STM JOURNALS

Trends in
Mechanical Engineering & Technology

ISSN: 2231-1793 (Online)
ISSN: 2347-9965 (Print)
Volume 14, Issue 1, 2024
DOI (Journal): 10.37591/TMET

http://engineeringjournals.stmjournals.in/index.php/TMET/index

Review TMET

Integration of Taguchi and MCDM Techniques for the Optimization of Experimental Parameters in Electrical Discharge Machining: A Research

Jatin Mehra[1,*], Sandeep Kumar[2]

Abstract

Electric discharge machining (EDM) represents a non-conventional approach to machining, particularly beneficial for processing hard-to-machine materials or components with high length-to-diameter ratios or intricate shapes. Widely employed across various industries such as automotive, chemical, aerospace, biomedical, and tool and die, EDM offers a unique method for achieving precise shapes and dimensions. Unlike traditional machining methods where form is attained through the interaction of the tool and workpiece, EDM operates without direct contact between these components. Alternatively, it uses carefully calibrated electrical discharges to remove impurities surrounding the object. Consequently, optimizing input process parameters is critical to enhancing machining efficiency and accuracy. In this work, the technique of Taguchi is used to investigate and optimize the parameters for electrostatic machining. By systematically varying and analyzing process parameters, this approach aims to identify the most effective combination for maximizing machining performance. Through meticulous experimentation and analysis, this research endeavors to contribute to the advancement and refinement of electric discharge machining processes. A die-sinking EDM-FORM P 350 sinker spark subsidence machine is used for the testing. Graphite is used as electrode tool material with mild steel as work-piece material and Kerosene as dielectric fluid in the present experimental work. throughout the optimization handle, the following four crucial process parameters are alternately modified: the input voltage (V), pulse-on time (Ton), pulse-off time (Toff), and discharge current (I). To systematically explore and optimize these parameters, the Taguchi L9 orthogonal array is employed in the experimental design. Utilizing the L9 orthogonal array facilitates the investigation of main factors and their interactions with the response variables, specifically material removal rate and surface roughness. By analyzing the effects of individual factors as well as their interplay, this approach aims to uncover the optimal combination of process parameters for maximizing material removal rate while minimizing surface roughness.

***Author for Correspondence**
Jatin Mehra
E-mail: sandeepmits3@gmail.com

[1]M. Tech Scholar, Department of Mechanical Engineering, School of Research and Technology, People's University, Bhopal, Madhya Pradesh, India
[2]Assistant Professor, Department of Mechanical Engineering, School of Research and Technology, People's University, Bhopal, Madhya Pradesh, India

Received Date: March 22, 2024
Accepted Date: April 08, 2024
Published Date: April 17, 2024

Citation: Jatin Mehra, Sandeep Kumar. Integration of Taguchi and MCDM Techniques for the Optimization of Experimental Parameters in Electrical Discharge Machining: A Research. Trends in Mechanical Engineering & Technology. 2024; 14(1): 6–14p.

Keywords: Surface roughness, material removal rate, electric discharge machining, Taguchi method

INTRODUCTION

Electric discharge machining (EDM) stands out as a prominent non-traditional machining method widely embraced across industries. This technique harnesses thermoelectric energy to selectively remove unwanted material from a workpiece through a sequence of discrete electrical sparks occurring between the workpiece and an electrode. During the process, a pulse discharge transpires within a minute gap between the workpiece and the electrode, effectively eliminating undesired material through melting and vaporization. For spark generations past to occur, the electrode and the workpiece must both be electrically conductive. Thermal energy, produced within the dielectric medium, induces melting and vaporization of the workpiece through ionization. Furthermore, the electrical discharges generate impulsive pressure via dielectric explosion, facilitating the removal of melted material. This enables precise control over material removal, allowing for the fabrication of intricate and accurate machine components. Nevertheless, incomplete flushing of melted material can lead to residual material solidifying and forming discharge craters. Consequently, machined surfaces may exhibit micro-cracks and pores due to the high-temperature gradient experienced during the process, thus compromising surface finish quality. Numerous studies have investigated the surface finish of materials machined via EDM, revealing the influence of various machining parameters on surface roughness. Still, the complex interactions among these parameters make it difficult to achieve an ideal surface quality The present work presents the objective of optimizing the parameters of the EDM (Engineer technique.

Investigations have indicated that the output parameters of EDM increased with the increase in pulsed current and the best machining rates were achieved with copper and aluminum electrodes [1]. Surface roughness tends to rise as the discharge duration increases. This phenomenon primarily arises from the heightened release of discharge energy during this period, leading to the expansion of the discharge channel [2]. Significant electrode wear was observed in the EDM process in which DIN 1.2714 tool steel and on-time current were used. Experimental results have indicated that the EDM process caused a ridged surface and induced machining damage in the surface layer, and increased the surface roughness [3]. Raising the pulse current while diminishing the pulse-on duration offers an efficient strategy for mitigating the occurrence of the surface cracking phenomenon [4]. The median depth of the transform layer is found to increase with greater levels of the pulse present and pulse-on duration [5]. Machining characteristics of EN-8 steel were investigated and empirical models were developed for the prediction of output parameters viz MRR, TWR, and surface roughness using linear regression analysis [6]. Analysed results yielded that peak current and pulse on time were the most significant parameters for MRR and TWR respectively. Peak current and electrode rotation were the most significant parameters for surface roughness [6]. The effects of electrode tool materials and machining input parameters such as current, and pulse-on time on AISI D3 EDM characteristics were studied, and reported that the graphite electrode, having the highest material removal rate and precise dimension, and low tool wear ratio, is the most appropriate material for steel machining [7].

Literature Survey

Dr. Genichi Taguchi introduced the Taguchi Approach as a standardized Design of Experiment (DOE) technique aimed at determining the optimal combination of variables within specified experimental conditions [8,9]. Three basic steps are involved in this methodology: choosing an orthogonal array, figuring out the Signal-to-Noise (S/N) ratio, and performing an analysis of variance (ANOVA). By utilizing a limited number of trials, an orthogonal array is meticulously designed to comprehensively explore the entire parameter space [10, 11]. A process's or product's ability to withstand changes in noise factor can be determined by looking at the signal-to-noise ratio (S/N). To examine how process parameters affected the machining process, an ANOVA was employed [12].

Single-performance maximizing the efficiency was the ideal application for this technique [13, 14].

However, many industrial processes entail addressing multiple response variables. As a result, by combining the Taguchi technique with the ideas of Multi-Criteria Decision-Keeping (MCDM), an initially single-performance optimization challenge can be changed into a multi-performance optimization problem. The ideal processing circumstances are subsequently found using the MCDM technique.

Hwang and Yoon [15] introduced the TOPSIS method, which is an order preference method based on similarity to the ideal solution. When addressing multiple criteria problems, the TOPSIS methodology was an MCDM method for selecting the best response from a group of possibilities. The optimal solution, as per the primary principle of this method, is characterized by its proximity to the positive ideal solution and its distance from the negative solution. Thus, employing TOPSIS-based Taguchi optimization proves valuable in transforming a multi-performance simulation-optimization problem into a single-performance issue. For example, Balasubramaniyan, S. [16] combined Taguchi and TOPSIS approaches to determine the ideal process variables for turning EN25 steel with coating the carbide tools. Similarly, Nahak, P. [17], employed TOPSIS and the Taguchi method in the turning of austenitic stainless steel. Using a hybrid strategy, and their the best machining parameters were found to minimize blade-cutting forces and surface roughness, while enhancing the rate of material removal for the designated tool and work materials in the testing sector.

Additionally, Kumar et al. [18]. The use of the response surface approach and Grey relation analysis to optimize WEDM machining settings has been proposed and implemented. The ideal operating characteristic circumstance was offered by the Grey correlation grade.

Sharma et al. [19] Research into various EDM techniques aims to improve surface smoothness, material removal rate, and dimensional accuracy by fine-tuning various input parameters to achieve these goals. Taguchi (L9 OA) and the Analysis of Variance (AOV) method were used for EN-31 tool steel in order to enhance the wire cut EDM results. Marelli and others [20] In order to optimize WEDM machining settings and reactions, a number of methodologies were employed in this review of studies, including the Taguchi Method, ANOVA, GRA, ANN, and PCA. By using these techniques, the impact of wire-cut EDM process parameters on superalloy surface roughness (SR) and material removal rate (MRR) was investigated.

The material removal rate (MRR) and surface roughness may be improved by adjusting parameters such as pulse on/off time, servo voltage, peak current, and kerf width (SR).

Satyam and Saif [21] Pulse time, pulse current, and peak current are all variables that will be studied in this experiment. Wire EDM material removal rates can be improved by implementing the proper strategy in this study. The experiment's Taguchi L9 design (DOE) was used. The rate at which material was removed was found to be most closely related to the flow rate. Machining settings were examined to see if they affected MRR-like responses.

Subramanian et al. [22] The Taguchi technique was employed in this work to optimize wire-cut EDM processing parameters to reduce surface roughness. ANOVA was used to identify the most significant factor influencing surface The most important factor influencing surface roughness was determined using ANOVA roughness. After current and pulse on time, pulse off time (44.69%) was shown to be the most important element in determining the quality of surface roughness (4.58%). In order to maximize process variables like MRR, EWR, and overcut during EDM of M2 tool steel, Purohit et al. [23] use a L9 orthogonal array-based Taguchi technique. EDM parameters for Si_3N_4-TiN conducting ceramic composite with Cu-electrode, such as MRR, TWR, WR, SR, etc., were studied by Selvarajan et al. [24] in order to improve form and orientation tolerance using GRA based on Taguchi L25 orthogonal arrays. Mandalio and associates [25] To investigate the effects of various EDM process variables on the AISI M2 steel, the Design of Experiment (DOE), L27 orthogonal array Taguchi technique, and regression analysis using tungsten-thorium electrodes were utilized. However, TOPSIS & GRA have utilized EDM to determine the ideal configuration for AISI M2 steel using W-Th (tungsten–thorium). Surface integrity and dimensional accuracy were studied using fuzzy-TOPSIS-based multi-criteria decision-making (MCDM) by Dewangan et al. [26].

Bhuyan et al. [27] The TOPSIS method was used to find the best possible process parameters. Drilling, for example, has benefited greatly from GRA's widespread application in process optimization.

Methodology and Experiments

The experimental setup of EDM, selection of work-piece material, selection of tool material, design of experiments by Taguchi's method, and ANOVA analysis are discussed. The information obtained from EDM experimentation is used to calculate the rates of material removal (MRR) and Surface Roughness (SR). The electric discharge machine used in the present work is a type of die-sinking EDM machine (Table 1).

Table 1. Machine Specification.

S.N.	Characteristics	Range
1	X, Y, Z travel	350 × 250 × 300 mm
2	Machine Dimension (width x depth x height)	1900 × 1690 × 2398 mm
3	Total Weight Without Dielectric	2800 kg
4	Work-piece Dimensions (W x D x H)	790 × 490 × 350 mm
5	Max. Electrode Weight	50 kg
6	Max. Work-piece Weight	500 kg
7	Bath Level	100- 325 mm
8	Dielectric Capacity	410 litre
9	There is no filter in Dielectric	4
10	Generator Type	ISPG Integrated
11	Current	80 – 140 ampere
12	Minimum Surface Roughness (Ra)	0.08 µm

To experiment, SAE 1015 mild steel measuring 80 ×50 × 5 mm was utilized. Mild steel grade 1015 is widely employed for various applications, including machining, thanks to its versatility and weldability. It is commonly utilized for lightly stressed components like studs, bolts, gears, and shafts. Additionally, it can be casehardened to improve wear resistance. SAE 1015 mild steel is readily accessible in bright rounds, squares, flats, and hot rolling rounds. It can also be obtained in sawn blanks and tailor-made blocks of specific sizes.

Taguchi Method

Taguchi has pioneered inventive techniques for optimizing process parameters. This methodology relies on experimental analysis employing statistical principles. In the development process, Taguchi used the following three stages in his optimization method;

a. System design,
b. Parameter design
c. Tolerance design

The experiments were carried out using a die-sinking EDM machine, where graphite served as the electrode tool material, mild steel as the workpiece material, and kerosene as the dielectric fluid. In this testing setup, various method components were systematically adjusted, including pulse-on time (Ton), pulse-off time (Toff), source voltage (V), with current to discharge (I).

Throughout the experiments, measurements were taken for Material Removal Rate (MRR) and Surface Roughness Average (SRa). To facilitate the experimental design, Taguchi developed a specialized set of factorial experiments. They picked source voltage, pulse-on time, pulse-off time, and current flow for procedure variables for their investigation.

Table 2. Parameter design

Input Process Parameters	Symbol	Level 1	Level 2	Level 3
Voltage (V)	A	25	30	100
Current (A)	B	10	15	20
Pulse on time (T_{on}) (µs)	C	35	50	100
Pulse off time (T_{off}) (µs)	D	5	8	9

The experiments were carried out using a die-sinking EDM machine, where graphite served as the electrode tool material, mild steel as the workpiece material, and kerosene as the dielectric fluid. The process parameters in this experimental setup, such as the pulse-on time (Ton), pulse-off time (Toff), source voltage (V), and discharge current (I), were changed methodically (Table 2).

Throughout the experiments, measurements were taken for Material Removal Rate (MRR) and Surface Roughness Average (SRa). To facilitate the experimental design, Taguchi developed a specialized set of factorial experiments. The special set of designs, or Taguchi Robust Design method, makes use of orthogonal arrays (OAs), a mathematical tool, and signal noise ratio (SNR) to study a large number of experimental process variables with a small/reduced number of experiments. The orthogonal arrays have a method for fractional factorial experiments and help with the Taguchi approach's experimental design process. The orthogonal array aids in examining the effects of primary and interacting parameters by reducing the quantity of trial runs (Table 3).

Table 3. Experiments and corresponding SR and MRR values.

Exp. Run	A	B	C	D	MRR	Surface Roughness
1	25	10	35	9	5.55	6.914
2	25	10	100	5	6.15	6.056
3	25	15	35	9	5.24	7.375
4	30	10	100	5	5.12	7.375
5	30	15	50	5	6.11	6.062
6	30	20	50	5	6.25	6.914
7	100	10	35	9	5.44	6.291
8	100	10	100	8	5.96	7.531
9	100	20	100	8	5.9	7.375

A multicriteria decision analysis technique is called the TOPSIS Method, or Method for Order of Preference by Similarity to Ideal Solution. In order to compare a set of alternatives, this compensatory aggregation method calculates the geometric distance between each alternative and the ideal alternative—that is, the alternative that receives the highest score across all criteria. Additionally, it normalizes the scores for each criterion and establishes weights for each. According to TOPSIS [28, 29], the criteria are presumed to be monotonically increasing or decreasing [28, 29].

The steps involved in multi-objective optimization are [30]:

Step 1: The structure of the matrix

$$X = \begin{bmatrix} x_{12} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots & \dots \\ \dots & \dots & \dots & \cdots \\ x_{m1} & x_{m2} & \dots & x_{mn} \end{bmatrix}$$

which xij is a crisp value that represents how well each alternative Ai performs in relation to each criterion Cj.

Step 2: Calculate the Normalized the matrix X by using the following formula:

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{j=1}^{J} {x_{ij}}^2}}$$

Step 3: Construct the weighted normalized decision matrix by multiplying:

$$V_{ij} = w_{ij}.r_{ij}$$
$$A^* = \{(max\ v_{ij} |\ j\ \in J), (min\ v_{ij} | j\ \in J')\}$$
$$A^- = \{(min\ v_{ij} |\ j\ \in J), (max\ v_{ij} | j\ \in J')\}$$

Step 5: Calculate the separation measure

$$S_i^* = \sqrt{\sum_{j=1}^{n} \left(v_{ij} - v_j^*\right)^2}$$
$$S_i^- = \sqrt{\sum_{j=1}^{n} \left(v_{ij} - v_j^-\right)^2}$$

Step 6: Calculate the relative closeness to the ideal Solution

$$P_i^* = {S_i^-} \Big/ {S_i^* + S_i^-}\ , 0 \le P_i^* \le 1$$

Step 7: Calculate the total score and select the alternative closest to one.

Integration of Taguchi & TOPSIS

The normalized decision matrix for the provided data is shown in Table 4. Table 5 illustrates the weighting. Decision structure shows the weights assigned to each output response variable, while Table 4 shows the corresponding Euclidian distances, degrees of closeness, and ranks for a given set of input parameters. All of these were extracted from a prepared Excel document.

Table 4. Normalized values of responses.

Exp. Run	MRR	SR
1	0.3212	0.3340
2	0.3559	0.2926
3	0.3032	0.3563
4	0.2963	0.3563
5	0.3536	0.2928
6	0.3617	0.3340
7	0.3148	0.3039
8	0.3449	0.3638
9	0.3414	0.3563

For this experiment, we are considering assigning equal weight to both the selection criteria as 0.5000, or we can say, as there are only two criteria for the selection of a most suitable set of experiments, the importance of both criteria is the same. Finding the weighted normalized values of the responses is the next step; these are displayed in Table 6.

Table 5. Weighted normalized values of responses.

Exp. Run	**MRR**	**SR**
1	0.1606	0.1670
2	0.1779	0.1463
3	0.1516	0.1781
4	0.1481	0.1781
5	0.1768	0.1464
6	0.1808	0.1670
7	0.1574	0.1520
8	0.1724	0.1819
9	0.1707	0.1781

We calculate the Euclidian distance (S+&S-), which is the point nearest and farthest from the ideal solutions. These Euclidean distances are used to calculate the Pi value, or degree of proximity to the best solution. The maximum Pi value is shown as the first ranking of the calculated values, which are displayed in Table 7.

Table displays the set of input parameters ranked by a condensed TOPSIS table.

Table 6. Separation measure, Relative closeness values, and Ranking.

Exp. Run	**S+**	**S-**	**P_i**	**Rank**
1	0.0290	0.0124	0.3004	7
2	0.0029	0.0363	0.9262	1
3	0.0432	0.0117	0.2125	8
4	0.0457	0.0111	0.1961	9
5	0.0041	0.0353	0.8969	2
6	0.0207	0.0327	0.6120	3
7	0.0241	0.0177	0.4229	6
8	0.0366	0.0285	0.4379	4
9	0.0334	0.0252	0.4295	5

Table 7. Final evaluation of experiments.

Exp. Run	**A**	**B**	**C**	**D**	**MRR**	**SR**	**Rank**
1	25	10	35	9	5.55	6.914	7
2	25	10	100	5	6.15	6.056	1
3	25	15	35	9	5.24	7.375	8
4	30	10	100	5	5.12	7.375	9
5	30	15	50	5	6.11	6.062	2
6	30	20	50	5	6.25	6.914	3
7	100	10	35	9	5.44	6.291	6
8	100	10	100	8	5.96	7.531	4
9	100	20	100	8	5.90	7.375	5

RESULT

This study helped determine the optimized set of parameters selection for Electro Discharge Machine (EDM) the objective was to obtain a low surface roughness (SR) and maximize metal removal rate

(MRR). In these investigations, nine sets of tests were carried out and an L9 Taguchi orthogonal array was used, the corresponding input parameters are V, I, $T_{on,}$ and T_{off}.

The following results were drawn from the experiment and its design: the most appropriate set of parameters, or Ra & MRR, is given; the numerous objectives are optimized using the Technique for Order of Preference (TOPSIS) into a single objective. The results of the best solutions for both positive and negative ideal solutions are listed in Table 5. The output performances are arranged in Table 6 based on the values of their proximity coefficients. The highest proximity coefficient value indicates a closer relationship between the largest MRR and the least amount of roughness on the exteriorWhen we set the setting for the experiment to Voltage = 30V, Discharge Current = 10A, Ton = 100µs, Toff = 5µs, we get poor results; when we set the parameters to Voltage = 25V, Discharge Current = 10A, Ton = 100µs, Toff = 5µs, we get the best results. A weight factor of 0.5 is assigned to each performance. The technique known as TOPSIS yielded optimal surface roughness of 6.056 µm and metal removal rate of 6.15 mm3/min for 0.5-0.5 significance.

CONCLUSION

The present study demonstrates how a combination of factors can be effectively used to determine the optimal procedure. In order to achieve this, a two-step methodology is presented, wherein the median weight method uses the team of decision-making members' expertise in determining the significance of the criteria.

REFERENCES

1. Shankar Singh, S. Maheshwari, P.C. Pandey, “Some investigations into the electric discharge machining of hardened tool steel using different electrode materials,” Journal of Materials Processing Technology, vol. 149, pp. 272–277, 2004
2. Yusuf Keskin, H. Selcuk Halkacı, Mevlut Kizil, “An experimental study for determination of the effects of machining parameters on surface roughness in electrical discharge machining,” Int J Adv Manuf Technol, vol. 28, pp. 1118–1121, 2006
3. H. Zarepour, A. Fadaei Tehrani, D. Karimi, S. Amini, “Statistical analysis on electrode wear in EDM of tool steel DIN 1.2714 used in forging dies,” Journal of Materials Processing Technology, vol. 187–188, pp. 711–714, 2007
4. Y.H. Guu, Max Ti-Kuang Hou, “Effect of machining parameters on surface textures in EDM of Fe-Mn-Al alloy,” Materials Science and Engineering, vol. A 466, pp. 61–67, 2007
5. T.Y. Tai, S.J. Lu, “Improving the fatigue life of electro-dischargemachined SDK11 tool steel via the suppression of surface cracks,” International Journal of Fatigue, vol. 31, pp. 433–438, 2009
6. K.D. Chattopadhyay, S. Verma, P.S. Satsangi and P.C. Sharma, “Development of empirical model for different process parameters during rotary electrical discharge machining of copper–steel (EN-8) system,” J. Mater. Process. Techno. vol. 209, pp. 1454–1465, 2009.
7. Khoshkish, Ashtiani, Goreyshi, Effects of Tool electrode material on electrical discharging machining process of hardened tool AISI D3, Iran Conference of Manufacturing Engineering.
8. Taguchi, G.K.S.; Konishi, S. Taguchi Methods Orthogonal Arrays and Linear Graphs: Tools for Quality Engineering; American Supplier Institute: Dearborn, MI, USA, 1987.
9. Karna, S.K.; Sahai, R. An Overview on Taguchi Method. Int. J. Eng. Math. Sci. 2012, 1, 1–7.
10. Hanif, M.I.; Aamir, M.; Ahmed, N.; Maqsood, S.; Muhammad, R.; Akhtar, R.; Hussain, I. Optimization of facing process by indigenously developed force dynamometer. Int. J. Adv. Manuf. Technol. 2019, 100, 1893–1905.
11. Yang, W.P.; Tarng, Y. Design optimization of cutting parameters for turning operations based on the Taguchi method. J. Mater. Process. Technol. 1998, 84, 122–129.
12. Ribeiro, J.E.; César, M.B.; Lopes, H. Optimization of machining parameters to improve the surface quality. Proced. Struct. Integr. 2017, 5, 355–362.
13. Lee, D.H.; Park, J.S.; Ryu, M.R.; Park, J.H. Development of a highly efficient low emission diesel engine-powered co-Generation system and its optimization using Taguchi method. Appl. Therm. Eng. 2013, 50, 491–495.

14. Wu, H.W.; Wu, Z.Y. Using Taguchi method on combustion performance of a diesel engine with diesel/Biodiesel blend and port-inducting H2. Appl. Energy 2013, 104, 362–370.
15. Hwang, C.L.; Yoon, K. Multiple Attribute Decision Making Methods and Applications; A State-of-the-Art Survey; Springer: Berlin/Heidelberg, Germany, 1981.
16. Balasubramaniyan, S.; Selvaraj, T. Application of integrated Taguchi and TOPSIS method for optimization of process parameters for dimensional accuracy in turning of EN25 steel. J. Chin. Inst. Eng. 2017, 40, 267–274.
17. Nahak, P.; Dubey, M. Optimization in Turning Austenitic Stainless Steel using TOPSIS and Taguchi Method. Int. J. Eng. Manag. Res. 2016, 6, 428–434.
18. A. Kumar, T. Soota, and J. Kumar, ‘Optimisation of wire-cut EDM process parameter by Grey-based response surface methodology’, J Ind Eng Int, vol. 14, no. 4, pp. 821–829, Dec. 2018.
19. S. Sharma, U. K. Vates, and A. Bansal, ‘Parametric Optimization of EN-31 Steel in Wire Cut Electro Discharge Machining by Taguchi Technique’, Advanced Science, Engineering and Medicine, vol. 12, no. 7, pp. 881–887, Jul. 2020.
20. D. Marelli, S. K. Singh, S. Nagari, and R. Subbiah, ‘Optimisation of machining parameters of wire-cut EDM on super alloy materials–A review’, Materials Today: Proceedings, vol. 26, pp. 1021–1027, Jan. 2020.
21. S. Tiwari and M. Saif, ‘Optimization of Wire-cut EDM of Aluminum alloy 6061 using Taguchi’s approach for maximizing MRR’, vol. 7, pp. 2173–2181, Aug. 2020.
22. K. S. PhD, A. N. PhD, N. Vinayagam, S. J. Muthiya, and R. R. PhD, ‘Optimization of Wire Cut EDM Process Parameters of Al/SiO2 Composites Using Taguchi Method’, SAE International, Warrendale, PA, SAE Technical Paper 2020-28–0426, Sep. 2020.
23. R. Purohit, R. S. Rana, R. K. Dwivedi, D. Banoriya, and S. K. Singh, ‘Optimization of Electric Discharge Machining of M2 Tool Steel Using Grey Relational Analysis’, Materials Today: Proceedings, vol. 2, no. 4, pp. 3378–3387, Jan. 2015.
24. L. Selvarajan, C. Sathiya Narayanan, R. Jeyapaul, and M. Manohar, ‘Optimization of EDM process parameters in machining Si3N4–TiN conductive ceramic composites to improve form and orientation tolerances’, Measurement, vol. 92, pp. 114–129, Oct. 2016.
25. G. Mandaloi, S. Singh, P. Kumar, and K. Pal, ‘Effect on crystalline structure of AISI M2 steel using tungsten–thorium electrode through MRR, EWR, and surface finish’, Measurement, vol. 90, pp. 74–84, Aug. 2016.
26. S. Dewangan, S. Gangopadhyay, and C. K. Biswas, ‘Study of surface integrity and dimensional accuracy in EDM using Fuzzy TOPSIS and sensitivity analysis’, Measurement, vol. 63, pp. 364–376, Mar. 2015.
27. R. K. Bhuyan, B. C. Routara, and A. Kumar Parida, ‘An approach for optimization the process parameter by using TOPSIS Method of Al–24%SiC metal matrix composite during EDM’, Materials Today: Proceedings, vol. 2, no. 4, pp. 3116–3124, Jan. 2015.
28. Vaddi VR, Ch SR, Bushaboina SK, Banka H. Application of TOPSIS with Taguchi Method for Multi-Attribute Optimization of Machining Parameters in EDM. SAE Tech. Pap. Ser. 2018.
29. NGUYEN PH, T M, Pham DV, Shirguppikar S, Nguyen TN, Nguyen TC, et al. Multiobjective optimization of micro EDM using TOPSIS method with Tungsten carbide electrode. Sādhanā. 2022 Sep; 47(3):1–12.
30. Somasundaram M, Kumar JP. Multi response optimization of EDM process parameters for biodegradable AZ31 magnesium alloy using TOPSIS and grey relational analysis. 2022 Sep;47(3):1–14.