğlu, S., Gökkaya, H., Akıncıoğlu, G.
  The Effect of Deep Cryogenic treatment on the Roughness of Hastelloy C22 Super Alloy in electrical discharge machining
  (2017) *1St International Conference of Advanced Materials and Manufacturing Technologies.*,
  Safranbolu, Karabük, Turkey

- Xing, Q., Gao, X., Zhang, Q.
  Effects of processing parameters on electrode loss of micro-EDM milling with spiral electrode
  (2022) *Int J Adv Manuf Technol*, 121, pp. 4011-4021.

- Xing, Q., Yao, Z., Zhang, Q.
  Effects of processing parameters on processing performances of ultrasonic vibration-assisted micro-EDM
  (2021) *Int J Adv Manuf Technol*, 112, pp. 71-86.

- George, P.M., Raghunath, B.K., Manocha, L.M., Warrier, A.M.
EDM machining of carbon-carbon composite - a Taguchi approach
(2004) *J Mater Process Technol*, 145, pp. 66-71.

- Akıncıoğlu, S.
Taguchi optimization of multiple performance characteristics in the electrical discharge machining of the TIGR2
(2022) *Facta Universitatis Ser: Mech Eng*, 20, pp. 237-253.

- Vikas, S., Roy, A.K., Kumar, K.
Effect and optimization of machine process parameters on MRR for EN19 & EN41 materials using Taguchi
(2014) *Procedia Technol*, 14, pp. 204-210.

- Chandramouli, S., Eswaraiah, K.
Optimization of EDM Process parameters in Machining of 17–4 PH Steel using Taguchi Method
(2017) *Mater Today Proc*, 4, pp. 2040-2047.

- Ju-Long, D.
Control problems of grey systems
(1982) *Syst Control Lett*, 1, pp. 288-294.

- Ju-Long, D.
Introduction to grey system theory
(1989) *J Grey Syst*, 1, pp. 1-24.

- Chen, T., Zhu, Y., Xi, X.X.
Process parameter optimization and surface integrity evolution in the high-speed grinding of TiAl intermetallics based on grey relational analysis method
(2021) *Int J Adv Manuf Technol*, 117, pp. 2895-2908.

- Lin, C., Shan, Z.
Use of the Taguchi method and grey relational analysis to optimize turning operations with multiple performance characteristics
(2007) *Mater Manuf Processes*, 19, pp. 209-220.

- Natarajan, N., Arunachalam, R.M.
Optimization of micro-EDM with multiple performance characteristics using taguchi method and grey relational analysis
(2011) *J Sci Ind Res (India)*, 70, pp. 500-505.

- Meena, V.K., Azad, M.S.
Grey relational analysis of micro-EDM machining of Ti-6Al-4V alloy
(2012) *Mater Manuf Processes*, 27, pp. 973-977.

- Singh, S.
Optimization of machining characteristics in electric discharge machining of 6061Al/Al2O3p/20P composites by grey relational analysis
(2012) *Int J Adv Manuf Technol*, 63, pp. 1191-1202.

- Muthuramalingam, T., Mohan, B.
Application of Taguchi-grey multi responses optimization on process parameters in electro erosion
(2014) *Measurement (Lond)*, 58, pp. 495-502.

- Tang, L., Guo, Y.F.
Electrical discharge precision machining parameters optimization investigation on S-03 special stainless steel
(2014) *Int J Adv Manuf Technol*, 70, pp. 1369-1376.

- Tang, L., Du, Y.T.
Experimental study on green electrical discharge machining in tap water of Ti-6Al-4V and parameters optimization
(2014) *Int J Adv Manuf Technol*, 70, pp. 469-475.

- Meena, V.K., Azad, M.S., Singh, S., Singh, N.
Micro-EDM multiple parameter optimization for Cp titanium
(2017) *Int J Adv Manuf Technol*, 89, pp. 897-904.

- Karmiris-Obratański, P., Papazoglou, E.L., Leszczyńska-Madej, B.
An optimalization study on the surface texture and machining parameters of 60CrMoV18-5 steel by EDM
(2022) *Materials*, 15 (3559-15), p. 3559.

- Nas, E., Akıncıoğlu, S.
Optimization of cryogenic treated nickel-based superalloy in terms of electro-erosion processing performance
(2019) *Acad Platform-J Eng Sci*, 7, pp. 115-126.

- Aravindan, N., Ashok Kumar, U., Laxminarayana, P.
Multi response optimisation of EDM parameters for micro channels machining of SS 316 with Taguchi – GRA
(2018) *Mater Today Proc*, 5, pp. 27028-27035.

Correspondence Address
Saleh T.; Autonomous Systems and Robotics Research Unit (ASRRU), Malaysia; email: tanveers@iium.edu.my

Publisher: Springer Science and Business Media Deutschland GmbH

ISSN: 02683768
CODEN: IJATE
Language of Original Document: English
Abbreviated Source Title: Int J Adv Manuf Technol
2-s2.0-85161298657
Document Type: Review
Publication Stage: Final
Source: Scopus