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Assessment of Surface Quality during EDM of AISI 4147 with Copper Tool

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Abstract: This experimental assessment is performed to estimate the impact of EDM parameters on surface quality while machining AISI 4147 with a copper tool. The need of the present-day is to achieve good surface quality. Here, an investigation was performed to depict surface quality characteristics with respect to machine variables. The machined specimens were examined under white light interferometry (WLI) for the crests and troughs developed post-machining. The range of average surface finish was found to be between 5.32 to 7.67 µm. The test of model highlighted that the relation linking the EDM variables and surface roughness could be modelled using quadratic equations. As per the SMSS and lack of fit tests, a quadratic model is suggested for the roughness trend obtained. The analysis apprised that duration (p-value = 0.0006) major influence on the surface quality produced while the depth of machining (p-value = 0.9251). At all levels of on time, the surface roughness initially increases and then tends to decrease on increasing peak current. At all current levels, the surface roughness is almost constant with the machining depth; as suggested by ANOVA, it is the least influencing factor. At all levels of duration, the surface roughness is almost constant with depth of machining, and as suggested by ANOVA, it is the least influential factor. Model surface plots are curved representing the presence of quadratic terms in the model. Model validation for surface finish showed that the residual error was lower than 1.48%, proving the adequacy of the model.

Introduction

The spark erosion machining, also termed Electro Discharge Machining, removes the excess material from the work surface by the heat of a spark through melting and vaporization. The sparks continue to erode the surface until the final shape is achieved. In order to make the process more effective, electrodes are submerged in the dielectric medium. The need of the present-day is to achieve good surface quality. Numerous investigations and analyses have been carried out to evaluate the impact of EDM parameters on the surface finish achieved by EDM machining. Numerous studies have been conducted to optimize the machining parameters. Majority of studies have focused on creating machined surfaces of higher quality.

Numerous investigations have been carried out on various materials to ascertain how EDM parameters affect surface roughness. Several attempts have been made to optimise the EDM settings to improve the surface quality. In an examination of the impact of discharge energy, it is discovered that discharge energy directly affects surface roughness (Gostimirovic et al., 2012). The surface roughness increases uniformly with the discharge power and time.

After examining how various electrodes affected surface roughness, it was concluded that Cu-W electrodes produced a superior surface finish compared to copper and graphite electrodes (Gopalakannan et al., 2012). When using ZrB_2–Cu composite as an EDM electrode, it was discovered that ZrB_2–40wt% Cu composite tool surfaces had an average surface roughness that is greater

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than Cu tool (Khanra et al., 2007). Research proved that increasing the pulse current and pulse on time consequently increases the surface roughness (Daneshmand et al., 2013). Electro-discharge craters of rotational sparks are fewer due to the electrical arc's continual movement, and the surface roughness of rotational sparks is less than that of traditional sparks. Surface roughness rises as process parameter values rise (Tang and Du, 2014).

A low current setting produced the best surface quality. SR rises as pulse on time and voltage increases (Singh et al., 2013). A test of the impact of electrode material on surface quality concluded that copper tungsten electrodes had to be chosen over copper electrodes to have the least surface roughness (Maheshwari et al., 2008).

Another investigation revealed that adding particles to the dielectric considerably enhanced the machined surface's surface finish. The main important elements influencing surface roughness were found to be powder concentration, current, and pulse on time (Bhattacharya et al., 2013). Compared to graphite and copper, Cu-W reportedly gives the lowest SR. The tool material is a significant influencing element in surface roughness (Payal et al., 2016). The goal of minimizing surface roughness is to maintain the peak current at its optimal level. The roughness average values rise in tandem with an increase in pulse on time, necessitating an optimal pulse on time. Raising the pulse-off time does not affect the roughness value (Annamalai et al., 2014). The influence of EDM parameters found that that the pulse current sharply influences and increases the surface roughness (Shabgard et al., 2011). It was also found that peak current is the most dominating parameter towards surface roughness, whereas the percentage of alloying elements in the PM tool and duty factor doesn't significantly affect surface roughness (Gill and Kumar, 2007). According to the study, tool electrodes should have a negative polarity in order to reduce surface roughness, and an increase in pulse on time results in rougher surfaces. The EDM method reduces the specimen's surface roughness by adding powder particles to the dielectric fluid. In the EDM process, rougher surfaces are produced at higher peak currents (Singh et al.., 2012).

According to one research, flushing pressure and increased electrode rotation levels are likely to result in improved surface quality. As the current increases, the surface roughness rises, and as the electrode rotates more, it falls (Chandrasekaran et al., 2013). It was also found that roughness is influenced by pulse off time and surface roughness initially increases rapidly with an increase in pulse off-time and then decreases slowly with an increase in pulse off-time (Rajesh et al., 2014). Even when the SR increases with greater pulse current levels, an extended pulse-on period causes the electric plasma channel to expand, which lowers the SR (Rizvi and Agarwal, 2016).

An investigation on Nimonic 90 to identify the influence of EDM parameters on the finish of the surface produced. They also incorporated powder mixed dielectric and concluded that it reduces the roughness of the workpiece. Their research also found that the most important parameter for roughness was pulse on time. The rest of the selected parameter moderately influences the roughness (Alhodaib et al., 2012).

Another investigation on Nimonic 80A for surface roughness while machining on powder mixed EDM concluded that mixing powder in dielectric leads to lower surface roughness. When chromium is mixed with the dielectric, it leads to increase the roughness. When aluminium is used with dielectric, the finish of the workpiece improves (Modi et al., 2019).

While machining AISI 4340 on EDM to assess the value of roughness of the machined surface using various EDM parameters, the investigation reported that a poor surface finish was obtained with higher discharge energy (Giridharan et al., 2016; Jain et al., 2023). Another experimental investigation of surface roughness during EDM of AISI 4340 found that on-duration is the major influencing factor for surface roughness. They also found that the surface finish can be improved by setting lower values of machining parameters. They also developed the model which was adequate for predicting surface roughness values (Rizvi et al., 2020).

From the above research, the gap identified for this investigation is to study the influence of EDM parameters viz. peak current, pulse on time, and depth of machining on the surface quality followed by simultaneous optimization of responses using response surface methodology (RSM) in order to recommend optimal parameter settings.

Materials and Methods

This assessment seeks to evolve a model to predict surface quality of AISI 4147 while machining on EDM. Trials were planned based on RSM technique and a set of twenty experiments were performed. The surface roughness was assessed using white light interferometry through BRUKER Contour GT-K, as shown in Figure 1 below.

The lowest and highest level of EDM parameters were fixed during the preliminary trials. At lower electrical parameters, no sparking was observed. Above 7A current and 30μsec on-duration, arcing was achieved. Below 0.5 mm depth, no significant machining was obtained. Table 1 below represents the set of parameters with their levels. Table 2 depicts the average surface roughness achieved for each trial.

Result and Discussion

The surface roughness data obtained in Table 2 is analyzed to depict the complying polynomial equation to assess the relation between machine variables and surface roughness. As per the SMSS and lack of fit tests, a quadratic model is suggested for the roughness trend obtained. Tables 4 and 5 illustrates the SMSS and lack of fit tests, respectively.

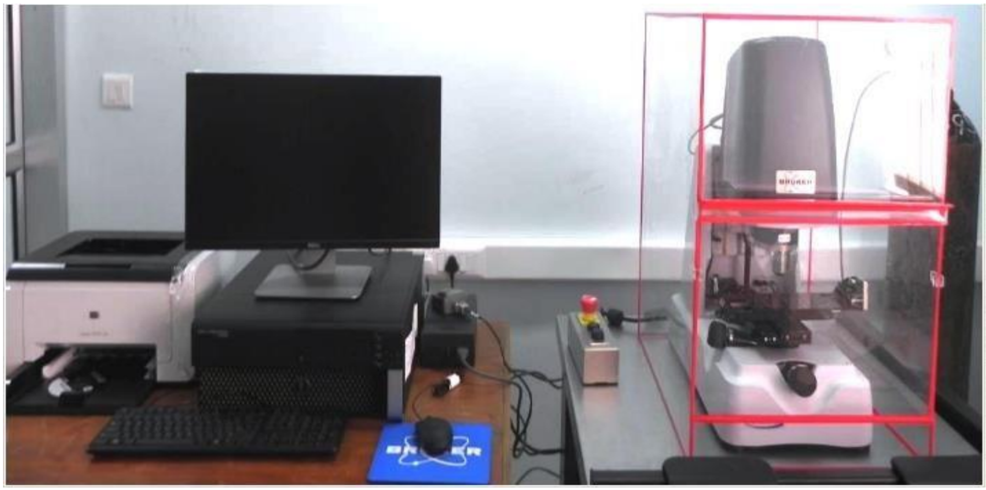

Figure 1. BRUKER Contour GT-K.

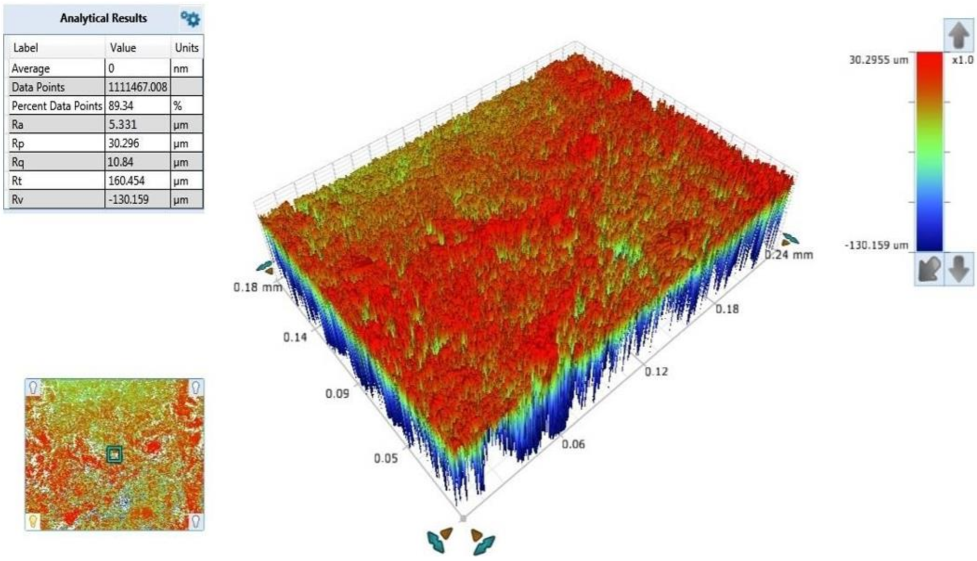

Figure 2. Surface Roughness measurement of Sample 4 using white light interferometry.

Table 1. Parameters and their levels.

Parameters	Current	Pulse on Time	Depth of Machining
Units	A	μsec	mm
Level 1	1	10	0.5
Level 2	4	20	0.8
Level 3	7	30	1.1

The above figure 2 shows the roughness measurement of sample 4 using white light interferometry. AISI 4147 is selected as the work material while pure copper is chosen as the tool. It is a medium-carbon alloy steel that possesses high hardenability and resists abrasion, fatigue, and impact. Table 3 shows the chemical composition of AISI 4147 by weight.

Furthermore, Analysis of Variance for Quadratic model was performed for roughness of machined surface, as depicted in Table 6. The current model is significant in this case, as indicated by the model F-value of 8.36. The probability that this F-value is the result of noise is

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Table 2. Calculation of Surface Roughness.

Exp. No.	Peak Current (Ip)	Pulse on time (Ton)	Depth of Machining (mm)	*Ra 1*	*Ra 2*	*Ra 3*	*Surface Roughness (Average) (μm)*
1	1	10	0.5	5.83	5.86	5.85	5.85
2	7	10	0.5	6.35	6.3	6.31	6.32
3	1	30	0.5	7.28	7.34	7.33	7.32
4	7	30	0.5	6.99	7.05	7.01	7.02
5	1	10	1.1	5.53	5.54	5.45	5.5
6	7	10	1.1	6.44	6.41	6.46	6.44
7	1	30	1.1	7.15	7.15	7.13	7.14
8	7	30	1.1	7.39	7.33	7.41	7.38
9	1	20	0.8	5.34	5.31	5.32	5.32
10	7	20	0.8	6.07	6.13	6.12	6.11
11	4	10	0.8	7.64	7.68	7.68	7.67
12	4	30	0.8	7.52	7.47	7.53	7.51
13	4	20	0.5	6.91	6.85	6.86	6.87
14	4	20	1.1	6.83	6.82	6.83	6.83
15	4	20	0.8	6.57	6.56	6.57	6.57
16	4	20	0.8	6.59	6.59	6.61	6.6
17	4	20	0.8	6.55	6.55	6.53	6.54
18	4	20	0.8	6.6	6.63	6.62	6.62
19	4	20	0.8	6.59	6.61	6.61	6.6
20	4	20	0.8	6.59	6.58	6.58	6.58

Table 3. Chemical constituents of AISI 4147 by weight.

Material	% Composition
Iron	97.33
Phosphorous	0.03
Manganese	0.87
Sulphur	0.04
Chromium	0.8
Carbon	0.47
Silicon	0.25
Molybdenum	0.21

merely 0.13%. This suggests that the model accurately describes the data within the necessary 95% confidence interval. The importance of the model terms is shown by a p-value less than 0.05. Peak current, pulse on time, square of peak current, and square of pulse on time are important model parameters for the current model.

Depth of machining was shown to have the least impact on surface roughness among the selected electrical characteristics (p-value = 0.9251). Pulse on duration is the major dominating variable (p-value = 0.0006) for the present model, which substantiates the previous research on surface roughness.

A polynomial equation Eq. (1) is developed from the response surface modelling to relate the input EDM factors to the surface roughness produced.

$$\begin{aligned} Surface\ Roughness(\mu m) = \\ = 8.34373 + 0.972520 \times Current \\ - 0.292358 \times Pulse\ on\ time \\ - 3.29237 \times Depth\ of\ machining \\ - 0.006125 \times Current \\ \times Pulse\ on\ time \\ + 0.140278 \times Current \\ \times Depth\ of\ machining \\ + 0.017083 \times Pulse\ on\ time \end{aligned}$$

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$$\times\, Depth\ of\ machining - 0.111364 \times Current^2 + 0.008727 \times Pulse\ on\ time^2 + 1.47475 \times Depth\ of\ machining^2 \ldots\ldots Eq.(1)$$

Table 4. Sequential Model Sum of Square Test (SMSS).

Source	Sum of Square	DOF	Mean Square	F-Value	p-value	
Mean vs Total	881.66	1	881.66			
Linear vs Mean	2.57	3	0.8552	2.82	0.0724	
2FI vs Linear	0.4186	3	0.1395	0.4087	0.7494	
Quadratic vs 2FI	3.57	3	1.19	13.66	0.0007	Suggested
Cubic vs Quadratic	0.8091	4	0.2023	19.67	0.0013	Aliased
Residual	0.0617	6	0.0103			
Total	889.08	20	44.45			

Table 5. Lack of Fit Test.

Source	Sum of Square	DOF	Mean Square	F-value	p-value	
Linear	4.85	11	0.4412	558.48	<0.0001	
2FI	4.43	8	0.5543	701.67	<0.0001	
Quadratic	0.8669	5	0.1734	219.46	<0.0001	Suggested
Cubic	0.0577	1	0.0577	73.08	0.0004	Aliased
Pure Error	0.0039	5	0.0008			

Table 6. Analysis of Variance for Surface Roughness.

Source	Sum of Square	DOF	Mean Square	F-value	p-value	
Model	6.55	9	0.728	8.36	0.0013	Significant
A-Peak Current	0.458	1	0.458	5.26	0.0448	
B-Pulse on Time	2.11	1	2.11	24.19	0.0006	
C-Depth of Machining	0.0008	1	0.0008	0.0093	0.9251	
AB	0.2701	1	0.2701	3.1	0.1087	
AC	12.75	1	12.75	1.46	0.2541	
BC	0.021	1	0.021	0.2413	0.6339	
A^2	2.76	1	2.76	31.72	0.0002	
B^2	2.09	1	2.09	24.05	0.0006	
C^2	0.0484	1	0.0484	0.5563	0.4729	
Residual	0.8708	10	0.0871			
Lack of fit	0.8669	5	0.1734	219.46	<0.0001	Significant
Pure Error	0.0039	5	0.0008			
Cor Total	7.42	19				

The equation in terms of actual parameters is utilized for predicting the responses for provided level of every parameter. The extent of each parameter is to be stated in primal units.

The surface plot for the quadratic response model of surface roughness is depicted in Figure 3, 4 and 5. The surface plot in Figure 3 shows that the impact of peak current and pulse on duration varies towards surface roughness, and a curved plot is obtained to represent the presence of quadratic terms in the model. At all levels of on time, the surface roughness initially increases and then tends to decrease on increasing peak current. With the current constant, the roughness of the machined surface initially decreases and then increases as we increase the duration level. In order to achieve a better surface finish, extreme level of current and a medium level of on duration are suggested.

The surface plot in Figure 4 shows that the impact of peak current varies towards surface roughness at all levels of depth of machining. A curved plot is also obtained to represent the presence of quadratic terms in the model. At all current levels, the surface roughness is almost constant with the machining depth; as suggested by ANOVA, it is the least influencing factor. The surface roughness initially increases and then tends to decrease

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when the current is increased at all levels of depth of machining.

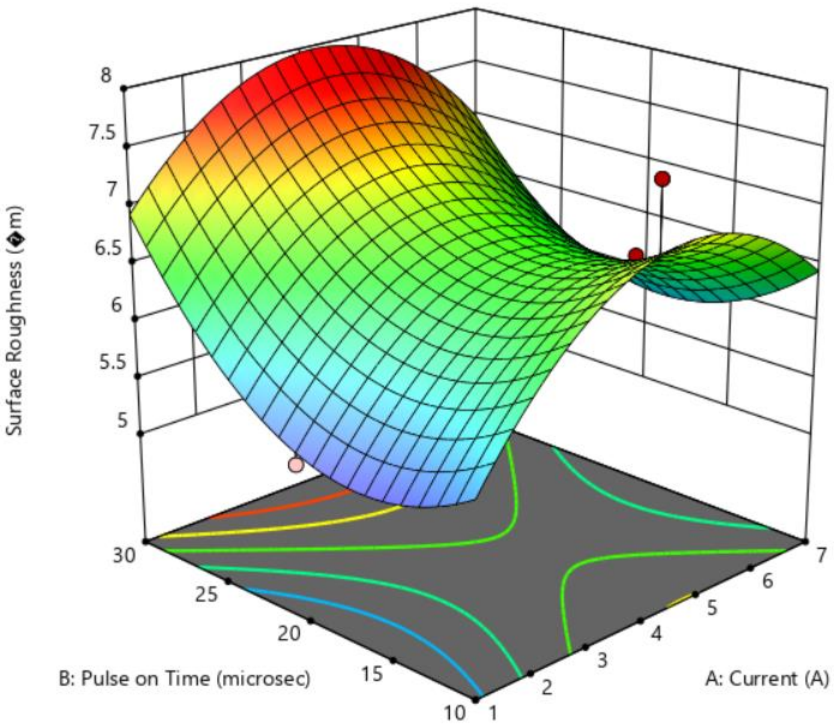

Figure 3. Surface Plot for Surface Roughness with pulse on time and current.

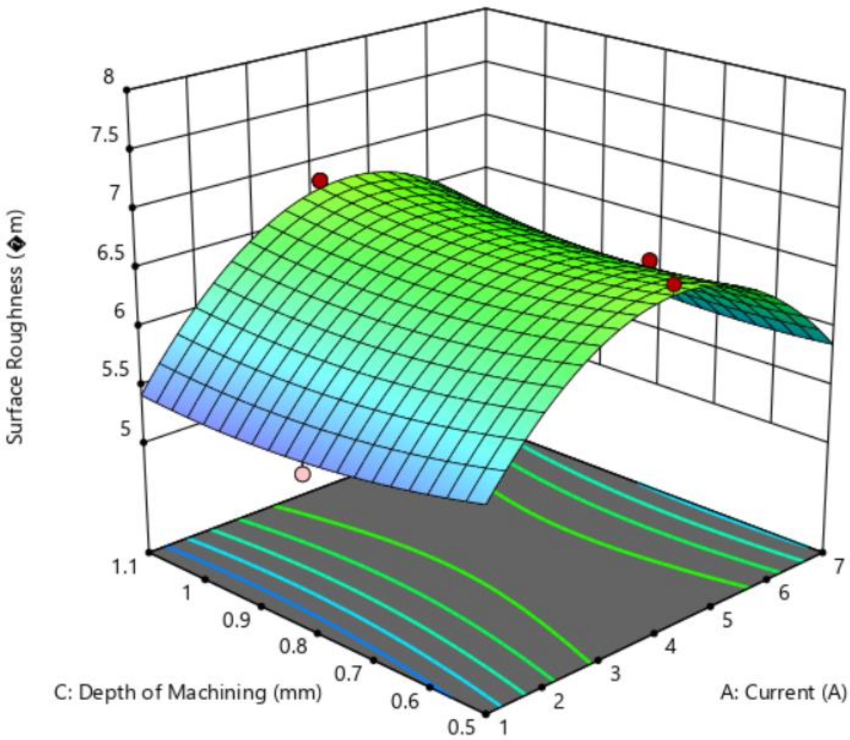

Figure 4. Surface Plot for Surface Roughness with current and depth of machining.

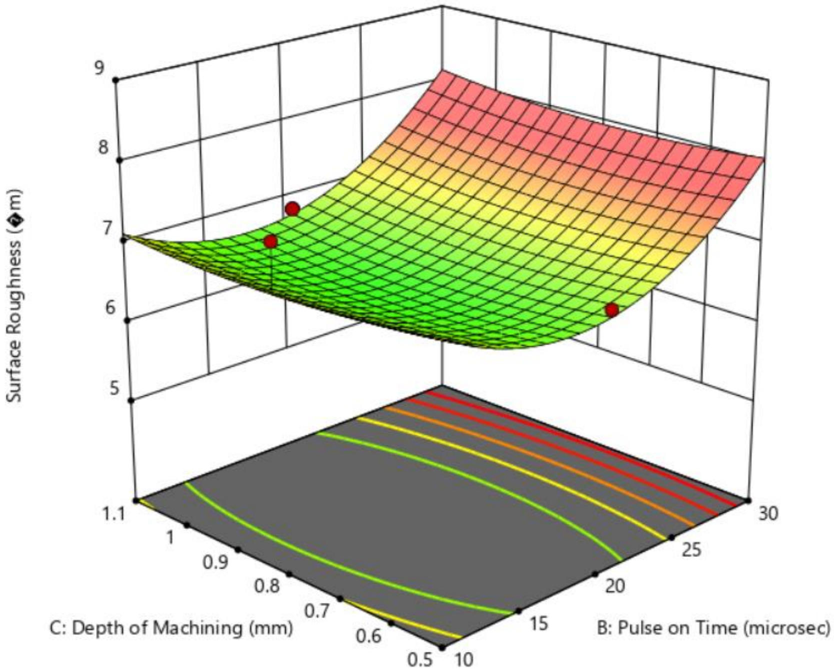

Figure 5. Surface Plot for Surface Roughness with depth of machining and pulse on time.

The surface plot in Figure 5 depicts that the impression of on-duration varies towards surface roughness at all the depths of machining. A curved plot is also obtained to represent the presence of quadratic terms in the model. At all levels of on duration, the surface roughness is almost constant with the depth of machining and as suggested by ANOVA it is the least influencing factor. The tool wear rate initially decreases and then tends to increase with the level of on duration at all levels of machining depth.

Model Validation

Point prediction calculates the predicted value of surface roughness based on the developed algorithm accompanied by their 95% prediction interval value. The validation run value and the predicted value are compared by residual error to determine the validity of the model. Table 7 depicts the result of validation with the set of EDM variables. The table shows that the residual error is below 1.48%, which specifies adequacy of the model to estimate the surface roughness under 95% CI while the residual error corresponding to the predicted value is within 5%.

Table 7. Model Validation of Surface Roughness

S.No.	Machine Variables			Predicted Value	Prediction Interval		Validated Value	Residual Error %
	Current	On-duration	Depth of machining	Surface Roughness (µm)	95% PI low	95% PI high	Surface Roughness (µm)	
1	4	20	0.8	6.63791	6.41187	6.86395	6.54	1.48%

Conclusion

The conclusions were drawn from the research carried out during the Electro-discharge machining of AISI 4147 using copper electrodes. The impact of machining variables was analyzed on surface roughness and the following inferences were made:

- The roughness of the machined surface was measured using white light interferometry through BRUKER Contour GT-K and three roughness tests of each machined surface specimen were taken and the analysis was carried out on the average roughness values of tests in order to analyse the

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impact of EDM parameters. SMSS and Lack of fit tests were performed, and they highlighted that the relationship linking the EDM variables and surface roughness could be modelled using quadratic equations.

- Analysis of Variance for the Quadratic model was conducted for the surface roughness and F-value of 8.36 of the model shows its significancy. For present model, peak current, on-duration, square of current and square of on-duration are significant model terms.
- Depth of machining was shown to have the least impact on surface roughness among the selected electrical characteristics (p-value = 0.9251). Pulse on duration is the major dominating variable (p-value = 0.0006) for the present model, substantiating the previous research on surface roughness.
- The surface plot for the quadratic response model of surface roughness suggested that in order to achieve a better surface finish, an extreme level of current and medium level of on-duration is suggested. The surface roughness is almost constant with depth of machining and as suggested by ANOVA it is the least influencing factor.

The residual error was found to be below 1.48%, which specifies the adequacy of the model to estimate the surface roughness under 95% CI, while the residual error corresponding to the predicted value is within 5%.

Conflict of Interest

The authors declare no conflict of interest.

References

Alhodaib, A., Shandilya, P., Rouniyar, A.K., & Bisaria, H. (2012). Experimental Investigation on Silicon Powder Mixed-EDM of Nimonic-90 Superalloy. *Metals, 11*, 1-17. https://doi.org/10.3390/met11111673

Annamalai, N., Sivaramakrishnan, V., Kumar, B.S., & Baskar, N. (2014). Investigation and Modeling of Electrical Discharge Machining Process Parameters for AISI 4340 steel. *International Journal of Engineering and Technology, 5*, 4761-4770.

Beri, N., Maheshwari, S., Sharma, C., & Kumar, A. (2008). Performance Evaluation of Powder Metallurgy Electrode in Electrical Discharge Machining of AISI D2 Steel Using Taguchi Method. *International Journal of Mechanical, Aerospace, Industrial, Mechatronic and Manufacturing Engineering, 2*, 225-229.

Bhattacharya, A., Batish, A., & Kumar, N. (2013). Surface characterization and material migration during surface modification of die steels with silicon, graphite and tungsten powder in EDM process. *Journal of Mechanical Science and Technology, 27*, 133-140. https://doi.org/10.1007/s12206-012-0883-8

Chandrasekaran, C., Kanagarajan, D., & Karthikeyan, R. (2013). Optimization of EDM Characteristics of WC/5ni Composites Using Response Surface Methodology. *International Journal of Recent Technology and Engineering, 2*, 108-115.

Daneshmand, S., Kahrizi, E.F., Neyestanak, A.A.L., & Ghahi, M.M. (2013). Experimental Investigations into Electro Discharge Machining of NiTi Shape Memory Alloys using Rotational Tool. *Int. J. Electrochem. Sci., 8*, 7484-7497. https://doi.org/10.1016/S1452-3981(23)12820-3

Giridharan, A., & Samuel, G.L. (2016). Analysis on the effect of discharge energy on machining characteristics of wire electrical discharge turning process. *Journal of Engineering Manufacture, 230*, 2064–2081. https://doi.org/10.1177/0954405415615732

Gopalakannan, S., & Senthilvelan, T. (2012). Effect of Electrode Materials on Electric Discharge Machining of 316 L and 17-4 PH Stainless Steels. *Journal of Minerals and Materials Characterization and Engineering, 11*, 685-690. https://doi.org/10.4236/jmmce.2012.117053

Gostimirovic, M., Kovac, P., Skoric, B., & Sekulic, M. (2012). Effect of electrical pulse parameters on the machining performance in EDM. *Indian Journal of Engineering & Materials Sciences, 18*, 411-415.

Hascalık, A., & Caydas, U. (2007). Electrical discharge machining of titanium alloy (Ti–6Al–4V). *Applied Surface Science, 253*, 9007-9016. https://doi.org/10.1016/j.apsusc.2007.05.031

Jain, A., Kumar, C. S., & Shrivastava, Y. (2023). An Effort for Identifying Suitable Machining Range During Drilling of a Novel Al-Based Composite Using Electric Discharge Machine. *Int. J. Exp. Res. Rev., 36*, 327-346. https://doi.org/10.52756/ijerr.2023.v36.030

Khanra, A.K., Sarkar, B.R., Bhattacharya, B., Pathak, L.C., & Godkhindi, M.M. (2007). Performance of ZrB2–Cu composite as an EDM electrode. *Journal of Materials Processing Technology, 183*, 122-126. https://doi.org/10.1016/j.jmatprotec.2006.09.034

Modi, M., & Agarwal, G. (2019). Effect of aluminium and chromium powder mixed dielectric fluid on electrical discharge machining effectiveness. *Advances in Production Engineering & Management*, *12*, 323-332. https://doi.org/10.14743/apem2019.3.330

Payal, H., Maheshwari, S., & Bharti, P.S. (2016). Effect of Tool Material on Surface Roughness in Electrical Discharge Machining. *Journal of Production Engineering*, *9*, 27-30.

Rajesh, S., Jawalkar, C.S., Mishra, R.R., Sharma, A.K., & Kumar, P. (2014). Study of Recast Layers and Surface Roughness on Al-7075 Metal Matrix Composite during EDM Machining. *International Journal of Recent advances in Mechanical Engineering*, *3*, 53-62.

Rizvi, S.A.H., & Agarwal, S. (2016). An investigation on surface integrity in EDM process with a copper tungsten electrode. *18th CIRP Conference on Electro Physical and Chemical Machining*, *42*, 612-617. https://doi.org/10.1016/j.procir.2016.02.254

Rizvi, S.A.H., Agarwal, S., & Bharti, P.K. (2020). Modeling of Surface Roughness of AISI 4340 Using Copper-Tungsten Tool in Die Sinking EDM. *Materials Today Proceedings*, *22*, 2334-2340. https://doi.org/10.1016/j.matpr.2020.03.355

Shabgard, M., Seyedzavvar, M., & Oliaei, S.N.B. (2011). Influence of Input Parameters on the Characteristics of the EDM Process. *Journal of Mechanical Engineering*, *57*, 689-696. https://doi.org/10.5545/sv-jme.2011.035

Singh, G., Singh, P., Tejpal, G., & Singh, B. (2012). Effect of Machining Parameters on Surface Roughness of H13 Steel in EDM Process using Powder Mixed Fluid. *International Journal of Advanced Engineering Research and Studies*, *2*, 148-150.

Singh, B., Kumar, J., & Kumar, S. (2013). Investigating the Influence of Process Parameters of ZNC EDM on Machinability of A6061/10% SiC Composite. *Advances in Materials Science and Engineering*, *13*, 1-8. https://doi.org/10.1155/2013/173427

Tang, L., & Du, Y.T. (2014). Experimental study on green electrical discharge machining in tap water of Ti–6Al–4Vand parameters optimization. *Int. J. Adv. Manuf. Technol.*, *70*, 469-475. https://doi.org/10.1007/s00170-013-5274-5

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