



Experimental investigation of nanographene mixed in the copper electrodes for electrical discharge machining



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HIGHLIGHTS

- Electrodes were manufactured using the stir-casting method.
- The effect of nanographene powder on EDM process performance was studied.
- Nanographene powder improved TWR by 15.10% and MRR by 29.67%.
- Current and pulse on time were the most influential factors.

ABSTRACT

Nanotechnology in electrode manufacturing is a new technique to enhance the machinability of materials that are difficult to machine using electrical discharge machining (EDM). Since the wear of electrodes in the EDM process usually has a high effect on the process performance, thus it is important to conduct a study to reduce the tool wear rate (TWR) and increase the Material removal rate (MRR). This study aims to improve the operation performance of nanomaterial graphene in the electrode industry. In this experimental work, single-layer nanographene with a concentration of (2%wt) was mixed into a copper matrix using the stir-casting method for machining AISI 1005 Carbon Steel. The parameters selected are discharge current I_p (20, 30, and 40 A), pulse on time T_{on} (100, 200, and 300 μ s), and pulse off time T_{off} (100, 150, and 200 μ s). All the experimental runs were conducted using Design Expert 13 software at three levels and ANOVA for the statistical study. The results of this study manifested that the EDM performance was significantly enhanced by utilizing the powder of nanographene and enhancement through the performance measures of TWR and MRR improved by 15.10% and 29.67%, respectively, and enhanced the economic efficiency of this technology through the improved mechanical and electrical properties. Finally, scanning electron microscopy (SEM) was used to examine the effect of nanographene on the machined surface quality. The surface obtained from the copper electrode elucidated more surface flaws compared to the electrode mixed with nanographene powder.

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1. Introduction

The electrical discharge machining (EDM) method is one of the most important manufacturing processes that has received great attention worldwide. Manufacturing companies have worked to submit various proposals to provide the best solutions to the engineering problems they face during the EDM process.

Through their research, Sharma et al. [1] and Hasan et al. [2] explained that EDM is one of the most important nontraditional processes, which can be widely used to produce hard and geometrically complex parts and give better surface finish accuracy. Matanda et al. [3] and Ishfaq et al. [4] clarified that the EDM process leads to the generation of an electrical spark between the tool and the workpiece, and this spark leads to the removal of materials from the workpiece in the presence of a suitable dielectric fluid. Chaudhari et al. [5] and Surani et al. [6], after studying the parameters affecting the EDM process, concluded that the desired result in the EDM is achieved by identifying the input factors that require effective balancing.

Several researchers have studied the impact of nanomaterials on the performance of EDM. Kumar et al. [7] and Prakash et al. [8] explained that mixing the nanopowders in appropriate quantities is one of the most important techniques that help improve the process variables and greatly enhance the machining features. This new approach improves the rate of material removal and surface quality. Prakash et al. [9] and Le et al. [10] found that the addition of nanopowders in the EDM process helps increase the thermal conductivity, increase the amount of electrical discharge, reduce the breakdown strength of the material, and improve the amount of electrical spark. In their experimental work, Marashi et al. [11] used many nanopowders at several concentrations to improve the machining results.

Chaudhari et al. [12] conducted a study on the impact of nanographene powder on the wire electrical discharge machining process. By inserting suspended nanographene powder, they noted the formation of concerted sparking and active debris flushing. This led to a minimization in SR and an enhancement in MRR because of the high erosion resistance of nanographene. SR and MRR improved by 9.35% and 24.01%, respectively. Also, the machined surfaces using Scanning Electron Microscopy (SEM) proved an optimization in the morphology of the surface, which was distinguished by decreased microcracks and some defects. In their research, Vora et al. [13] studied how various concentrations of nano-graphene powder influence the EDM of shape memory alloy, and the result observed that utilizing the nanographene powder showed a significant enhancement in MRR by 75.18%. Moreover, the insertion of nanographene also decreased the surface roughness and dimensional deflection. The surface flaws were significantly reduced because of the addition of nanographene powder. Ishfaq et al. [14] investigated The effect of nanographene powder on the performance of EDM technology by using Taguchi's design (L18) to manufacture part of (Ti6Al4V). The results of the experimental work observed an improvement in the surface finish using nanographene powder mixed with dielectric fluid.

Rakesh Chaudhari et al. [15] discovered The impact of nanopowders such as graphene and alumina and tested them under optimal operating parameters. A significant improvement was observed in the performance of the EDM process using nanopowders compared to the traditional technique due to the exceptional properties of nanomaterials, such as high electrical conductivity, and it demonstrated a higher enhancement than alumina powder. Also, the surface morphology obtained by scanning electron microscopy (SEM) for the traditional process illustrated larger surface defects than the process with powder mixed. Pham Van et al. [16] studied and analyzed the effect of nanographene powder coating on the performance of aluminum electrodes for machining Ti-6Al-4V. The results showed an improvement in the performance parameters TWR and MRR due to improved properties of the electrodes compared to uncoated electrodes.

As illustrated in prior studies, very little research has worked on improving the performance of the EDM process using nanomaterials. No study has been conducted on the effect of the nanomaterial of electrodes on the performance measures. The present experimental work used nanographene powder to study the influence on the TWR and MRR. Current (I_p), pulse on time (T_{on}), and pulse off time (T_{off}) were regarded as machining parameters for AISI 1005 carbon steel. Experimental relations were created by (Design Expert 13) software. ANOVA was used for the statistical study. Finally, a scanning electron microscope (SEM) was operated to investigate nanographene's effect on the machined surface's morphology.

2. Materials and method

2.1 Fabrication of copper-nanographene electrodes

The stir casting technique is one of the methods used to manufacture electrodes, characterized by its ease and low cost. Single-layer nanographene powder with a concentration of (2%wt) was mixed into a copper matrix of (98%wt) To ensure increased dispersion, a more homogeneous, increased hardness, and improved electrical and thermal conductivity of the electrode. At the start, the furnace is preheated to a temperature of 500 °C. Then, the pure copper material is melted at a temperature of 1230 °C. After that, nanographene powder is added gradually after covering it with copper foil, and the mixing process continues to obtain the highest homogeneity between the materials, as shown in Figure 1.

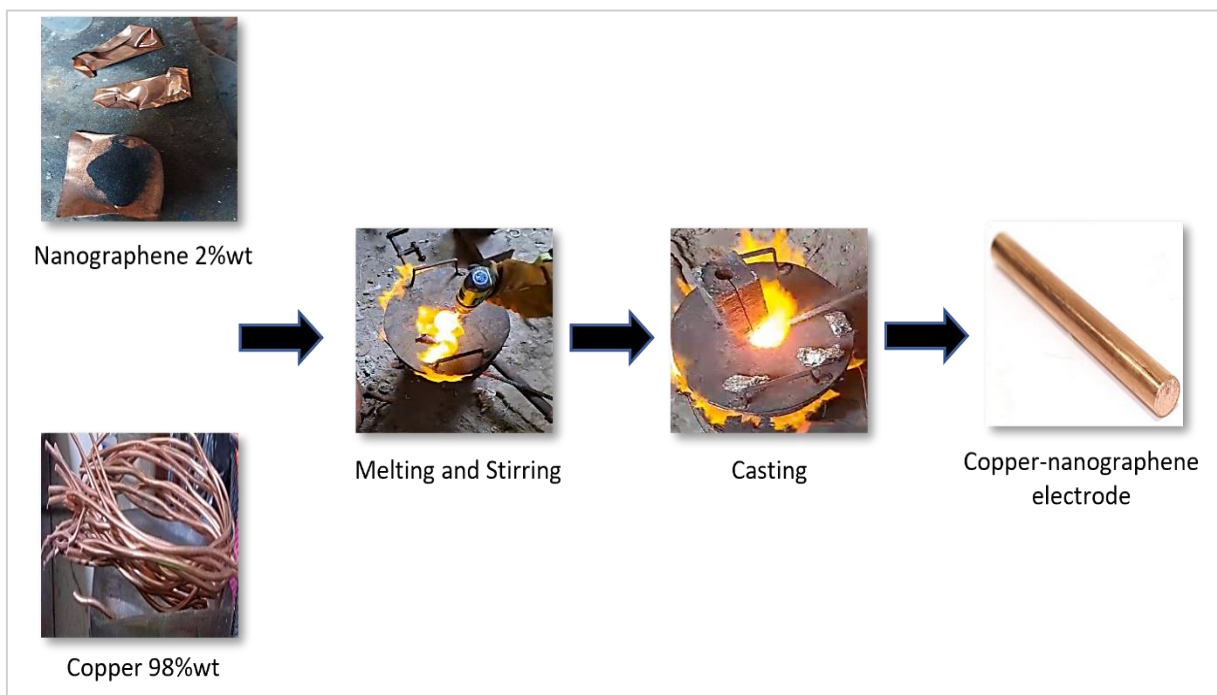


Figure 1: Fabrication steps of copper-nanographene using stir-casting

2.2 Characterisation

A scanning electron microscope (SEM) is an accurate and effective device utilized to scan and magnify surfaces of 1 μm to 1 nm, depending on the equipment used to generate electron beams. The scanning electron microscope (TESCAN/VEGA) device was used to measure the machined surface quality of the workpiece. Further, the Vickers microhardness tester was utilized to measure the hardness of the samples at a load value of (500 Kg) for (15 seconds). Five readings were registered for the specimen, and an average was taken. There is a direct impact between the thermal conductivity of the electrode tool and the EDM performance by reducing the TWR, and the (Lee’s Disc) device was used to measure the thermal conductivity of copper and copper-nanographene electrodes. Moreover, electric conductivity plays an effective role in the Electrical Discharge Machining (EDM) process, and there is a direct contact between the electric conductivity of the electrode tool and the performance of the (EDM) process. The (Keithley 2700 Multimeter/Data Acquisition System M3275) device was utilized to measure the electric conductivity of copper and copper-nanographene electrodes.

2.3 Workpiece and electrodes

In this work, the material of the workpiece that has been selected is (AISI 1005 Carbon Steel), as a square shape (30 x 30 mm) with a thickness of (2 mm) to make a diameter hole (10 mm). Figure 2 illustrates the workpiece with a sketch before machining. The workpiece was linked to the negative polarity terminal of the EDM machine. The workpiece's chemical composition was assessed by utilizing (the Master Xpert) machine for analysis of materials, as depicted in Table 1. Two separate electrodes, copper and copper-nanographene, were used. The electrode was linked to the EDM machine's positive polarity terminal, as shown in Table 2.

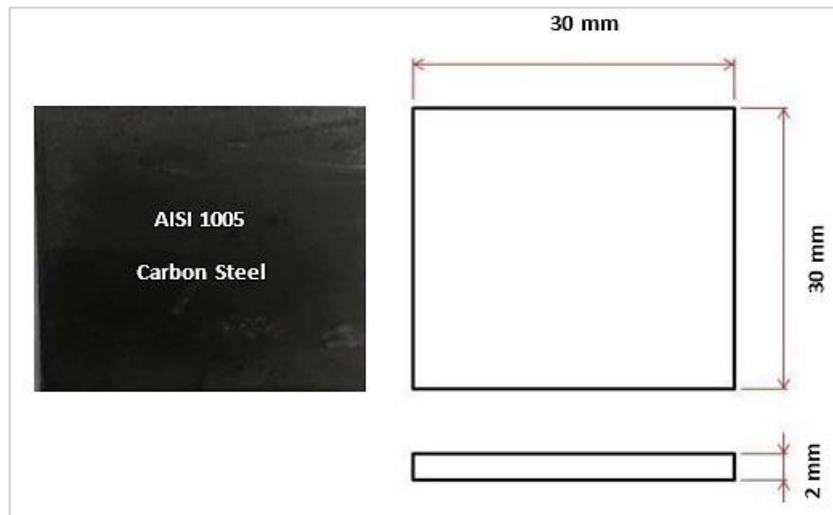


Figure 2: Workpiece dimensions before machining

Table 1: Chemical composition of (AISI 1005 Carbon Steel)

| Materials | C% | Si% | Cu% | Mn % | P% | S% | Cr% | Mo% | Ni% | Ti% | Fe% |
|-----------|-------|-------|-------|-------|-------|-------|-------|-------|-------|--------|---------|
| Weight % | 0.049 | 0.003 | 0.028 | 0.231 | 0.008 | 0.011 | 0.014 | 0.004 | 0.011 | 0.0005 | Balance |

Table 2: Electrodes material

| Part | Electrode material | Electrode geometry | Electrode end profile |
|------|-------------------------------|--------------------|-----------------------|
| 1- | copper electrode | | Diameter 10 mm |
| 2- | Copper-nanographene electrode | | Diameter 10 mm |

2.4 Performance of EDM machine

The present study used a Chamer EDM machine model (CM 323+50 N) to implement the runs of the experimental work. Figure 3 reveals the basic principle and schematic of the EDM process. In this study, the dielectric fluid used is Transformer oil, AISI 1005 carbon steel is used as a workpiece, and two types of electrodes are copper and copper-nanographene with a diameter of 10 mm. The parameters that influence performance measures most were selected based on previous studies [17, 18]. I_p , T_{on} , and T_{off} were regarded as machining parameters, and TWR and MRR as performance measures. Through the experimental runs, (2 mm) drilling depth and a gap of (0.02 mm) was maintained. The experiments were designed using Design Expert 13 software. Table 3 lists the machining parameters at different levels and other operation conditions. The statistical significance of machining parameters was studied and analyzed using ANOVA.

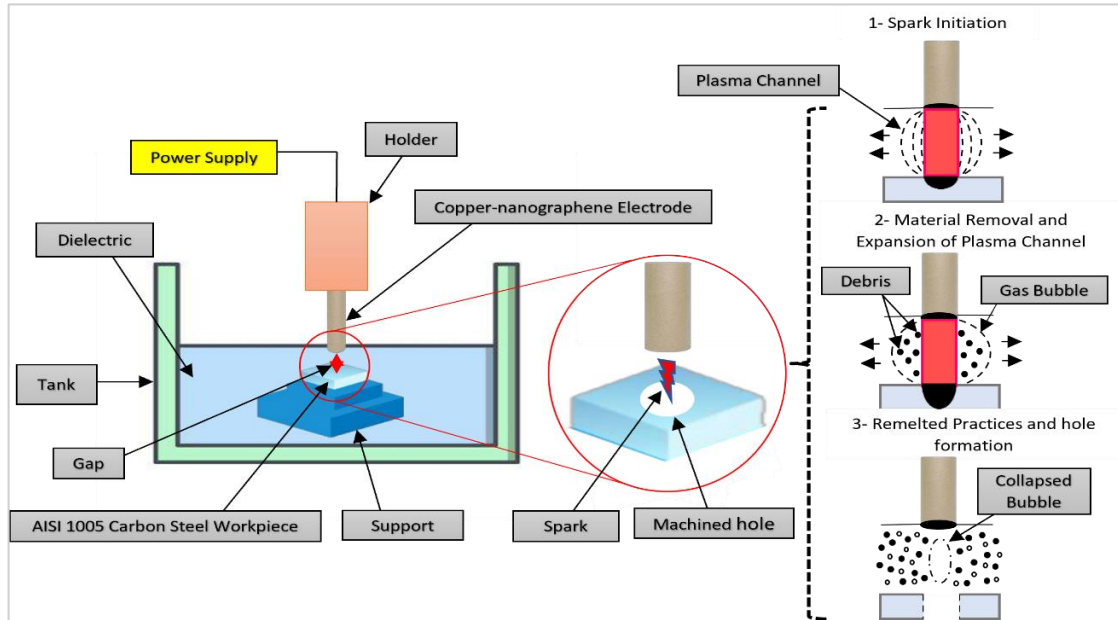


Figure 3: Schematic basic principle of the EDM process

Table 3: Details of the EDM Machine parameters

| Factors | Parameters | Levels/Values | | |
|---------|---------------------------|--------------------|-----|-----|
| | | L1 | L2 | L3 |
| A | Current (A) | 20 | 30 | 40 |
| B | Pulse on time (μ s) | 100 | 200 | 300 |
| C | Pulse off time (μ s) | 100 | 150 | 200 |
| D | Polarity | Positive Electrode | | |
| E | Type of dielectric | Transformer oil | | |
| F | Depth of cut | 2 mm | | |
| G | Gap | 0.02 mm | | |
| H | Voltage | 140 V | | |

The Tool wear rate (TWR) and Material removal rate (MRR) were calculated using Equations 1 and 2, respectively [17].

$$TWR = \frac{W_i - W_f}{Dt \times T} \quad (\text{mm}^3/\text{min}) \quad (1)$$

where, W_i : Tool initial weight (mg), W_f : Tool final weight (mg), T : Machining time (min), and Dt : Tool density (gm/mm^3)

$$MRR = \frac{W_i - W_f}{D_w \times T} \quad (\text{mm}^3/\text{min}) \quad (2)$$

where, W_i : Workpiece initial weight (gm), W_f : Workpiece final weight (gm), T : Machining time (min), and D_w : Workpiece density (gm/mm^3).

3. Results and discussion

Table 4 shows the outcome of experimental work conducted as per the Design Expert 13 software experiments at the selected parameters and the performance measures of TWR and MRR for the electrodes of copper and copper-nanographene, noting the least TWR of $1.203 \text{ mm}^3/\text{min}$ for a trial run 9 and the highest MRR of $15.904 \text{ mm}^3/\text{min}$ for a trial run 2 using

copper-nanographene electrodes. Also, the highest TWR of 1.744 mm³/min for trial run 2 and the least MRR of 10.343 mm³/min for trial run 1 using copper electrodes were observed.

Table 4: Evaluation of TWR and MRR for the EDM parameters

| No. | Operating Parameters | | | Copper | | Copper-nanographene | |
|-----|-----------------------|-------------------------|--------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|
| | I _p (A) | T _{on} (μs) | T _{off} (μs) | TWR (mm ³ /min) | MRR (mm ³ /min) | TWR (mm ³ /min) | MRR (mm ³ /min) |
| 1 | 20 | 300 | 150 | 1.466 | 10.343 | 1.235 | 13.452 |
| 2 | 40 | 300 | 150 | 1.744 | 11.716 | 1.482 | 15.904 |
| 3 | 20 | 200 | 200 | 1.449 | 10.418 | 1.228 | 13.335 |
| 4 | 40 | 200 | 100 | 1.638 | 11.309 | 1.356 | 14.890 |
| 5 | 30 | 100 | 200 | 1.545 | 10.442 | 1.292 | 14.198 |
| 6 | 30 | 300 | 100 | 1.553 | 10.774 | 1.315 | 14.483 |
| 7 | 20 | 200 | 100 | 1.45 | 11.548 | 1.241 | 14.099 |
| 8 | 40 | 100 | 150 | 1.657 | 11.403 | 1.388 | 14.943 |
| 9 | 20 | 100 | 150 | 1.434 | 11.435 | 1.203 | 13.664 |
| 10 | 30 | 100 | 100 | 1.543 | 11.863 | 1.308 | 13.814 |
| 11 | 30 | 300 | 200 | 1.564 | 11.532 | 1.327 | 13.980 |
| 12 | 40 | 200 | 200 | 1.697 | 11.870 | 1.414 | 15.830 |

Measurements of the main properties of the copper and copper-nanographene electrodes are recorded in Table 5. The decrease in TWR is due to the fact that the nanographene material has a higher melting point than copper. This outcome resulted in a lower wear resistance of the copper electrode compared to the copper-nanographene electrode. Also, the nanographene has an electrical conductivity larger than the copper material; the nanographene material has a lower density than the copper material. The electrical spark easily forms due to these factors in copper-nanographene electrodes compared with copper electrodes. Moreover, the sparks produced by copper-nanographene electrodes have the least thermal energy. Hence, the electrode material's melting and evaporation rate is also lower.

The greater electrical conductivity of nanographene compared to copper leads to an increase in MRR. This makes the generation of sparks in the copper-nanographene electrodes faster, so the number and thermal energy of sparks are high in the operation area. This contributes to the rising rate of melting and evaporation of the material of the workpiece. Also, the nanographene density is lesser than copper material. Thus, the thermal energy of the copper-nanographene electrodes utilized for operating is also higher, as illustrated performance criteria of EDM in Figure 4 (a) using the copper-nanographene electrode and (b) using the copper electrode.

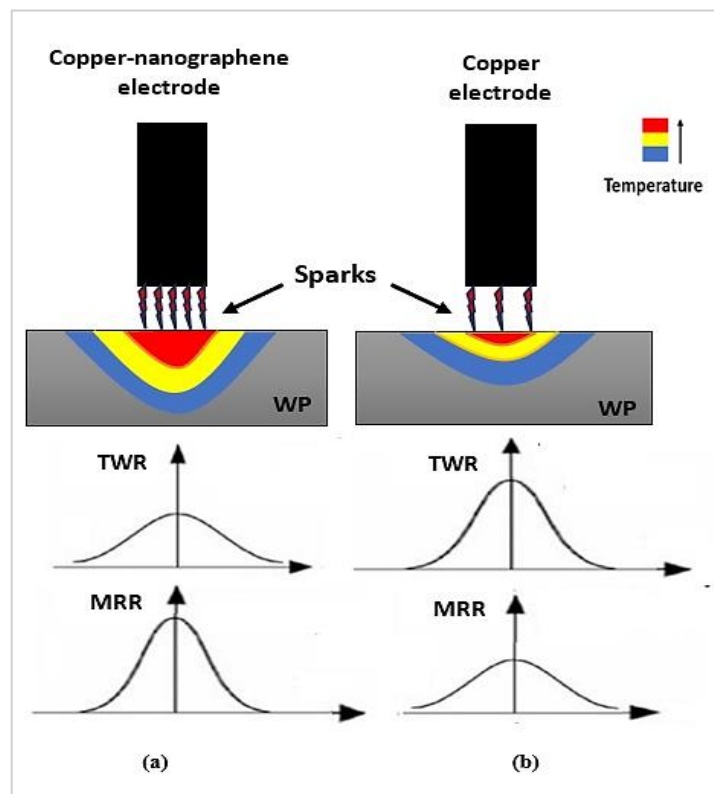


Figure 4: Performance criteria of EDM using various electrodes: (a) copper-nanographene and (b) copper

Table 5: Properties of Electrodes Materials

| Property | Unit | Copper | Copper nanographene |
|------------------------|------------------|----------------------|-----------------------|
| Hardness | HV | 107 | 152 |
| Electrical resistivity | Ωm | 1.7×10^{-8} | 2.85×10^{-8} |
| Thermal conductivity | W/mK | 400 | 520 |
| Density | g/cm^3 | 8.9 | 8.7 |

3.1 Statistical analysis for TWR

Based on ANOVA results for TWR, Tables 6 and 7 show the analysis results for copper and copper-nanographene electrodes. The dominant parameters were determined for all aspects of the operating process. Statistical test (F-test) determines the significance of each parameter. A larger (F-value) refers to a more significant parameter, while the (p-value) linked to the F-value reverses the possibility of the observed data. A statistically greater effect of the factor is referred to if the (p-value) is equal to or lower than (0.05). It was observed that the value of the discharge current has a significant impact on the TWR of the EDM process, which contributes 72.56% using copper electrodes. The parameter of I_p is important for evaluating the spark energy over the machining region [19]. Also, the T_{on} is the second parameter influencing the TWR in the EDM technique, with a contribution of 23.79% using copper electrodes. The T_{off} factor contributes slightly to the TWR; the residual is attributed to an error.

The coefficient of determination R^2 was used to check the fit of the models. The correlation coefficient R^2 value is 96.03% for TWR of copper electrodes. The nanographene powder may prevent the wear produced by the thermal energy, reducing the tool wear rate.

Table 6: ANOVA for TWR of copper-nanographene electrode

| Source | Sum of Squares | DF | Mean Squares | F-value | P-value | |
|--------------|----------------|----|--------------|---------|----------|-------------|
| Model | 0.0709 | 3 | 0.0236 | 29.06 | < 0.0001 | Significant |
| A- I_p | 0.0612 | 1 | 0.0612 | 82.60 | < 0.0001 | |
| B- T_{on} | 0.0195 | 1 | 0.0195 | 3.34 | 0.0708 | |
| C- T_{off} | 0.0012 | 1 | 0.0012 | 0.2584 | 0.6249 | |
| Residual | 0.0065 | 8 | 0.0008 | | | |
| Cor Total | 0.0884 | 11 | | | | |

$R^2 = 95.6\%$, Adjusted $R^2 = 91.44\%$, Predicted $R^2 = 90.09\%$

Table 7: ANOVA for TWR of copper electrode

| Source | Sum of Squares | DF | Mean Squares | F-value | P-value | |
|-------------|----------------|----|--------------|---------|----------|-------------|
| Model | 0.1131 | 3 | 0.0377 | 64.42 | < 0.0001 | Significant |
| A- I_p | 0.0997 | 1 | 0.0997 | 187.50 | < 0.0001 | |
| B- T_{on} | 0.0327 | 1 | 0.0327 | 4.68 | 0.0625 | |
| C- T_{of} | 0.0036 | 1 | 0.0036 | 1.08 | 0.3298 | |
| Residual | 0.0014 | 8 | 0.0006 | | | |
| Cor Total | 0.1374 | 11 | | | | |

$R^2 = 96.03\%$, Adjusted $R^2 = 94.53\%$, Predicted $R^2 = 92.06\%$

This study focused on both I_p and T_{on} in the TWR analysis because they represented the most important among the machining parameters and were observed to have an effective and important role in the alteration of TWR response. In contrast, the T_{off} parameter was found to have a slight impact. 3D response surface plots in Figure 4 demonstrate how the TWR is impacted by the variations in I_p and T_{on} for various electrode materials. The minimum TWR is 1.203 mm^3/min when the values of both I_p and T_{on} are low 20 A and 100 μs , respectively, for a trial run 9 when using copper-nanographene electrodes, and the value of TWR increases with increasing the values of I_p and T_{on} , as shown in the Figure 5a. The decrease in TWR could be possible because the nanographene material has a higher melting point than copper material. This outcome resulted in higher wear resistance of the copper-nanographene electrodes than the copper electrodes, reducing the melting and vaporization of electrode material inside the spark region [20].

In Figure 5b, the 3D response surface plot evinces that the copper electrodes have a higher TWR value than copper-nanographene electrodes because copper's melting point is lower, and they require higher thermal energy to generate a sufficient electrical spark in the ignition area. Consequently, the amount of electrode wear is high. ANOVA results for TWR are displayed in Tables 3 and 4. It was noted that the regression model term is significant. The coefficient of determination R^2 was used to check the fit and precision of the created model if the R^2 value is near one [21]. The R^2 values in Tables 5 and 6 have proved the fit of the developed regression of the model.

3.2 Statistical analysis for MRR

Tables 8 and 9 illustrate the ANOVA of copper and copper-nanographene electrodes regarding MRR. The machining parameter of I_p , which contributes 78.67% using copper-nanographene electrodes, greatly influences the MRR in the EDM technique. Also, the T_{on} parameter, with a contribution of 18.48%, has been the second factor influencing the MRR. The T_{off}

manifested a minimum influence on the rate of material removal. The coefficient of correlation R2 is 97.14% for the MMR of copper-nanographene electrodes, which has proved the fit of the developed regression of the model.

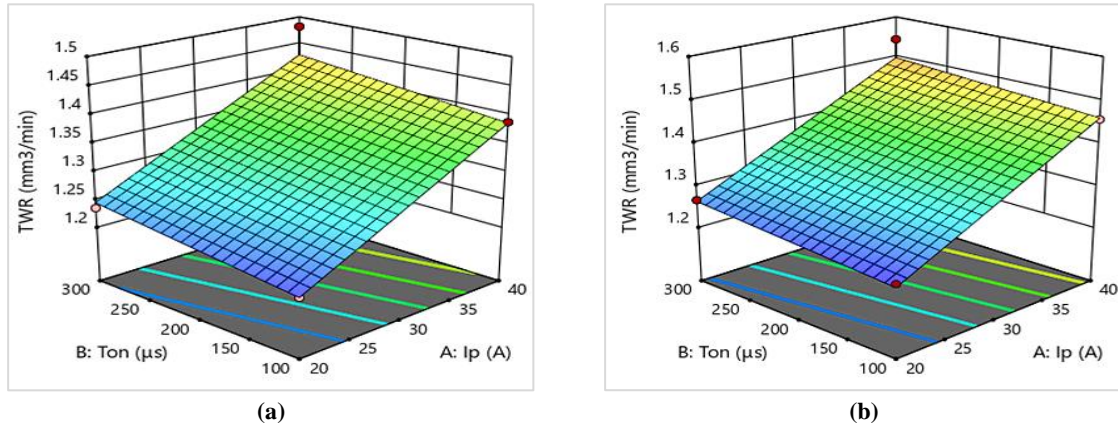


Figure 5: 3D Response surface plots for TWR; (a) copper-nanographene electrode and (b) copper electrode

Table 8: ANOVA for MMR of copper-nanographene electrode

| Source | Sum of Squares | DF | Mean Squares | F-value | P-value | |
|--------------|----------------|----|--------------|---------|---------|-------------|
| Model | 6.27 | 3 | 2.09 | 9.31 | 0.0055 | Significant |
| A- I_p | 8.15 | 1 | 8.15 | 27.39 | 0.0008 | |
| B- T_{on} | 1.9145 | 1 | 0.1145 | 0.0192 | 0.8931 | |
| C- T_{off} | 0.1143 | 1 | 0.0143 | 0.5095 | 0.4956 | |
| Residual | 0.1801 | 8 | 0.2247 | | | |
| Cor Total | 10.3589 | 11 | | | | |

$R^2 = 97.14\%$, Adjusted $R^2 = 91.04\%$, Predicted $R^2 = 90.32\%$

Table 9: ANOVA for MMR of copper electrode

| Source | Sum of Squares | DF | Mean Squares | F-value | P-value | |
|-------------|----------------|----|--------------|---------|---------|-------------|
| Model | 3.48 | 6 | 0.5794 | 25.21 | 0.0014 | Significant |
| A- I_p | 0.8154 | 1 | 0.7154 | 35.48 | 0.0019 | |
| B- T_{on} | 0.2957 | 1 | 0.2757 | 3.29 | 0.1293 | |
| C- T_{of} | 0.0997 | 1 | 0.0997 | 8.26 | 0.0349 | |
| Residual | 0.0149 | 5 | 0.0230 | | | |
| Cor Total | 1.2257 | 11 | | | | |

$R^2 = 96.8\%$, Adjusted $R^2 = 92.96\%$, Predicted $R^2 = 91.57\%$

To study and analyze the MRR, the present work focused on the I_p and T_{on} as they are the most influential factors noticed to have an effective role in altering MRR values, Whereas T_{off} was found to have a slight influence. 3D response surface plots in Figure 6 explain how the MRR is affected by varying I_p and T_{on} for different electrode materials using (a) copper-nanographene electrode and (b) copper electrode. It was observed that rising the I_p and T_{on} results in higher MRR values for copper and copper-nanographene electrodes. The maximum MRR is 15.904 mm³/min at I_p (40 A) and T_{on} (300 µs) for trial run 2 using copper-nanographene electrodes. The reason behind this can be clarified by the electrical conductivity of nanographene powder being larger than the copper material, so the thermal energy and sparks number are high in the machining region, increasing the melting and evaporation of particles from the workpiece material. [22]

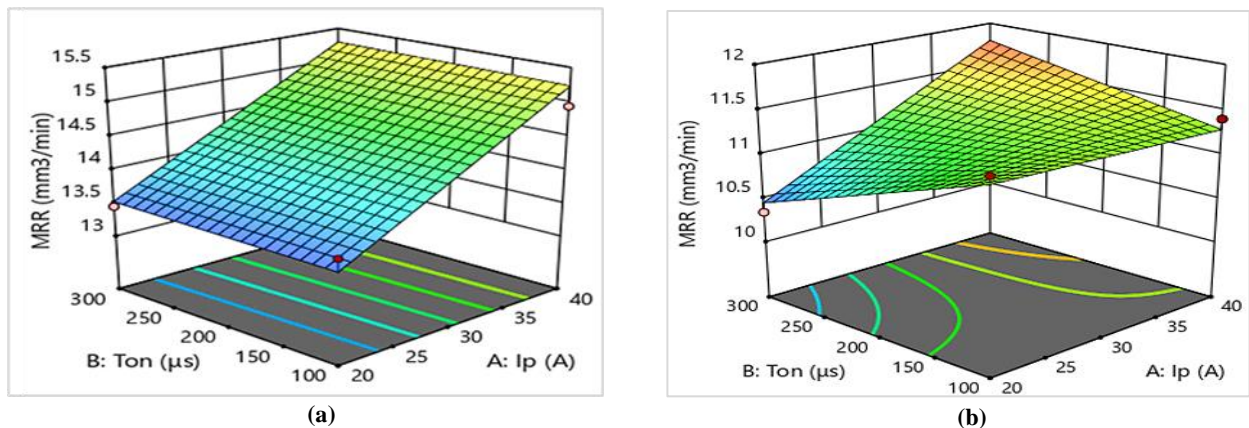


Figure 6: 3D Response surface plots for MRR; (a) copper-nanographene electrode and (b) copper electrode

3.3 Investigating the impact of nanographene powder on machined surfaces

The influence of nanographene was investigated on the machined surface. The accuracy control of different factors is important in the EDM process to achieve a machined surface free of flaws, such as micro-cracks, micropores, and globule size. The outcome for copper-nanographene electrodes portrayed a higher significance than that of copper electrodes. However, it is very important to assess the flaws in the machined surface, Figure 7 depicts the SEM micrograph of the machined surface using (a) copper-nanographene electrodes and (b) copper electrodes, respectively.

The micrograph of the surface obtained for copper electrodes has more surface flaws than the copper-nanographene electrodes. The machined surface of copper-nanographene electrodes demonstrated the least surface flaws in micro-cracks, micropores, and globules. The significant electrical conductivity of the nanoparticle stabilized the EDM and expanded the gap of operating and enhancement cleaning of the particles of debris [23,24]. For this reason, a significant improvement in the machined surfaces was noticed.

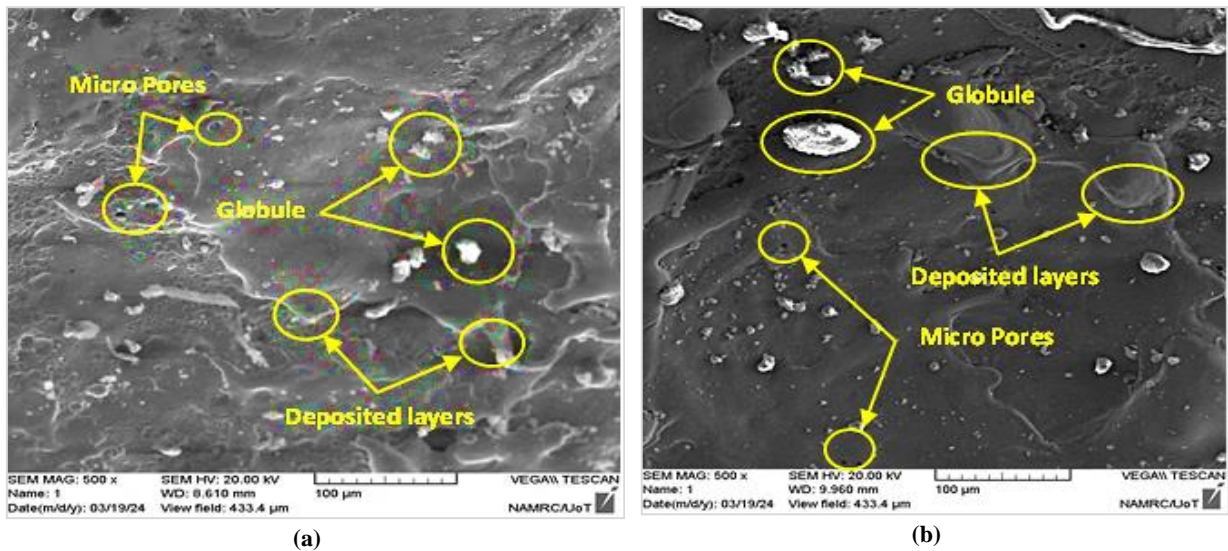


Figure 7: Micrography of the produced surface; (A) Electrode of copper-nanographene and (B) Electrode of copper. Current (40 A), T_{on} (300 μ s), and T_{off} (100 μ s)

4. Conclusion

The current study investigated the impact of nanographene powder on EDM performance. The following is a summary of the most important conclusions obtained:

- Observed that among the machining parameters, the current (I_p) and pulse-on time (T_{on}) significantly impact the performance measures.
- The TWR improved by 15.10% with the copper-nanographene electrodes. This can be attributed to the high microhardness of the nanographene powder, which enhances the tool's wear resistance.
- The MRR was enhanced by 29.67% with the copper-nanographene electrodes. This can be attributed to the nanographene powder's high electrical and thermal conductivity, which increased the thermal energy in the machining area, leading to enhanced MRR.
- The surface obtained using copper electrodes exhibited more surface defects, such as microcracks, micropores, and globules, than those obtained by copper-nanographene electrodes.

Nanographene powder has elucidated many benefits in the EDM optimization process. Therefore, there is a need to conduct many future studies to explore additional benefits, such as reducing energy consumption and increasing the machining rate, in addition to improving the cleaning and debris removal process from the machining area.

Author contributions

Conceptualization, O. Sabbar, A. Khleif, and B. Albaghdadi; data curation, O. Sabbar and A. Khleif, and B. Albaghdadi; formal analysis, O. Sabbar and A. Khleif; investigation, O. Sabbar, A. Khleif, and B. Albaghdadi; ; methodology, O. Sabbar, A. Khleif, and B. Albaghdadi.; project administration, O. Sabbar, A. Khleif, and B. Albaghdadi, resources, O. Sabbar, A. Khleif, and B. Albaghdadi.; software, O. Sabbar, A. Khleif, and B. Albaghdadi.; supervision, O. Sabbar, A. Khleif, and B. Albaghdadi.; validation, O. Sabbar, A. Khleif, and B. Albaghdadi.; visualization, O. Sabbar, A. Khleif, and B. Albaghdadi.; writing—original draft preparation, O. Sabbar, A. Khleif, and B. Albaghdadi.; writing—review and editing, O. Sabbar, A. Khleif, and B. Albaghdadi. All authors have read and agreed to the published version of the manuscript.

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Data availability statement

Statement the data supporting this study's findings are available on request from the corresponding author.

Conflicts of interest

The authors declare that there is no conflict of interest.

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