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Research Article

Enhancement Material Removal Rate Optimization of Sinker EDM Process Parameters Using a Rectangular Graphite Electrode

Sumanto[1], Acim Maulana[2], Dodi Mulyadi[2], Khoirudin[2], Siswanto[2], Sukarman[2], Ade Suhara[3], Safril[4]

[1]*Department of Mechanical Engineering, Sekolah Tinggi Teknik Karawang, Jl. Lingkar Tanjungpura, Karawang, West Java, 41313, Indonesia*
[2]*Department of Mechanical Engineering, Universitas Buana Perjuangan Karawang, Jl. Ronggo Waluyo Sirnabaya, Karawang, West Java, 41361, Indonesia*
[3]*Department of Industrial Engineering, Universitas Buana Perjuangan Karawang, Jl. Ronggo Waluyo Sirnabaya, Karawang, West Java, 41361, Indonesia*
[4]*Department of Mechanical Engineering, Universiti Malaysia Pahang, Lebuhraya Tun Razak, 26300 Gambang, Kuantan, Pahang, Malaysia*

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CORRESPONDENCE

Phone : +62-267-8403140
E-mail : sukarman@ubpkarawang.ac.id

ABSTRACT

This article discusses the optimization of sinker electrical discharge machining (sinker EDM) processes using SPHC material that has been hardened. The sinker EDM method is widely employed, for example, in the production of moulds, dies, and automotive and aeronautical components. There is neither contact nor a cutting force between the electrode and the work material in sinker EDM. The disadvantage of the sinker EDM is its low material removal rate. This work aims to optimize the material removal rate (MRR) using graphene electrodes in a rectangular configuration. The SPHC material was selected to determine the optimum MRR model of the sinker EDM input parameter. The Taguchi experimental design was chosen. The Taguchi technique used three input parameters and three experimental levels. Pulse current (I), spark on time (Ton), and gap voltage were among the input parameters (Vg). The graphite rectangle was chosen as an electrode material. The input parameter effect was evaluated by S/N ratio analysis. The result showed that pulse current has the most significant impact on material removal rate in the initial study, followed by spark on time and gap voltage. All input parameters are directly proportional to the MRR. For optimal material removal rate, the third level of pulse current, spark on time, and gap voltage must be maintained. In addition, the proposed Taguchi optimization model could be applied to an existing workshop floor as a simple and practical electronic tool for predicting wear and future research.

INTRODUCTION

The sinker electrical discharge machining (sinker EDM) is a non-conventional machining process using an electrode chisel to scrape the work material and create dimensions and shape [1]. The sinker EDM process is utilised extensively in producing dies, moulds, and spare parts for the automotive and aerospace industries [2]. During the sinker EDM process, there is no immediate contact between the work material and the tool electrode; therefore, machining errors due to tool electrode deformation, vibration-related inaccuracies, chatter, and mechanical stresses are not happen [3]. During the eroding of work materials, the tools used and materials are dipped in a dielectric medium [4]. This is done after machining recently developed hardened carbon steel. The sinker EDM machine manages the movement of the electrode tool to erode the material by generating an electric spark with a high frequency [5]. The sinker EDM can eliminate chatter, mechanical stress, and vibration problems in conventional machining.[6]. Flushing/washing the diffused particles in the inter-electrode gap presents the most complex challenge during the sinker EDM process. Residual material deposited in the opening of the work material and the electrode can result in warping of the work material and trigger a short circuit. In the sinker EDM process, the surface finish (surface profile) and surface integrity of the resulting work material will have a significant impact on the MRR [7].

Optimizable sinker EDM parameters include peak current, pulse on time, pulse off time, and gap voltage. The peak current is one of the most important parameters sinker EDM, alongside pulse on time [8]. Pulse-on time or pulse duration is the time interval during which the spark (electron discharge) occurs between the electrode and the work material once the breakdown voltage of the dielectric has been reached, thereby ionizing the dielectric [9]. As a result, the spark causes deterioration of the material of the work material [10]. Pulse-off time is one of the parameters for sinker EDM. During this period, no electrode voltage is present. A decrease in pulse-off time for a pulse period results in an increase in pulse on time, which increases discharge, sparking

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efficiency, and cutting rate [11]. At extremely brief pulse-off times, wire rupture and an unstable discharge can occur. When sparking becomes unstable, the pulse-off time must be lengthened in order to reduce the pulse duty factor and average gap. current. Peak current is the maximum current available for each pulse from the power supply/generator [12]. The average current is the average amperage measured in the spark gap over one complete cycle. During the machining process, the sinker EDM machine ammeter measures the average current. The spark on time of sinker EDM is the length of time that the spark is performing work and eroding the work material material [3].

The gap voltage is the alternating voltage between two electrodes. The voltage applied to a spark determines its total energy [13]. The Sinker EDM process is time-consuming because each spark between the electrodes only removes negligible material. It is desirable to have a mathematical model that can predict the material removal rate (MRR) based on the properties of the material and the variables involved in the process. It has been demonstrated that the MRR for Sinker EDM is proportional to the peak current but not the shape of the current-time profile; this indicates that the model is insensitive to either the on-time or the off-time conditions.

Several researchers have studied to improve the quality and productivity of the sinker EDM process, such as carried out by [14], [15], [10], and [16]. Surface roughness is associated with enhanced quality. In contrast, material removal rate, electrode wear rate, and overcut dimension are all associated with enhanced productivity. Al Akbari and Baseri investigated sinker EDM by establishing the optimal input parameters for the predetermined sinker EDM procedure [14]. The selected research input parameters include pulse current, pulse on time, and electrode rotation. The selected outcome variables are surface roughness, material removal rate, overcut, and electrode wear rate. The research used the Taguchi experiment, which used three levels of experiments to formulate an experimental layout using a work material with X210Cr12 (SPK) material. The electrodes material is provided by pure copper (99.9% Cu). Analysis of variance (ANOVA) was being utilized to determine the significance of the influence of input parameters on the response variable. The input parameters provided include current, pulse on time, electrode rotation speed, and electrode geometry. The results of the ANOVA showed that the most influential parameters influencing material removal rate (MRR), electrode wear rate (EWR), and surface roughness (Ra), respectively, were current, pulse on time, and electrode geometry [14].

Sutan et al., conducted further research on sinker EDM using the RSM technique approach [15]. The selected process parameters are pulse current, pulse on time, and peak current. E-EDM research uses multiple response variables, namely MRR, Ra, and EWR. The Taguchi experiment with three levels of experiments was used to formulate the layout. The study used the work material, EN 353 steel, and pure copper for the electrode material. The results of the response surface methodology (RSM) analysis showed that the optimum values of EWR, MRR, and Ra were 6.47 mm^3/min, 17.62 mm^3/min, and 4.54 m, respectively. The optimum conditions were obtained by setting the pulse on time, peak current, and pulse off-time parameters respectively at 100.77 s, 45A, and 25.43 s [15]. The sinker EDM study was also carried out by [10]. with the Taguchi experimental method. The parameters provided include pulse on-time, discharge-current, and pulse current. The study chose MRR and Ra as response variables. The research design used the Taguchi experimental technique and the RSM. Three sinker EDM input parameters and three experimental levels were chosen to optimize the sinker EDM process on heat-treated tool steel with a hardness of 55 HRC. Copper material was chosen as the sinker EDM electrode.

The result of the sinker EDM process has a roughness *(Ra)* between 1.0-2.0 m, and the maximum roughness value is optimized based on the desirability technique [10]. Chandramouli, also researched the sinker EDM process using the work material, precipitation-hardening stainless steel. The input parameters of the sinker EDM process that have been chosen, namely peak current, pulse off time, pulse on time, and tool life. The selected-response variables were material removal rate and surface roughness. The Taguchi experimental technique was chosen to formulate the experimental layout. The PH Steel 17-4 material was chosen for the work material. The tungsten-copper alloy material was chosen as the electrode. ANOVA was used to evaluate the effect of input variable on response outcome [16].

Even though research has been conducted and evaluated on sinker EDM, the optimization of MRR in the sinker EDM process utilizing the hardened SPHC (JIS G3131) material has not been performed and worked. The Taguchi method was used and implemented to optimize the material for this investigation. Taguchi Method to optimize the parameters of the sinker EDM process. The Taguchi method minimises the amount of process variation by utilising a solid experimental design. Because this non-traditional production process is more expensive than conventional production methods, this method is suitable for optimising productivity in EDM sinkers. The Taguchi technique will utilize three input parameters and three experimental levels. As input factors for evaluating the performance of the sinker EDM process, the parameters pulse current (I), spark on time (Ton), and gap voltage (Vg) was chosen by using the SPHC (JIS G-3302) and graphite for the work material and electrode materials. The objective is to determine the optimal MRR for sinker EDM parameters. The optimal MRR will achieved the productivity of sinker EDM processes. This work was completed and performed according to the recommendations for sinker EDM process parameters that produced the optimal MRR using a rectangular graphene electrode.

METHOD

Experimental Preparation and Setup

The most essential performance indicators for sinker EDM are metal removal rate, surface finish of the work piece, and overcut dimension [17][18]. Discharge current, pulse duration, pulse frequency, wire speed, wire tension, and dielectric flow rate are machining parameters that influence the performance measurements. The SPHC steel sheet material work material has been selected in this studied. The material specifications, including chemical composition and mechanical properties, follow the JIS G 3131 standard [19] [20]. Material prepared by stamping and followed by hardening and sinker EDM machine processed. Rectangle graphite material was selected for electrode sinker EDM processes. The measuring instruments used in this research included roughness meter, and digital scale. A roughness meter is used to evaluate surface work material roughness of the sinker EDM results, a digital scale provided to evaluate the mass of the work material and electrode in conditions before and after machining, The C-TEK ZNC-50A type sinker EDM machine has been completed using for this research. The sinker EDM process using the C-TEK ZNC-50A type occurs in Figure 1.

Performance of the sinker EDM Machining process is possible with a high level of responsive material removal (MRR). MRR is the material removal rate from a work material. During the sinker EDM machinery process, an electric spark occurs between the electrode and the work material. Each spark delivers a tiny cavity, resulting in the erosion of the surrounding material. The MRR is the ratio of the difference between the work material's weight before and after sinker EDM to the material's density and machining time. Electric sparks are utilized in the sinker EDM method to determine the work material's material removal rate. Equation 1 presents directions for calculating MRR by combining experimental and theoretical methods [10] [21].

Graphite material was selected for electrode material. A graphite electrode attached to an EDM machine approaches a metal work material shaped by spark erosion. Sending a high electrical voltage through an electrode causes a spark that removes a small amount of material from the work material at a time. This dielectric fluid is sent through the gap between the graphite electrodes to clean/flush the space and achieve the work material's temperature stability. The electrode's constant sparks and the erosion of the material work together to cut the desired shape into the work material. Observing the material makes it evident that the consistency throughout is excellent. During the EDM process, the consistency of the graphite material stabilises the electrode and work material. If the structure of the graphite materials is inconsistent, the results of the EDM machining process will also be inconsistent. The consistency of the material is also crucial during the graphite electrode's machining. This consistency is a primary factor that enables the material and the machinist to maintain extremely tight tolerances and superior surface finishes.

Figure 1. The C-TEK ZNC-50A machine of sinker EDM

$$MRR = \frac{W_0 - W_1}{t.\rho} \quad (1)$$

Which MRR is provided for the material removal rate in mm^3/minutes; t described for the time of machining in minutes; ρ is the work material density (grams/cm^3). W_0 and W_1 indicate the mass of the work material before and after sinker EDM process, respectively, in grams. The sinker EDM process refers to the input parameters controlled for each iteration presented in

Table 2. The sinker EDM processing time (t) for each iteration is 5 minutes. The erosion of work material during each run was measured in grams/min, followed by dividing the difference between the material's weight before and after the process by the time required This method confirmed by previously studied [22]

Experimental Design

The Taguchi method is typically used in production process optimization and scientific studies because it uses a robust experimental design to minimize variations in production and research processes, such as in resistance spot welding [23] [24] , optimize the painting [25], and machining [26]. The whole condition allows for the smallest sample size for the required data collection by specifying input parameters that are predicted to significantly impact the product or research data quality [27]. The Taguchi method involves reducing process variation through a robust experimental design. This method's primary objective is to produce a high-quality product at a low cost [28]. Taguchi devised a method for designing experiments to determine the influence of various parameters on the mean and standard deviation of the process performance characteristics that determine how well the process performs. Taguchi's experimental design utilizes orthogonal arrays to organize the process-influencing parameters and the levels that must be varied. The Taguchi method does not test all possible supported combinations but a select few [29]. In order to save time and money, this test will generate a collection of essential data that can be used to determine which factors have the most significant impact on product quality with the least amount of experimentation.

Table 2. Taguchi Matrix for Optimizing the sinker EDM

Code	**Sinker EDM Parameters**	**Symbol**	**Level**		
			1	**2**	**3**
A	Pulse current, A	I	10	13	16
B	spark on time, (µs)	T_{on}	210	340	400
C	Gap voltage, V	V_g	40	45	50

A = Ampere, µs = micro second, and V= Volt

Table *2* provides Taguchi's experimental design direction.

Orthogonal Arrays (OA)

The OA typically uses a matrix to ensure a balanced level comparison within each factor and precisely determine the sample selected from a given group. The orthogonal array, also known as the OA, is one component of the total condition's set of experiments. However, this component may only correspond to one-quarter or one-eighth of the overall factorial experiment. Experiments are planned with the help of OA, data from experiments are analyzed, and the smallest number of experiments that can provide as much information about the factors that affect the parameters as possible is found. One of OA's advantages is its ability to identify factors with minimal tests that affected the saving cost and time during the trial process. [30]. Considered to be the most crucial aspect of orthogonal arrays is the selection of the appropriate combination of levels of input variables for each experiment.

According to the explanation in the introduction, pulse current, spark on time, and gap voltage is input variables that influence productivity, which is related to MRR. Taguchi designs require at least two trial levels and two input parameters. This research was designed with three experimental levels and three input variables. The number of experiments performed in a Taguchi design is represented by the symbol Lm, where m represents the total number of factors and L represents the total number of levels for each factor. There are numerous possible experiments when there are many factors and a range of levels for each factor. Thus, experiments require efficient factorial design. This requirement can be met by experimenting with an orthogonal array requiring fewer factor and level combinations. **Error! Reference source not found.** provided OA L9 (3^3) of the Taguchi implementation with three factors and three experimental levels, resulting in eight degrees of freedom. All iterations of the Taguchi design will be tested twice to ensure accurate data.

Signal to Noise Ratio (S/N Ratio)

The S/N ratio denotes the sensitivity value anticipated for the input parameter. In this experiment, the response variables each have their own set of data characteristics distinct from one another. If the objective is to maximize the response, we utilize the data with the larger-is-better characteristic. It can establish a high value at the intersection of such properties as tensile strength [31], MRR [15], volume [32], paint thickness [25], and compressive strength [33]. If the objective is to minimize the response (smaller is better), the Low value may be set to the point of diminishing returns. The point of diminishing returns is the point at which decreasing a variable's value makes little difference [34]. The nominal is the best describes the concept of delivering a performance close to the target (customer preference) in order to maximize customer satisfaction value, thereby exceeding the specification limits. The characteristic of MRR data is that the higher the value, the better, therefore MRR uses the larger is better data characteristic. The Taguchi technique provides three data characteristics, as shown in equations 2, 3, and 4.[25] [32].

Table 3.Orthogonal Array of input parameters for sinker EDM

Run No.	Input parameters			Sample identifications	
	A	B	C	R_1	R_2
1	1	1	1	R1-1	R2-1
2	1	2	2	R1-2	R2-2
3	1	3	3	R1-3	R2-3
4	2	1	2	R1-4	R2-4
5	2	2	3	R1-5	R2-5
6	2	3	1	R1-6	R2-6
7	3	1	3	R1-7	R2-7
8	3	2	1	R1-8	R2-8
9	3	3	2	R1-9	R2-9

Larger is better:

$$S/N\ ratios\ = -10\log \frac{1}{n_0}\sum_{i=1}^{n_0}\frac{1}{y_i^2} \quad (2)$$

Smaller is better:

$$S/N\ ratios\ = -10\log \sum_{i=1}^{n_0}\frac{y_i^2}{n_0} \quad (3)$$

Nominal is the best:

$$S/N\ ratios\ = -10\log \frac{\bar{y}^2}{s^2} \quad (4)$$

The MRR feature that defines it is the fact that productivity increases in direct proportion to the S/N ratio. It is essential to adjust the parameters so that they have the highest S/N ratio value possible if one is to achieve the highest possible level of productivity. Therefore, equation 2 is a feature of the S/N ratio that will be applied throughout the subject of this investigation.

RESULTS AND DISCUSSION

Material Removal Rate (MRR) Analysis

During the machining process, including sinker EDM machining as a non-conventional process, the MRR is one of the most important parameters to measure productivity. The material removal rate, or MRR, of the work material, is measured against a unit of time using the MRR. It provides information about the speed at which the work material is machined. Because the machining rate and the productivity rate are directly proportional to one another, a high machining rate is advantageous. Within the scope of this investigation, the sinker EDM procedure was timed for a full five minutes. An electronic weighing scale with an accuracy of approximately 0.001 grams was utilized to determine the mass before and after sinker EDM processes. W_o was described for mass before sinker EDM process and W_t was described for mass after sinker EDM processes.

A stopwatch was selected to confirm the time setting in the sinker EDM machine, and Equation 1 was used to calculate the MRR. MRR analyzes the working process to consider the input of sinker EDM parameter values, including current (lp), spark on time (Ton), and gap voltage. Because the discharge energy delivered into the machining zone was typically lower when the pulse current was smaller, the MRR was lower. As a result, the machined cavity was shallower, allowing debris to escape the machining area more quickly. On the other hand, the higher peak

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Figure 2. The sinker EDM sample of SPHC work material and graphene electrode

Table 4. Material removal rate of sinker EDM

Run No.	Input parameters			Massa work material (grams)				MRR (mm^3/minutes)		S/N Ratio
	Pulse current, A	Spark on time, (μs)	Gap voltage, V	W_{o-1}	W_{t-1}	W_{o-2}	W_{t-2}	R_1	R_2	
1	10	210	40	20.69	19.99	20.30	19.59	17.83	18.09	25.09
2	10	340	45	20.30	19.26	20.39	19.38	26.50	25.73	28.33
3	10	400	50	20.39	19.16	20.27	19.03	31.34	31.59	29.96
4	13	210	45	20.27	19.05	20.55	19.34	31.08	30.83	29.81
5	13	340	50	20.55	19.05	20.27	18.79	38.22	37.71	31.59
6	13	400	40	20.36	18.71	20.55	18.93	42.04	41.27	32.39
7	16	210	50	20.25	18.69	20.36	18.80	39.75	39.75	31.99
8	16	340	40	20.58	18.89	20.58	18.91	43.06	42.55	32.63
9	16	400	45	20.33	18.63	20.33	18.64	43.31	43.06	32.71

current equals more discharge energy, resulting in a deeper cavity. The debris becomes more difficult to expel from the machining zone as the cavity depth increases [35]. It causes short-circuiting and disrupts the electrical discharge, resulting in a low MRR. As a result, achieving maximum MRR necessitates finding the best pulse current value. The nine test sample in each iteration of sinker EDM process has been provided in Figure 2. Total sample of 18-units were identified by R1-1, R2-1, R1-2, R2-2, R1-3, R2-3, R1-4, R2-4, R1-5, R2-5, R1-6, R2-6, R1-7, R2-7, R1-8, R2-8, R1-9, and R2-9.

The experimental data for the MRR was derived from the mass of the wasted work material, which was calculated by subtracting the mass of the work material before sinker EDM from the mass of the work material after sinker EDM during the sinker EDM process. The MRR was at its lowest in iteration 1 and highest in iteration 9. These results consist of what was previously reached by [15] and the fundamental theory of sinker EDM applications [6]. Because of the effect of pulse current on MRR, we can see that as the magnitude of the pulse current grows, the magnitude of the MRR increases. An increase in spark energy makes melting and vaporization easier, which leads to an increase in pulse current and maximum rate of reaction (MRR). Because of this response, the MRR is increased because the impulse force in the spark gap increases. The MRR results of this study are listed in **Error! Reference source not found.**.

S/N Ratio Analysis

The experiments were carried out with the help of the DOE that Taguchi developed. Because it provides a reliable experimental matrix with the fewest possible trials to achieve the best results, the methodology developed by Taguchi is utilized extensively in various manufacturing systems. Taguchi enables the user to analyze the effect of machining variables on selected responses with as few trials as possible, thereby reducing the money spent and the time on the process [5]. Taguchi's experiments employ a two-step optimization technique. The first step uses the S/N ratio to identify the results' direction parameters. The secondary step uses to determine control input that bring the mean to the desired level while having an optimal effect on the S/N ratio. The signal-to-noise (S/N) ratio examines how the response fluctuates concerning target value under different noise situations. As previously stated, the quality attributes used in this study were "larger is better". It implies that performance with an increased S/N ratio will be of higher quality [36]. The level of the experiment will performance increases as the MRR of the test sample findings increases [15][16].

The values for the mean of MRR of productivity attributes, as well as the S/N ratio analysis investigation, were determined by applying Equation 2 to the data. **Error! Reference source not found.** demonstrates that Taguchi's design advises using pulse current, spark on time, and gap voltage on third level to achieve the optimum outcome of MRR. It' was demonstrated that the pulse current has the biggest delta value, followed by the spark on time and the gap voltage. The value of delta is calculated by taking the highest value of the signal-to-noise ratio and subtracting it from the value of the signal-to-noise ratio that is lowest. This circumstance demonstrates that the pulse current input parameter has the greatest value among the three parameters and changes in pulse current levels will increase MRR. Figure 3 depicts the results of a study of the S/N ratio produced by the sinker EDM method utilizing graphite and object electrodes for SPHC material preparation. The relationship between MRR and input parameters during the sinker EDM process of SPHC graphene electrodes is depicted in Figure 4. Observe that when the current increases, the MRR increases rapidly. Sultan et al. [15] demonstrated it through Taguchi experimental method. A negligible amount of heat is produced at low currents, most of which is absorbed by the environment and machine components. The remainder is used to melt and evaporate the working substance.

Analysis of Variance (ANOVA)

Analysis of variance also referred to as ANOVA, is a statistical method that divides data on observed variance into its components so that the information can be utilized in more tests [16]. This information can then be used to conclude the relationships between the variables. In order to gain insight into the connection between the dependent and independent variables, a two-way analysis of variance (ANOVA) is performed on data sets containing three or more distinct groups of information, and it is done so that the results of the analysis can be interpreted. In order to facilitate a better understanding of the connection between two or more input parameters, the variables were researched [4]. In the statistical analysis, analysis of variance (ANOVA) was utilized, which revealed the impact that machining factors had on output characteristics. Equations and an analysis of the ANOVA were developed with the assistance of statistical software. The significance level of 95%, required for identifying relevant model terms, was applied to evaluate the variables' relevance to the study. A P-value less than 5% indicates that the specific machining variable had a significant impact on

Table 5. Larger is better of the S/N ratio in sinker EDM

Level	**A-Pulse current, A**	**B-Spark on time, (μs)**	**C-Gap voltage, V**
1	27.79	28.96	30.04
2	31.26	30.85	30.29
3	32.44	31.69	31.18
Delta (Max. Min)	4.65	2.72	1.14
Rank	1	2	3

Table 6. The ANOVA for MRR of sinker EDM

Source	**DF**	**Seq SS**	**Adj MS**	**F**	**P**
A	2	441.80	220.899	35.08	0.028
B	2	131.65	65.826	10.45	0.087
C	2	14.42	7.211	1.15	0.466
Residual Error	2	12.59	6.296		
Total	8	600.46			

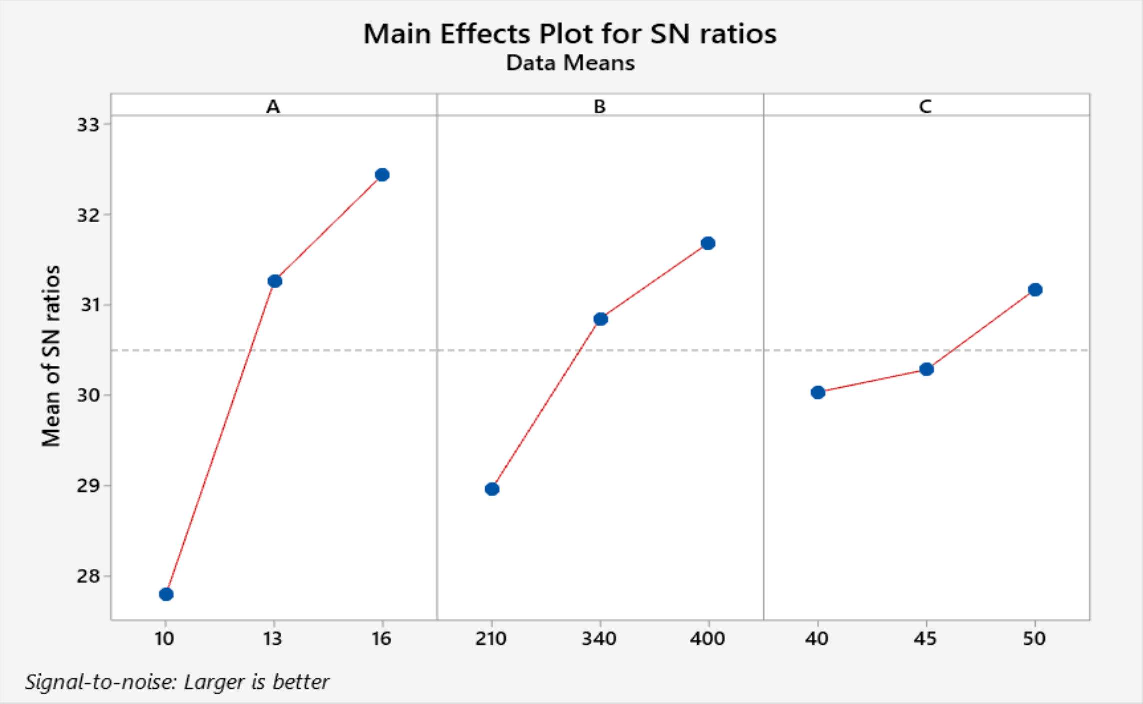

Figure 3. The S/N Ratio of Sinker EDM parameters

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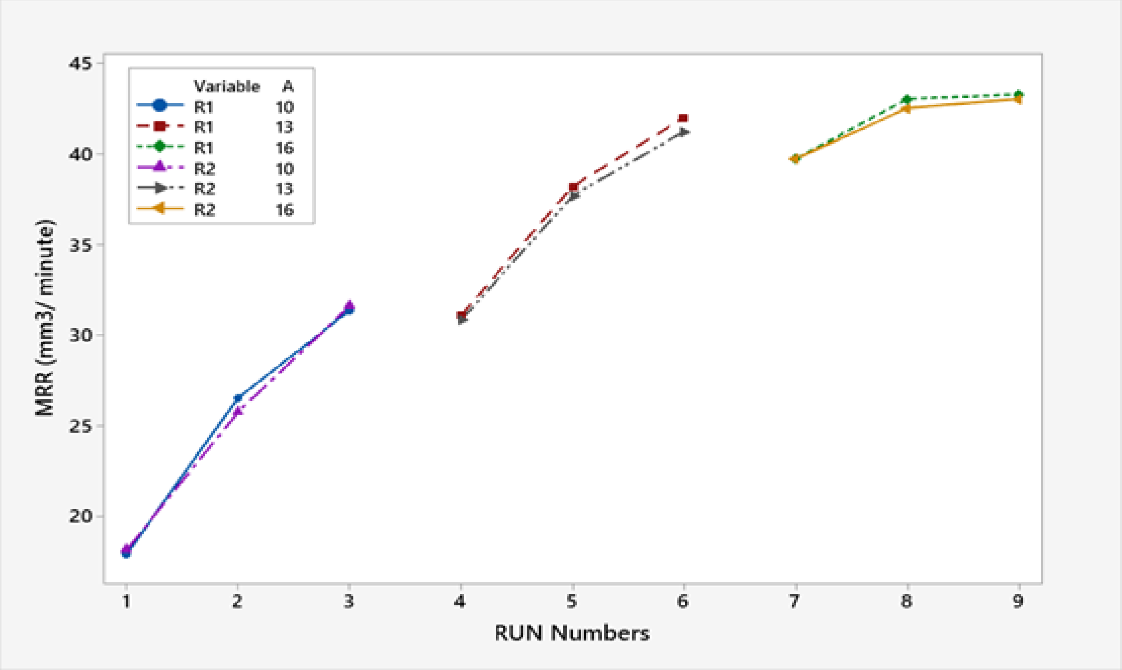

Figure 4. The relationship between MRR response and sinker EDM input parameters

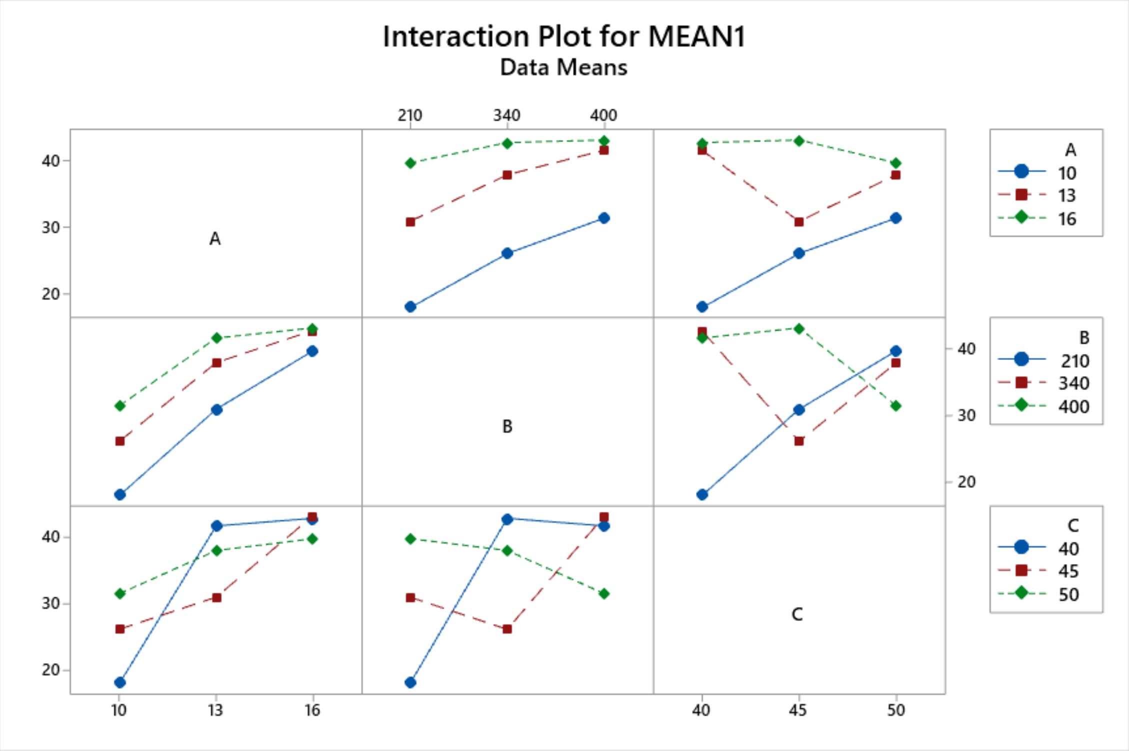

Figure 5. Interaction plot parameter of sinker EDM

determining the value of the respective response [22]. According to Table 6, when maximizing MRR, input factors A should be considered significant, while factors B and C should be considered less significant. The table shows that the input factor is significant when the P-value is less than 5%.

The P-value of 2.8% in Table 1 indicates that the pulse current has a statistically significant effect. This result follows the previous study by [18] [4], that pulse current is an input parameter that significantly affects MRR. It is also known that parameter spark on time has a substantial impact, as evidenced by the fact that its associated P value approaches 8.7%. In contrast, parameter gap voltage has no significant effect on the outcome, which is the MRR, with a P-value of about 56.5%. The phenomenon is consistent with sinker EDM studies conducted by [22].

DF donate for degree of freedom. Seq SS is Donate for the sum of squares, Adj. MS is Donate for the adjusted sum of squares, F is Donate for the F-value, and P is Donate for the P-value.

"Degrees of freedom" refers to the number of independent factors whose values could be approximated in statistical analysis [37]. Even though there are no limits on the values of these variables, they put limits on other variables that must be met for the data set to fit the approximate parameters [38]. The adjusted sum of squares is the sum of the sums of squares for all indicator variables that correspond to the term when all other definitions are considered [39]. The adjusted sum of squares is the distinction in error sums of squares when comparing the predictive model to the regression model obtained by ignoring the variable in the discussion [40]. The above term comes from the ANOVA. A ratio of two variances, or more specifically, two mean squares, is what is meant to be understood as an F-value [41]. Mean squares are nothing more than variances that have been adjusted to take into account the degrees of freedom (DF) that were used to approximate the variance [37]. The test statistic for F-tests is referred to as an F-value. In the context of testing a statistical hypothesis, the p-value is the level of negligible significance that indicates the possibility that a particular event will happen [25].

Interaction Plot Parameters

The purpose of the investigation of interaction plot parameters is to identify the components of the machining process as well as their interactions, which significantly impact the process's performance [16]. An Interaction Plot can be employed to demonstrate how the value of a second categorical variable changes the correlation between a variable and a continuous response. The means for one factor's levels are obtained by plotting along the x-axis, while the means for the other are plotted on different lines [42]. Examine the lines to see how interactions affect the connection between the variables and the response. The Parallel lines mean there is no interaction occurring. Whereas the nonparallel lines indicate there are have an interaction that occurs. The more nonparallel the lines are, the greater the strength of the interaction [43]. Before determining the recommended levels for factors A, B and C, it is necessary to analyze their interaction. The optimal value of factor F should be determined solely based on its interaction with factor A, as factor F is not very significant. As shown in Figure 5, the interaction between A x B and A x C has a less significant impact on MRR. As illustrated in Figure 5, the two independent factors, A x B and Ax C, cooperate to produce less significant effects, whereas the factors B x C cooperate to produce the most significant effects. In the interactions plot parameter, A indicated for pulse current factor, B represents for spark on the time factor and represents for gap voltage factor.

CONCLUSIONS

The sinker Electric discharge machining is extensively employed in the production of precision components. In comparison to conventional machining, the MRR of the sinker EDM is slower. Particularly the amount of MRR caused by sinker EDM. How we discharge depends upon discharging settings, such as material types and geometrical shapes. Electrode deterioration makes exact electrode feeding harder to regulate. Through sinker EDM through-rectangular machining trials, this work provides a Taguchi model for optimizing the MRR. The optimum parameter of the sinker EDM process using a rectangle graphite electrode and SPHC material work material has been achieved by pulse current at 3rd.level, spark on time at 3rd.level, and gap voltage at 3rd. level. The S/N ratio of each parameter is 32.44, 31.69, and 31.18. This indicates that the maximum level of productivity will be achieved under these conditions. In an initial study, the pulse current has a major parameter effect on MRR by a delta value of 4.65. The results of the ANOVA showed that the pulse current is a significant parameter for MRR, as evidenced by a P-value that was less than 5%. It has a contribution ratio of a 54.64%. In addition, the proposed Taguchi optimization model is highly effective when applied to real workshop floors as a simple and convenient tool for predicting wear, as well as in other research projects. Additional research will be conducted to examine the output parameters of other sinker EDM, including overcut dimension and electrode wear rates**.**

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NOMENCLATURE

MRR	meaning of material removal rate (mm/ minute)
W_0, W_1	meaning of mass before and after Sinker EDM (gram)
t	meaning of time in minute
ρ	meaning of density (gram/cm^3)
S/N ratios	meaning of signal to noise ratio
y_i	resp
$\bar{y}$	mea
n	num

AUTHOR(S

Sukarman

He lectures in mechanical engineering at the university of Buana Perjuangan Karawang. He contributes to academic journals as the principal author, a correspondent writer, or a co-author of scientific articles listed in Google Scholar and

Dodi Mulyadi

He is a lecturer at the University of Buana Perjuangan Karawang's Mechanical Engineering Department. In addition to giving lectures, he writes scientific articles as either the principal author or a co-author. published in national publications accredited by SINTA and international journals indexed by Scopus.

Khoirudin

Currently actively teaching at the University of Buana Perjuangan Karawang in the mechanical engineering department. Apart from teaching, he is also active in writing scientific articles as the principal author or co-author. The total

Approximately

are listed on Google Scholar. Some of them have published national periodicals that SINTA has accredited.

Ade Suhara

He is currently the dean of a technical faculty at the University of Buana Perjuangan Karawang and an active student in the industrial department. In addition to learning, he is active in article writing, whether as a primary or secondary author. There are approximately 19

number of scie

on Google Scholar is about 25 scientific articles. Some of them have been published in SINTA-accredited national journals.

Sumanto

He is currently employed as a mechanical engineering teacher at Karawang College of Technology. In order to co-author scientific articles, he works in the manufacturing industry in addition to teaching. His industry expertise greatly influenced the writing of this article.

secondary auth
available on Gc
of them have already appeared in Scopus-indexed and SINTA-
accredited natic

Acim Maulana

He is a lecturer in the mechanical engineering department at Karawang College of Technology at present. In addition to his teaching responsibilities, he is involved in the industry and has contributed to it by writing scientific articles. The writing of this article was significantly influenced by his industry knowledge.

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