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Analysis of WEDM for the Machining of OHNS (Oil Hardened No Shrinkage) Steel Using Response Surface Methodology (RSM)

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Abstract: OHNS (Oil-hardened shrinkage) steel is gradually becoming a significant material due to its wide scope of use in manufacturing industries. It is also revealed from the literature that very few efforts have been made to achieve the optimum parameter setting in the wire-EDM process for OHNS. The Wire Electric Discharge Machine (WEDM) appears to be a suitable option for machining intricate shapes in hardened materials. In this proposed work, the effects of various process parameters of WEDM such as pulse on time (P_{ON}), pulse off time (P_{OFF}), Wire feed rate (WF), and current (I) on the material removal rate (MRR), surface roughness (SR) and the overcut or Kerf width (KF). An L27 array was proposed for the experiment. Response Surface Methodology (RSM) was used to model and analyze the data. The pulse on time, pulse off time, pulse current, and voltage are the control parameters of EDM. RSM method was used to design the experiment using a rotatable central composite design as this is the most widely used experimental design for modeling a second–order response surface
Index Terms: Wire Electric Discharge Machine, OHNS, Response Surface Methodology

I. INTRODUCTION

Electrical discharge machining (EDM) is a nontraditional, thermoelectric process that erodes material from the workpiece by a series of discrete sparks between a work and tool electrode immersed in a liquid dielectric medium. These electrical discharges melt and vaporize minute amounts of the work material, which are then ejected and flushed away by the dielectric. The sparks occurring at high frequency continuously & effectively remove the workpiece material by melting & evaporation. The dielectric acts as a deionising medium between 2 electrodes and its flow evacuates the resolidified material debris from the gap assuring optimal conditions for spark generation. In microwire, EDM metal is cut with a special metal wire electrode that is programmed to travel along a preprogrammed path. A wire EDM generates spark discharges between a small wire electrode (usually less than 0.5 mm in diameter) and a workpiece with deionized water as the dielectric medium and erodes the workpiece to produce complex two- and three-dimensional shapes according to a numerically controlled (NC) path.[31] The wire-cut EDM uses a very thin wire 0.02 to 0.3 mm in diameter as an electrode and machines a workpiece with electrical discharge like a bandsaw by moving either the workpiece or the wire. Erosion of the metal utilizes the phenomenon of spark discharge which is the very same as in conventional EDM. The prominent feature of a moving wire is that a complicated cutout can be easily machined without using a forming electrode. Wire cut EDM machine consists of a machine proper composed of a workpiece contour movement control unit (NC unit or copying unit), workpiece mounting table, and wire driven section for accurately moving the wire at constant tension; a machining power supply which applies electrical energy to the wire electrode and a unit which supplies a dielectric fluid (distilled water) with constant specific resistance. The main goals of WEDM manufacturers and users are to achieve better stability and higher productivity of the WEDM process, i.e., higher machining rate with desired accuracy and minimum surface damage. However, due to a large number of variables and the stochastic nature of the process, even a highly skilled operator working with a state-of-the-art WEDM is unable to achieve optimal performance and avoid wire rupture and surface damage as the machining progresses. Although most of the WEDM machines available today have some kind of process control, selecting and maintaining optimal settings is an extremely difficult job. The lack of machinability data on conventional as well as advanced materials, precise gap monitoring devices, and an adaptive control strategy that accounts for the time-variant and stochastic nature of the process are the main obstacles toward achieving the ultimate goal of unmanned WEDM operation.[32]
Accompanying the development of the mechanical industry, the demand for alloy materials having high hardness, toughness, and impact resistance is increasing.

Nevertheless, such materials are difficult to machine using traditional machining methods. Hence, non-traditional machining methods including electrochemical machining, ultrasonic machining, electrical discharging machine (EDM), etc. are applied to machine such difficult-to-machine materials. WEDM process with a thin wire as an electrode transforms electrical energy into thermal energy for cutting materials. With this process, alloy steel, conductive ceramics, and aerospace materials can be machined irrespective of their hardness and toughness. Furthermore, WEDM is capable of producing a fine, precise, corrosion and wear-resistant surface.[33]

A. *Experimental Process*

Theoretical analysis and experiment will be done on the basis of the literature review. The present work will be conducted on a WEDM by using OHNS as a workpiece material and Molybdenum wire as a tool material to investigate the effect of input parameters Pulse On time Pulse off Time, Current, Wire Feed Rate on the output parameters Over Cut (Kerf width),

Material Removal Rate, Surface Roughness. In the present work, the experiments will be conducted on a CNC-WEDM. The parameter setting and machining time were displayed on a screen. The operating and controlling of the WEDM can also be done through the display screen and a keyboard.

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B. *Material Composition and properties Work-piece material*

OHNS will be used as work material. The OHNS is an important material for industrial applications. OHNS O1 is an Oil Hardened Non-Shrinkage Tool Steel, characterized by its characteristics of offering good wearing quality

C	Mn	Cr	W	V	Fe
0.95	1.15	0.5	0.5	0.2	remaining

Table 1: Composition% % of OHNS Steel

C. *Input-output terms definition and formula*

Input Process Parameter

1) Pulse On time [T_{on}]

The pulse on time is referred to as Ton and it represents the duration of time in microseconds, µs, for which the current is flowing in each cycle. During this time the voltage, VP, is applied across the electrodes. The Ton setting time range available on the machine tool is 1-99µs which is applied in steps of 1 unit. The single pulse discharge energy increases with increasing Ton period, resulting in a higher cutting rate. With higher values of Ton, however, surface roughness tends to be higher. The higher value of discharge energy may also cause wire breakage.

2) Pulse off Time [Toff]

The pulse off time is referred to as Toff and it represents the duration of time in microseconds, µs, between the two simultaneous sparks. The voltage is absent during this part of the cycle. The Toff setting time range available on the machine tool is 1 - 15µs. Which is applied in steps of 1 unit. With a lower value of Toff, there are more discharges in a given time, resulting in an increase in the sparking efficiency. As a result, the cutting rate also increases. Using very low values of Toff period, however, may cause wire breakage which in turn reduces the cutting efficiency. As and when the discharge conditions become unstable, one can increase the Toff period. This will allow a lower pulse duty factor and will reduce the average gap current.

3) Current [I]

The peak current is represented by IP and it is the maximum value of the current passing through the electrodes for the given pulse. The IP setting current range available on the present WEDM machine is 1–5 amperes. An increase in the IP value will increase the pulse discharge energy which in turn can improve the cutting rate further. For higher values of IP, gap conditions may become unstable with improper combinations of Ton, Toff, SV & SF settings. As and when the discharge conditions become unstable one must reduce the IP value.

4) Wire Feed [WF]

Wire feed is the rate at which the wire electrode travels along the wire guide path and is fed continuously for sparking. The wire feed range available on the present WEDM machine is 1–99 in steps of 1 It is always desirable to set the wire feed to maximum. This will result in less wire breakage, better machining stability, and slightly more cutting speed.

D. Output Process Parameter

1) Kerf width:[KF]

The kerf width of the workpieces was measured by a “Trimos” Measuring instrument.

2) Material removal rate and cutting speed: [MRR]

Lots of research has tried to maximize the material removal rate and cutting speed by different approaches. Because these factors can help to increase, economic benefits in WEDM considerably. Both of these factors (material removal rate and cutting speed) determine the same phenomenon which is the machining rate.

MRR value is normally obtained by the following equation:

MRR= $(W_i - W_f)/(T \times p)$ (mm^3/sec) Where,

W_i – Initial weight of work piece (gm) W_f – Final weight of work piece (gm) T – Period of trial (sec)

ρ – Density of workpiece material (gm/cm^3)

3) Surface roughness: [Ra]

It is a component of surface texture. It is qualified by vertical deviations of the real surface from its ideal form. The unit is micrometer

II. DESIGN OF EXPERIMENT

The Taguchi design of the experiment makes use of orthogonal arrays (OA) to help design the experiment. For the experimentation, the L27 orthogonal array is selected. The levels for the process parameters like discharge current, wire feed, and pulse on time

Time and pulse off time were selected based on the literature review. Four levels of each process parameter were selected as the non-linear behaviour of a process parameter can be studied if more than two levels are used. Ranges of the process parameters were decided as per the literature review, the setup range available on the machine, and its capability. A practical manual was considered before deciding the ranges of parameters as well as the machine manual for selection of the parameters for WEDM of OHNS O1. An experienced machine user from the company was also considered before selecting the range and levels of parameters. All the parameters were varied for the four levels each. The levels and ranges of the parameters along with the units are shown in Tables 2.2 and 2.3

S.N	Input	Symbol	Range
1	Pulse On Time	PON	1-99 µs
2	Pulse Off time	POFF	1-15 µs
3	Current	I	1-5 A
4	Feed Rate	WF	1-99

Table 2: Range Table

S.N	Input	Level 1 Min (-1)	Level 2 Medium(0)	Level 3 Max(1)
1	(P_{ON})	25	35	45
2	(P_{OFF})	4	6	8
3	(I)	2	3	4
4	(WF)	40	70	99

Table 3: Level Table

Machining of OHNS using a Molybdenum electrode was carried out with different settings and combinations of process parameters as per the L27 orthogonal array. Material removal rates were calculated by measuring their weight before and after machining and the time required for each experiment. Surface roughness was measured at three different places and the average value is taken for further statistical analysis. Kerf measured by using the trimos measuring instrument gives the experimental results for different settings and combinations of process parameters using the L27 orthogonal array. After completion of experimentation, MRR, surface roughness, and kerf of 27 specimens were measured. Their results are given in Table 5.3

III. RESPONSE SURFACE METHODOLOGY

Response surface methodology is a collection of mathematical and statistical techniques that are useful for modeling and analysis of problems in which several variables influence the response of interest. The objective is to find optimized cutting parameter values for the minimization or maximization of response. The response surface design is better, as it generates a second-order linear model of regression, which is a better predictive model than a first-order linear model.

Exp No	Input Parameters				Output Parameters		
	P_{ON}	P_{OFF}	I	WF	KERF(mm)	MRR(mm^3/sec)	Ra(µm)
1	35	6	3	70	0.415	2.352	6.366
2	35	4	3	99	0.401	2.928	5.152
3	35	6	2	40	0.401	1.669	5.056
4	35	6	3	70	0.388	2.511	5.363
5	35	4	3	40	0.386	1.777	5.273
6	35	8	3	40	0.381	2.153	5.530
7	45	6	3	40	0.349	2.177	6.246
8	25	8	3	70	0.4	2.159	4.953
9	25	6	3	99	0.397	2.316	4.675
10	35	8	3	99	0.391	2.599	4.672
11	45	6	3	99	0.393	2.554	4.425
12	35	6	2	99	0.406	2.118	4.519
13	35	6	4	99	0.375	2.653	4.546
14	25	6	2	70	0.397	1.687	4.209
15	35	6	3	70	0.354	2.409	5.683
16	25	6	3	40	0.382	2.114	4.752
17	45	4	3	70	0.351	2.359	5.664
18	35	6	4	40	0.33	2.688	4.896
19	35	4	4	70	0.363	3.078	4.903
20	45	8	3	70	0.364	2.962	5.355
21	35	4	2	70	0.386	1.760	4.538
22	25	4	3	70	0.379	2.547	4.191
23	25	6	4	70	0.355	3.184	4.584
24	45	6	2	70	0.395	1.760	4.688
25	35	8	4	70	0.402	1.849	4.464
26	35	8	2	70	0.363	3.214	5.151
27	45	6	4	70	0.31	3.385	4.844

Table 4: Experimental results

IV. EFFECTS OF CUTTING PARAMETERS

A. *Analysis of Variance*

For analysis of the data, the checking of the goodness of fit of the model is very much required. The model adequacy checking includes tests for the significance of the regression model, tests for the significance of model coefficients, and tests for lack of fit. For this purpose, analysis of variance (ANOVA) is performed. Analysis of variance (ANOVA) tests the hypothesis that the means of two or more populations are equal. ANOVA assesses the importance of one or more factors by comparing the response variable means at the different factor levels. The null hypothesis states that all population means (factor level means) are equal while the alternative hypothesis states that at least one is different. To perform an ANOVA, you must have a continuous response variable and at least one categorical factor with two or more levels. ANOVA requires data from approximately normally distributed populations with equal variances between factor levels. However, ANOVA procedures work quite well even if the normality assumption has been violated, unless one or more of the distributions are highly skewed or if the variances are quite different. Transformations of the original dataset may correct these violations. For example, you design an experiment to assess the durability of four experimental carpet products. You put a sample of each carpet type in ten homes and you measure durability after 60 days. Because you are examining one factor (carpet type) you use a one-way ANOVA. If the p-value is less than alpha, then you conclude that at least one durability mean is different. The p-value less than alpha indicates that the process is significant.

The name "analysis of variance" is based on the approach in which the procedure uses variances to determine whether the means are different. The procedure works by comparing the variance between group means versus the variance within groups as a way of determining whether the groups are all part of one larger population or separate populations with different characteristics.

1) *ANOVA for Kerf*

Source	**DF**	**Seq SS**	**Adj SS**	**Adj MS**	**F**	**P**
Regression	14	0.013170	0.013170	0.000941	3.74	0.014
Linear	4	0.010481	0.010481	0.002620	10.43	0.001
P_{ON}	1	0.001825	0.001825	0.001825	7.26	0.019
P_{OFF}	1	0.000102	0.000102	0.000102	0.41	0.536
CR	1	0.007057	0.007057	0.007057	28.08	0.000
FR	1	0.001496	0.001496	0.001496	5.95	0.031
Square	4	0.001530	0.001530	0.000383	1.52	0.257
$P_{ON}*P_{ON}$	1	0.000685	0.000670	0.000670	2.67	0.128
$P_{OFF}*P_{OFF}$	1	0.000030	0.000002	0.000002	0.01	0.924
CR*CR	1	0.000739	0.000516	0.000516	2.05	0.178
FR*FR	1	0.000077	0.000077	0.000077	0.31	0.591
Interaction	6	0.001159	0.001159	0.000193	0.77	0.609
$P_{ON}*P_{OFF}$	1	0.000016	0.000016	0.000016	0.06	0.805
$P_{ON}*CR$	1	0.000462	0.000462	0.000462	1.84	0.200
$P_{ON}*FR$	1	0.000210	0.000210	0.000210	0.84	0.378
$P_{OFF}*CR$	1	0.000064	0.000064	0.000064	0.25	0.623
$P_{OFF}*FR$	1	0.000006	0.000006	0.000006	0.02	0.877
CR*FR	1	0.000400	0.000400	0.000400	1.59	0.231
Residual Error	12	0.003016	0.003016	0.000251		
Lack-of-Fit	10	0.001147	0.001147	0.000115	0.12	0.992

Table 5: ANOVA for Kerf

It can be observed from Table 5 that the pulse on (P_{ON}), pulse off (P_{OFF}), current (CR), and wire feed (FR) affect the kerf.

S	R-sq	R-sq(adj)	R-sq(pred)
0.0158533	81.37%	89.63%	83.20%

Table 6: Model Summary

The fit summary recommended that the quadratic model is statistically significant for analysis of kerf. The ANOVA table for the quadratic model for kerf is shown in Table 6. The lack-of-fit term is not significant as desired. The results of the quadratic model for kerf are given in Table 6

2) ANOVA for Material Removal Rate

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Regression	14	5.85996	5.85996	0.41857	8.66	0.000
Linear	4	5.20969	5.20969	1.30242	26.95	0.000
P_{ON}	1	0.11801	0.11801	0.11801	2.44	0.144
P_{OFF}	1	0.01976	0.01976	0.01976	0.41	0.535
CR	1	4.51291	4.51291	4.51291	93.37	0.000
FR	1	0.55901	0.55901	0.55901	11.57	0.005
Square	4	0.20963	0.20963	0.05241	1.08	0.407
P_{ON}*P_{ON}	1	0.01653	0.00644	0.00644	0.13	0.721
P_{OFF}*P_{OFF}	1	0.05245	0.01756	0.01756	0.36	0.558
CR*CR	1	0.02461	0.00118	0.00118	0.02	0.878
FR*FR	1	0.11603	0.11603	0.11603	2.40	0.147
Interaction	6	0.44065	0.44065	0.07344	1.52	0.253
P_{ON}*P_{OFF}	1	0.24552	0.24552	0.24552	5.08	0.044
P_{ON}*CR	1	0.00410	0.00410	0.00410	0.08	0.776
P_{ON}*FR	1	0.00766	0.00766	0.00766	0.16	0.698
P_{OFF}*CR	1	0.00055	0.00055	0.00055	0.01	0.917
P_{OFF}*FR	1	0.12426	0.12426	0.12426	2.57	0.135
CR*FR	1	0.05856	0.05856	0.05856	1.21	0.293
Residual Error	12	0.57998	0.57998	0.04833		
Pure Error	2	0.01298	0.01298	0.00649		
Total	26	6.43994				

Table 7: ANOVA for MRR

It can be observed from Table 7 that the pulse on (P_{ON}), pulse off (P_{OFF}), current (CR), and wire feed (FR) affect the material removal rate.

S	R-sq	R-sq(adj)	R-sq(pred)
0.219844	90.99%	80.49%	78.83%

Table 8: Model Summary

The fit summary recommended that the quadratic model is statistically significant for the analysis of MRR. The ANOVA table for the quadratic model for MRR is shown in Table 8. The lack-of-fit term is not significant as desired. The results of the quadratic model for MRR are given in Table 8.The value of R^2 is over 90% which means that the regression model provides an excellent explanation of the relationship between the independent variables (factors) and the response (MRR).

3) ANOVA for Surface Roughness

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Regression	14	7.04445	7.04445	0.50318	5.58	0.002
Linear	4	2.60980	2.60980	0.65245	7.24	0.003
PON	1	1.24035	1.24035	1.24035	13.77	0.003
POFF	1	0.01360	0.01360	0.01360	0.15	0.704
CR	1	0.17521	0.17521	0.17521	1.94	0.188
FR	1	1.18064	1.18064	1.18064	13.10	0.004
Square	4	3.20506	3.20506	0.80127	8.89	0.001
PON*PON	1	0.24567	1.15651	1.15651	12.84	0.004
POFF*POFF	1	0.01188	0.50649	0.50649	5.62	0.035
CR*CR	1	2.39739	2.91396	2.91396	32.34	0.000
FR*FR	1	0.55012	0.55012	0.55012	6.11	0.029
Interaction	6	1.22959	1.22959	0.20493	2.27	0.106
PON*POFF	1	0.28676	0.28676	0.28676	3.18	0.100
P_{ON}*CR	1	0.01199	0.01199	0.01199	0.13	0.722
P_{ON}*FR	1	0.76038	0.76038	0.76038	8.44	0.013
P_{OFF}*CR	1	0.02592	0.02592	0.02592	0.29	0.602
P_{OFF}*FR	1	0.13579	0.13579	0.13579	1.51	0.243
CR*FR	1	0.00874	0.00874	0.00874	0.10	0.761
Residual Error	12	1.08118	1.08118	0.09010		
Lack-of-Fit	10	0.55621	0.55621	0.05562	0.21	0.964
Pure Error	2	0.52497	0.52497	0.26248		
Total	26	8.12563				

Table 9: ANOVA for Surface Roughness

It can be observed from Table 9 that the pulse on (P_{ON}), pulse off (P_{OFF}), current (CR), and wire feed (FR) affect the Surface roughness.

S	R-sq	R-sq(adj)	R-sq(pred)
0.300164	86.69%	81.17%	76.04%

Table 10: Model Summary

The fit summary recommended that the quadratic model is statistically significant for the analysis of Ra. The ANOVA table for the quadratic model for Ra is shown in Table 10. The lack-of-fit term is not significant as desired. The results of the quadratic model for Ra are given in Table 10

B. Mathematical Modeling

Mathematical modeling is a better statistical tool used to evaluate the values of response outcomes for various combinations of input parameters. This method of data evaluation helps in theoretical decision-making for finding optimal cutting conditions. The mathematical model can be derived by using Regression Analysis. In this work, a second-order linear model has been deduced for the readings obtained from the Response Surface method.

A typical model of a second-order mathematical model is shown in equation 1.

$y = n\beta 0 + \beta 1x1 + \beta 2x2 + \beta 3x1^2 + \beta 4x2^2 + \beta 5x1x2 + \ldots + \beta nxn$ ... **Eqn.1**

where

y – Response

n – Regression constant

B – Correlation coefficient

x1 , x2 , …, xn – are cutting parameters

The mathematical models of Kerf, Material Removal Rate, and Surface roughness deduced for this work are shown in Equations (2,3, and 4).

Regression Equation in Uncoded Units

$KERF=0.385667-0.0123333P_{ON}+0.00291667P_{OFF}-0.0242500CR+0.0112083 P_{ON}*P_{ON}+0.000666667P_{OFF}*P_{OFF}0.00983333CR*CR+0.00379167FR*FR0.00200000P_{ON}*P_{OFF}-0.0107500P_{ON}*CR+0.00725000P_{ON}*FR-0.00400000P_{ON}*FR-0.00400000P_{OFF}*CR-0.00125000P_{OFF}*FR+ 0.0100000 CR*FR$ Eqn.2

Regression Equation in Uncoded Units

$MRR=2.42400+0.0991667P_{ON}+0.0405833P_{OFF}+0.613250CR+0.215833FR+0.0347500P_{ON}* P_{ON}+0.0573750P_{OFF}*P_{OFF}+0.0148750CR*CR-0.147500FR*FR+0.247750P_{ON}*P_{OFF} +0.0320000P_{ON}*CR+0.0437500P_{ON}*FR+0.0117500P_{OFF}*CR-0.176250P_{OFF}*FR- 0.121000CR*FR$ Eqn.3

Regression Equation in Uncoded Units $RA=5.80400+0.321500P_{ON}+0.0336667P_{OFF}+0.120833CR-0.313667FR-0.465667P_{ON}*P_{ON}-0.308167P_{OFF}*P_{OFF}-0.739167CR*CR-0.321167FR*FR-0.267750P_{ON}*P_{OFF}-0.0547500P_{ON}*CR0.436000P_{ON}*FR+0.0805000P_{OFF}*CR0.184250P_{OFF}*FR+0.0467500CR*FR$ Eqn.4

Surface Plot and Inference for Surface Roughness

"Figures 1, 2, 3, 4, 5, and 6 show that surface roughness increases considerably with an increase in current rate, feed rate, and pulse-on time. An increase in pulse-on time also contributes to the rise in surface roughness.".

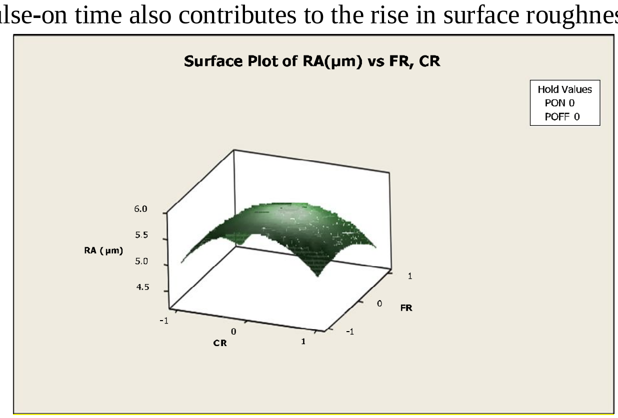

Fig 1- Surface plots for Ra vs. current, feed rate

As the current increases, the surface roughness (Ra) gradually improves for all current values. The data in the figure shows that the Ra value increases with an increase in the current rate, reaching its maximum value at a certain point. Additionally, the surface roughness tends to rise further as the feed rate increases.

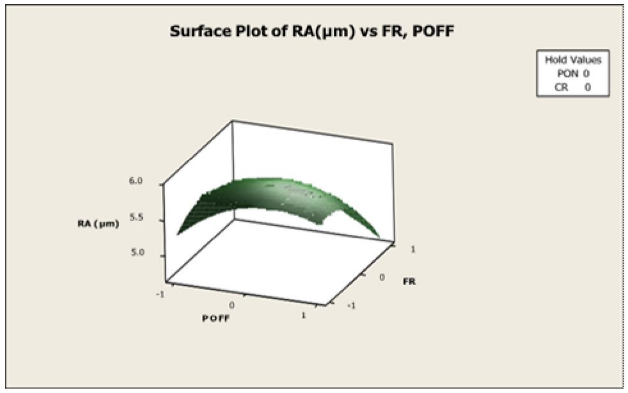

Figure 2- Surface plots for Ra vs. Poff, feed rate

"As the feed rate increases, the surface roughness (Ra) gradually improves for all feed rate values. The figure shows that the Ra value increases with an increase in the off-time (Poff) and rises up to its maximum level."

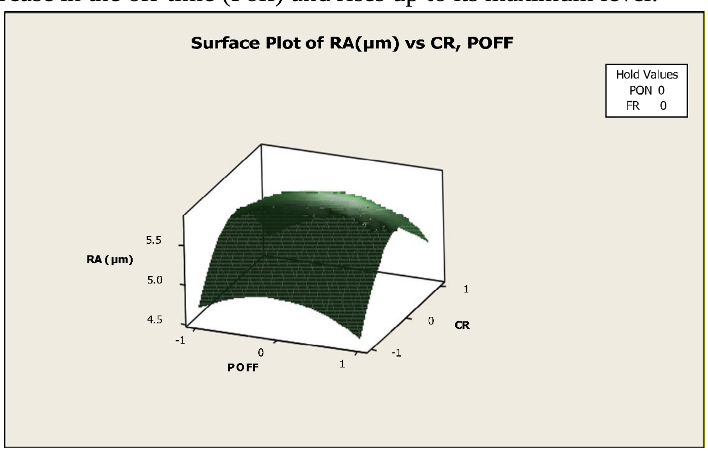

Fig 3- Surface plots for Ra vs. CR, Poff

"Figure 3 shows the estimated response surface for surface roughness (Ra) in relation to the design parameters of peak current and Poff. As seen in the figure, the Ra value tends to decrease significantly with decreasing peak current and Poff."

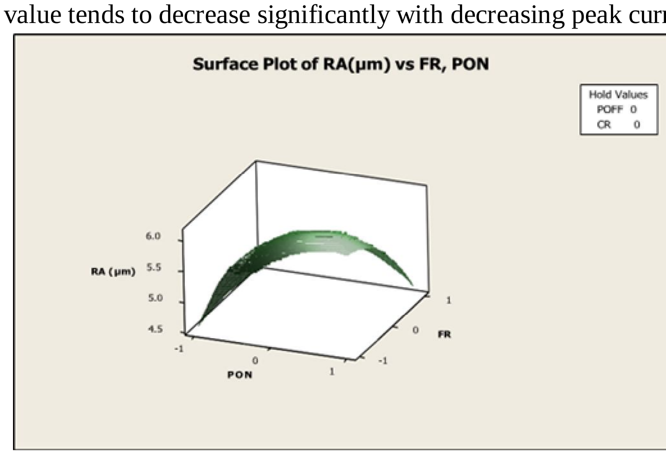

Fig 4-Surface plots for Ra vs. FR, PON

"Figure 4 shows the estimated response surface for surface roughness (Ra) in relation to the design parameters of feed rate and PON. As seen in the figure, the Ra value tends to decrease significantly with decreasing feed rate and PON value."

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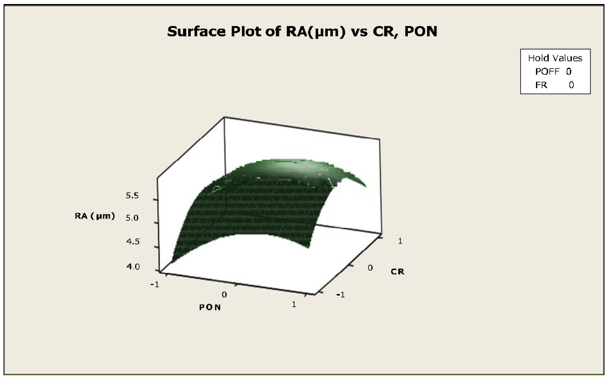

Fig 4-Surface plots for Ra vs. CR, PON

"Figure 5 shows that with an increase in current, the surface roughness (Ra) improves gradually for all current values. The figure also displays that the Ra value increases with the rise in current rate, reaching its maximum level, and tends to increase with the PON value."

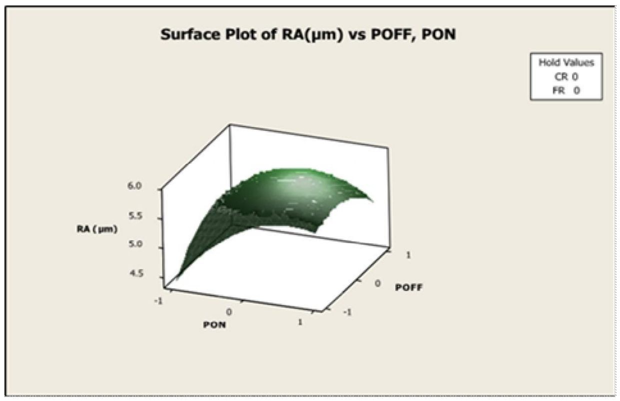

Fig 6-Surface plots for Ra vs. POFF, PON

"Figure 6 shows that the value of Ra increases with an increase in pulse-on time, rising up to its maximum level, and tends to increase further for higher values of Poff."

C. Surface Plot and Inference for Kerf

"Figures 7, 8, 9, 10, 11, and 12 show that kerf decreases considerably with an increase in current rate and pulse-on time, while it also decreases with pulse-off time and feed rate.

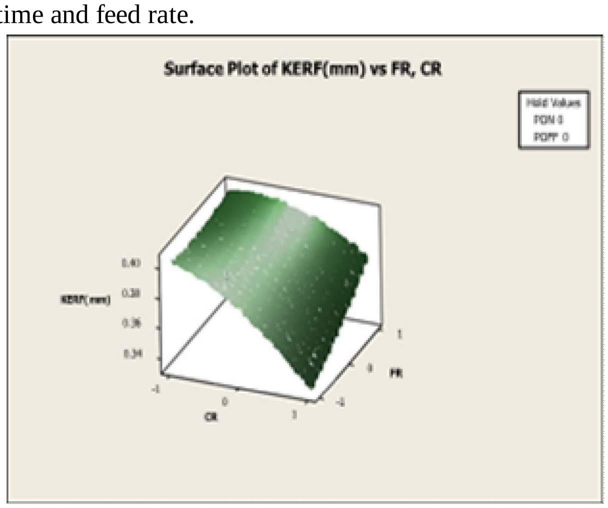

Fig 7-Surface plots for KERF vs. FR, CR

"Figure 7 shows that the value of kerf increases with an increase in feed rate, rising up to its maximum level, and then tends to decrease at higher values of current."

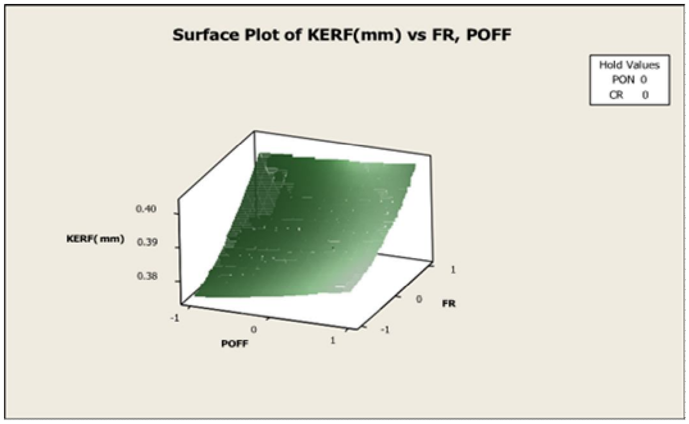

Fig 8-Surface plots for KERF vs. FR, POFF

"Figure 8 shows that the value of kerf increases with an increase in pulse-off time, rising up to its maximum level, and tends to increase further at higher feed rates."

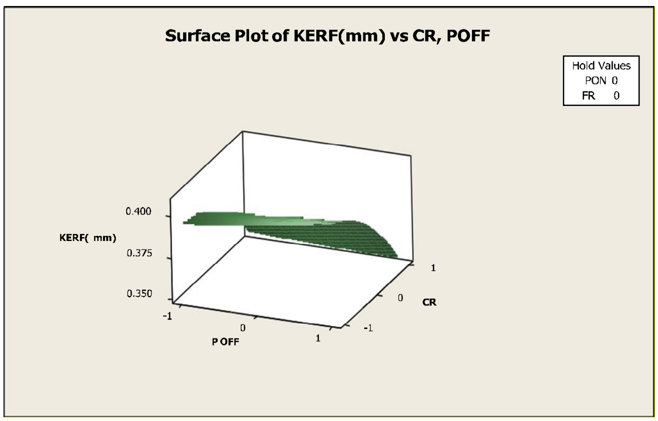

Fig 9 -Surface plots for KERF vs. POFF, CR

"Figure 9 shows the estimated response surface for kerf in relation to the design parameters of peak current and POFF. As seen in the figure, the kerf tends to decrease considerably with increasing current, but reduces with increasing POFF."

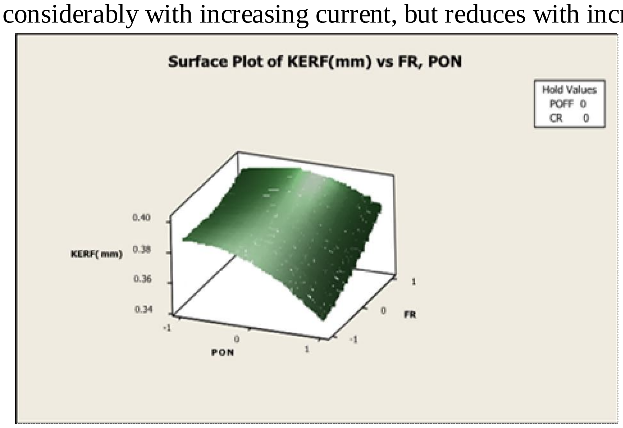

Fig 10 -Surface plots for KERF vs. FR, PON

"Figure 10 shows the estimated response surface for kerf in relation to the design parameters of feed rate and Pon. As seen in the figure, the kerf tends to decrease considerably with increasing Pon, while it reduces with decreasing feed rate."

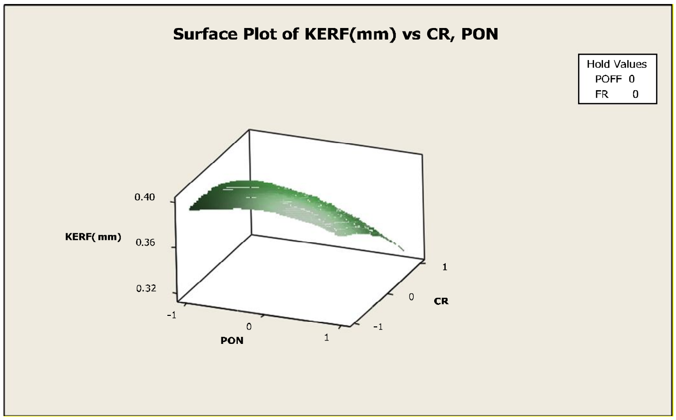

Fig 11 -Surface plots for KERF vs. PON, CR

"Figure 11 shows the estimated response surface for kerf in relation to the design parameters of current and Pon. As seen in the figure, the kerf tends to decrease considerably with increasing Pon, while it decreases with higher current."

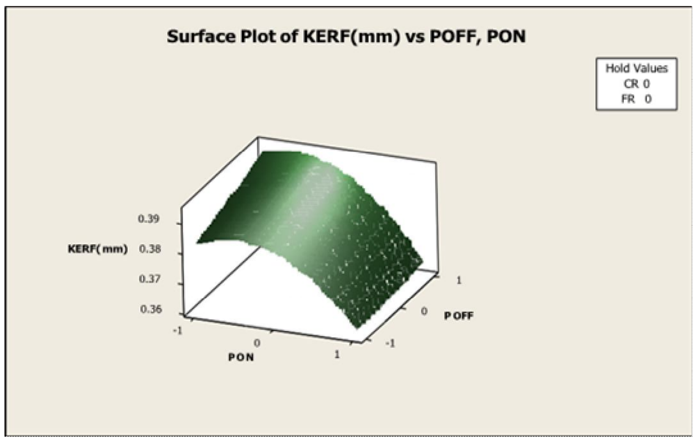

Fig 12-Surface plots for KERF vs. POFF, PON

"Figure 12 shows the estimated response surface for kerf in relation to the design parameters of Poff and Pon. As seen in the figure, the kerf tends to decrease considerably with increasing Pon, while it decreases with higher Poff."

D. Surface Plot and Inference for Material Removal Rate

"Figures 13, 14, 15, 16, 17, and 18 show that MRR increases considerably with an increase in the current rate, pulse-on time, pulse-off time, and feed rate."

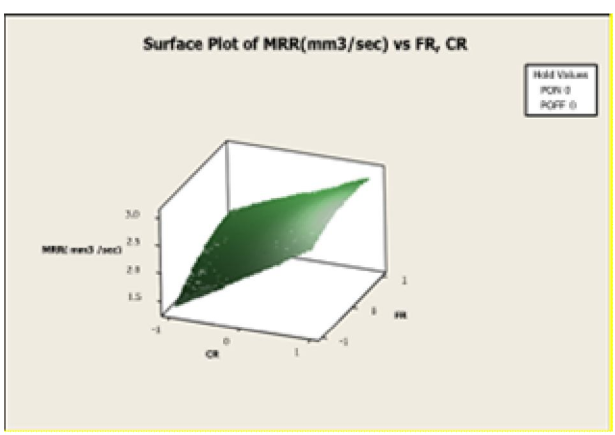

Fig 13-Surface plots for MRR vs. FR, CR

"Figure 13 shows the estimated response surface for Material Removal Rate (MRR) in relation to the design parameters of current rate (CR) and feed rate (FR). As seen in the figure, the MRR tends to decrease considerably with decreasing CR and reduces with lower FR."

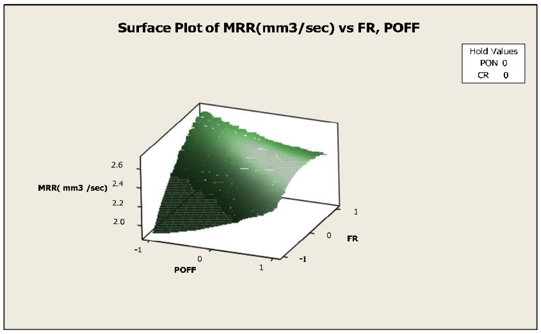

Fig 14-Surface plots for MRR FR vs POFF

"Figure 14 shows the estimated response surface for Material Removal Rate (MRR) in relation to the design parameters of Poff and feed rate (FR). As seen in the figure, the MRR tends to decrease considerably with decreasing Poff, while it decreases with higher FR."

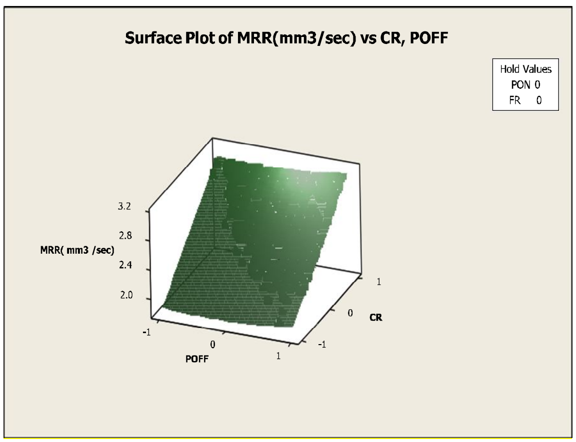

Fig 15-Surface plots for MRR vs. POFF, CR

"Figure 15 shows that the value of MRR increases with an increase in current rate, rising to its maximum level, and tends to increase with higher Poff."

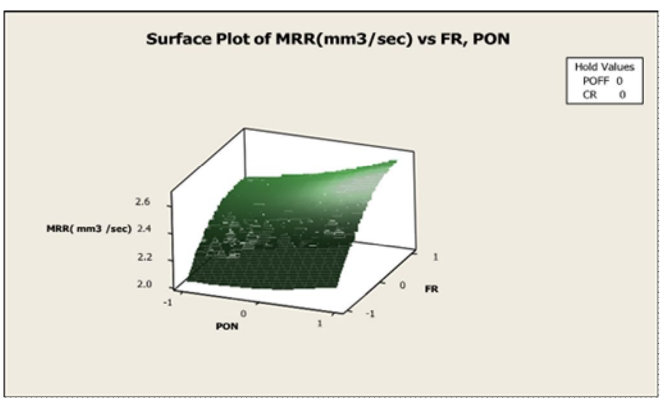

Fig 16-Surface plots for MRR vs. FR, PON

"Figure 16 shows that the value of MRR increases with an increase in Pon, rising to its maximum level, and tends to increase with higher feed rate (FR)."

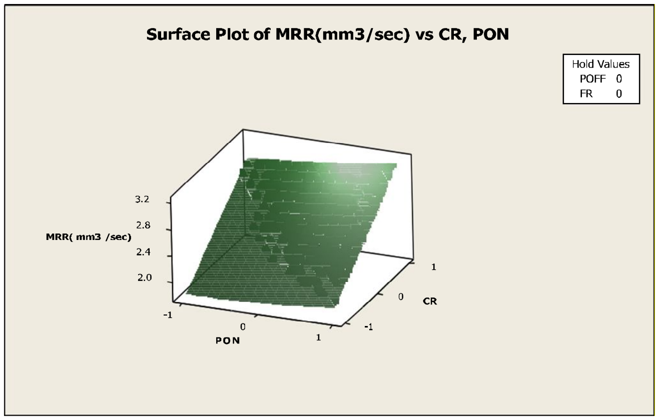

Fig 17-Surface plots for MRR vs. PON, CR

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"Figure 17 shows the estimated response surface for Material Removal Rate (MRR) in relation to the design parameters of current rate (CR) and Pon. As seen in the figure, the MRR tends to increase considerably with increasing Pon, while it also increases with higher CR."

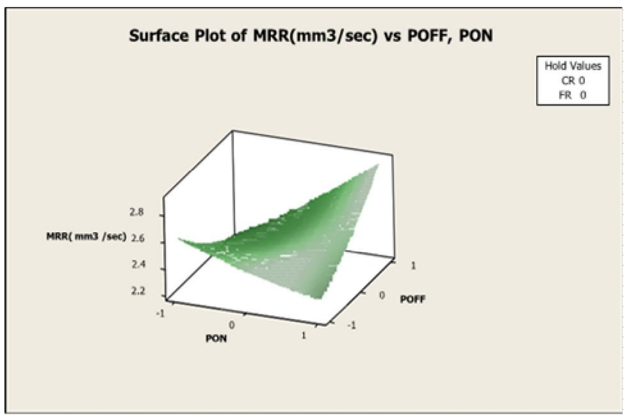

Fig 18-Surface plots for MRR vs. POFF, PON

"Figure 18 shows the estimated response surface for Material Removal Rate (MRR) in relation to the design parameters of Poff and Pon. As seen in the figure, the MRR tends to increase considerably with increasing Poff, while it decreases with higher Pon."

E. Optimization Using Response Surface Methodology

The figure shows the optimum parameters set of, pulse on time, pulse off time, current, and wire feed which give minimum response values of kerf, surface roughness, and maximum response value of M.R.R.

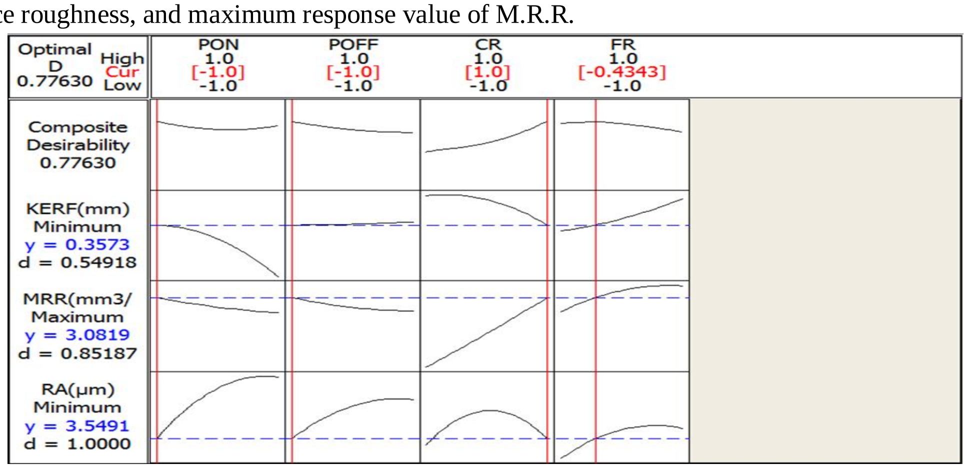

Figure 19 Multi-Optimization plot using RSM

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F. Optimization Result Table

Solution	PON	POFF	CR	FR	KERF(mm)	MRR(mm^3)	RA(µm)
1	-1	-1	1	- 0.4343	0.3573	3.0819	3.5491

Table 11: Results of response

G. Validation

Using this predicted setting of process parameters given in the table, experimentation is carried out and values of experimental responses MRR, kerf, and SR are calculated which are shown in Table 12

The percentage of improvement shows the amount of variation with actual experimental results. Prediction % error (Experimental result – RSM results) / (Experimental results) * 100

Response	Predicted	Experimental	Error %
MRR (mm3/min)	3.0819	3.158	2.41
kerf (mm)	0.3573	0.3628	1.52
Ra (µm)	3.5491	3.588	1.11

Table 12: Experimental validation of optimal setting

So, the average percentage error for Material removal rate is 2.41%, for kerf 1.52%, and for surface roughness is 1

V. RESULT AND DISCUSSION

The findings indicate clear trends in how the process parameters affect surface roughness, kerf, and material removal rate. Increasing the current rate, pulse-on time, and feed rate generally results in increased surface roughness but also contributes to higher MRR. Kerf width decreases with increases in these parameters, suggesting that more efficient and precise material removal is possible with optimized settings. These results highlight the importance of balancing the process parameters to meet specific machining goals, whether they focus on surface finish, cutting precision, or material removal efficiency.

In summary, the surface roughness and kerf are interrelated with the machining parameters, and MRR can be optimized by increasing the right parameters. Further studies could explore the impact of these parameters on other factors like tool wear, energy consumption, and overall process stability to optimize the machining process fully.

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VI. CONCLUSIONS

In this investigational experiment on WEDM, the effect of machining outputs taken into consideration is material removal rate, Kerf, and surface roughness of the OHNS workpiece using the Molybdenum electrode. These outputs are important in industrial applications. The conduction of the experiment depends upon various parameter settings such as discharge current (Ip), pulse on time (Pon) pulse off time (Poff), and wire feed (WF) have been selected. Based on the Box-Behnken design by Response Surface Methodology was conducted and the MINITAB 16 software package was used for analysis of the experiment. The second-order response models have been validated with analysis of variance. Finally, an attempt has been made to estimate the optimum machining conditions to produce the best possible response within the experimental constraints. Parameter values for multiple responses using RSM give settings that $\mathbf{P_{ON}}$ (µs)25, $\mathbf{P_{OFF}}$ (µs) 4, **CR** (I) 4, and **FR** 70**.**

The effect of WEDM working parameters on the output parameters is as follows:

1) Predicted optimum setting obtained for maximizing MRR and minimizing KF and Ra is Pulse on Time as 25 µs, Pulse off Time as 4 µs, Discharge Current as 4 A, Feed rate as 70 and predicted values of responses MRR, KF, and Ra are 3.0819, 0.3573, 3.5491, and experimental values are 3.158, 0.3628, 3.588 respectively. Errors obtained between experimental and predicted responses are very less and within an acceptable range. Hence it is concluded that models obtained for each response are more accurate hence it can be used for developing a robust, reliable knowledge base and early prediction of MRR, KF, and Ra without experimenting with the WEDM process for OHNS.
2) The percentage error for the Material removal rate is 2.41%, for the kerf 1.52% and for surface roughness is 1.11

REFERENCES

[1] Nihat Tosun a,∗, Can Cogunb, Gul Tosun a(2004), "A study on kerf and material removal rate in wire electrical discharge machining based on Taguchi method" Journal of Materials Processing Technology 152 (2004) pp.316–322

[2] J.R. Meva," A Comparative Experimental Investigation on Process Parameters Using Molybdenum, Brass and Zinc-Coated Wires in Wire Cut EDM" International Journal of Scientific & Engineering Research, Volume 4, Issue 7, July 2013 pp.1398-1407

[3] Farnaz Nourbakhsha, K. P. Rajurkarb,*, A. P. Malshec, Jian Cao, "Wire electro-discharge machining of titanium alloy," Procedia CIRP 5 (2013) pp. 13 – 18

[4] Pragya Shandilyaa*, P.K.Jainb, N.K. Jainc, "Parametric optimization during wire Electrical discharge machining using response surface methodology" Procedia Engineering 38 (2012) pp.2371 – 2377

[5] R.Ramakrishnan, L.Karunamoorthy, "Multi-response optimization of wire EDM operations using robust design of experiments" International Journal of Manufacturing Technology, Vol 29, 2006, pp.105-112

[6] Yu Huang, Wuyi Ming, Jianwen Guo, Zhen Zhang, Guangdou Liu, Mingzhen Li, Guojun Zhang, "Optimization of cutting conditions of YG15 on rough and finish cutting in WEDM based on statistical analyses" International Journal of Advanced Manufacturing Technology, Vol 69, 2013, pp.993-1008

[7] Thella Babu Rao, A.Gopala Krishna, "Simultaneous optimization of multiple performance characteristics in WEDM for machining ZC63/SiCp MMC" Advances in Manufacturing, Vol. 1, 2013, pp.265-275

[8] Tzeng C.J. and Chen R.Y., "Optimization of electric discharge machining process using the response surface methodology and genetic algorithm approach" International Journal of Precision Engineering and Manufacturing, 14 (2013): pp.709-717.

[9] Tzeng C.J., Yang Y.K., Hsieh M.H. and Jeng M.C., "Optimization of wire electrical discharge machining of pure tungsten using neural network and response surface methodology" Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture, 225(2011): pp. 841-852

[10] M. Durairaja, D. Sudharsunb,*, N. Swamynathanb "Analysis of Process Parameters in Wire EDM with Stainless Steel using Single Objective Taguchi Method and Multi-Objective Grey Relational "Grade Procedia Engineering 64 (2013) 868 – 877

[11] S.Boopathi1, K.Sivakumar2, R.Kalidas3 "Parametric Study of Dry WEDM Using Taguchi Method" Volume 2, Issue 4 (July 2012), PP. 63-68

[12] K. Kumara, R. Ravikumarb, "Modeling and Optimization of Wire EDM Process" Vol 3, Issue. 3, May.-June. 2013 pp-1645-1648

[13] U.K.Vates1 and N.K. Singh2, "Optimization of Surface Roughness Process Parameters of Electrical Discharge Machining of EN-31 by Response Surface Methodology" Volume 6, Number 6 (2013), pp. 835-840

[14] Goutam Kumar Bose1, Pritam Pain2, "Parametric Optimization of WEDM Process on OHNS Tool Steel Using Statistical Techniques"Volume 5, Issue 12, December 2015

[15] Chaturvedi, V. and Sharma, A. K. 2013, " Parametric Optimization of CNC Wire Cut EDM for OHNS Steel Using Moora Methodology"‖ 10th IRF International Conference, 04th October-2014, Bengaluru, India.

[16] V. Muthukuma, N. Rajesh, R. Venkatasamy, A. Sureshbabu, N.Senthilkumar, "Mathematical Modeling for Radial Overcut on Electrical Discharge Machining of Incoloy 800 by Response Surface Methodology", 3rd International Conference on Materials Processing and Characterization (ICMPC 2014), V. Muthukumar et al. / Proscenia Materials Science 6 (2014) 1674 – 1682.

[17] Zahid A. Khan, Arshad N. Siddiquee, Noor Zaman Khan, Urfi Khan, G. A. Quadir, "Multi response optimization of Wire electrical discharge machining process parameters using Taguchi based Grey Relational Analysis" 3rd International Conference on Materials Processing and Characterization (ICMPC 2014), Proscenia Materials Science 6 (2014) 1683 – 1695

[18] Poornima, Sukumar, "Optimization of machining parameters in CNC turning of martensitic stainless steel using RSM and GA" International Journal of Modern Engineering Research (IJMER) ISSN: 2249-6645.

[19] R.Rajesha and M. Dev Anandb, "The Optimization of the Electro-Discharge Machining Process Using Response Surface Methodology and Genetic Algorithms" Procedia Engineering 38 (2012) 3941 – 3950.

[20] Kamaljit Singh Mahal, Navjot Singh Mahal, Kamaldeep Chugh, "Experimental Investigation of Surface Roughness by the Application of Taguchi Method in Electric Discharge Machining" International Journal of Research in Mechanical Engineering & Technology, Vol. 4, Issue 2, October 2014, pp.53-55.

[21] Milan Kumar Das, Kaushik Kumar, Tapan Kr. Barman, Prasanta Sahoo, "Application of Artificial bee Colony Algorithm for Optimization of MRR and Surface Roughness in EDM of EN31 tool steel" Procedia Materials Science 6, 2014, pp.741 – 751

[22] Yacov sahijpaul1, Gurpreet singh2, "Determining the Influence of Various Cutting Parameters on Surface Roughness during Wet CNC Turning Of AISI 1040 Medium Carbon Steel" IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) Volume 7, Issue 2 (May - Jun. 2013), PP 63-72

[23] B.Guruprasad, Dr. Ragupathy, T.S.Badrinarayanan, "Statistical optimization and sensitivity analysis on mechanical property in hydrofracturing process" European Scientific Journal February 2013 edition vol.9, No.6 ISSN: 1857 –7881

[24] Sivaraosa,*a a b c, K.R.Milkey, A.R.Samsudin, A.K.Dubey, P.Kidd"Comparison betweenTaguchi Method and Response Surface Methodology (RSM) in Modelling CO2 Laser Machining" Volume 8 Number 1, February. 2014 IS SN 1995-6665 Pages 35 – 42

[25] Bhawna Bisht *, Jyoti Vimal**, Vedansh Chaturvedi** "Parametric Optimization of Electrochemical Machining Using Signal-To-Noise (S/N) Ratio" International Journal of Modern Engineering Research (IJMER) Vol 3, Issue.4, Jul - Aug. 2013 pp-1999-2006

[26] Benedict, G.F. (1987), "Electrical discharge machining (EDM), non-traditional manufacturing process", Marcel Dekker, Inc., New York & Basel, 231-232.

[27] Lok, Y.K. and Lee, T.C. (1997), "Processing of advanced ceramics using the wire-cut EDM process", Journal of Materials Processing Technology, 63 (1-3), 839-843.

[28] [28]Kozak, J., Rajurkar, K.P., Chandarana, N. (2004), "Machining of low electrical conductive materials by wire electrical discharge machining (WEDM) process", Journal of Materials Processing Technology, 149, 266-276

[29] Mitutoyo SJ-410 Manual

[30] Douglas C. Montgomery (2013), Design and Analysis of Experiments, 8th edition, International Student Version: Wiley Student Edition

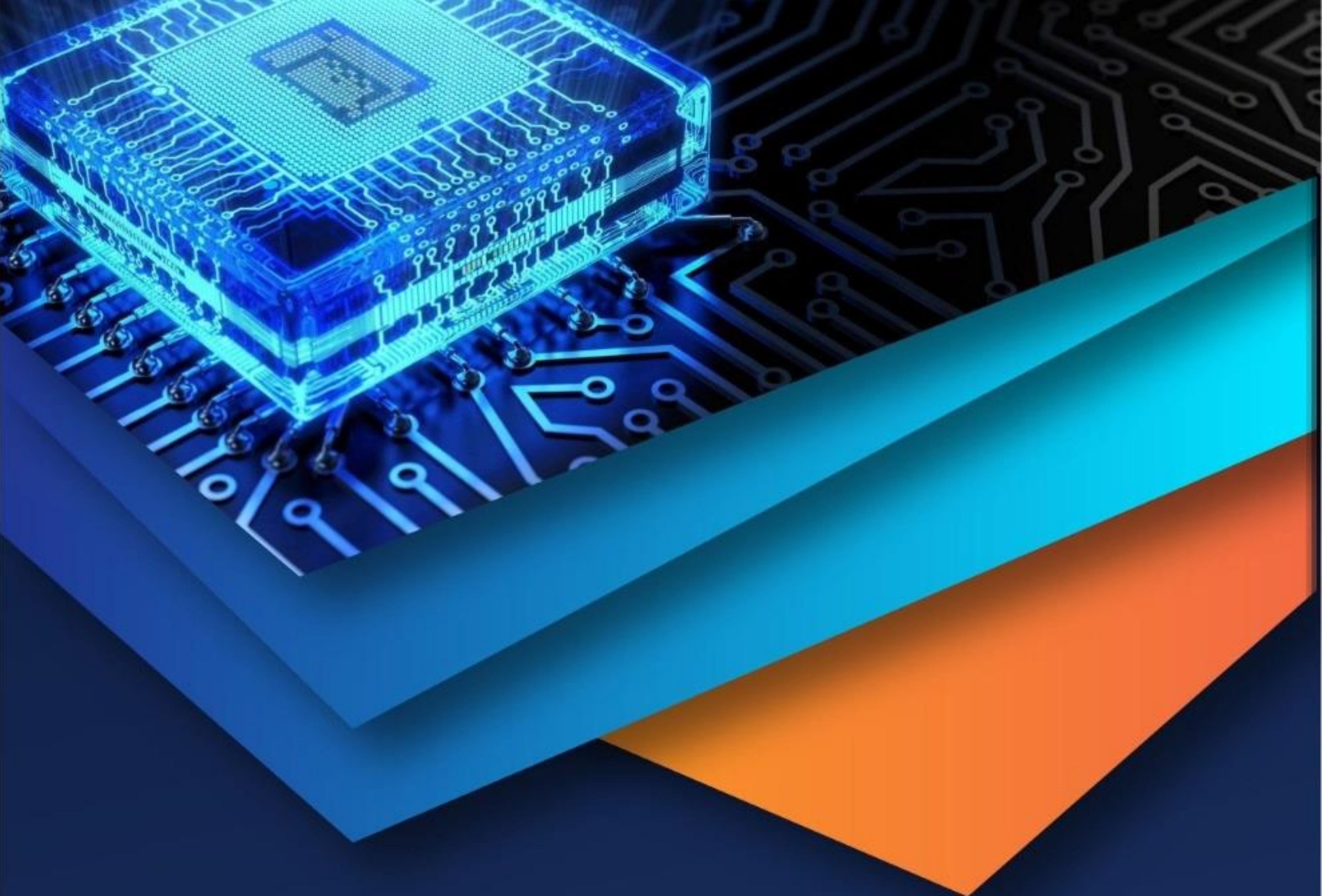
[31] Nand Lal Gupta,(May, 2011)"Optimization of micro-wire EDM operation using grey taguchi method",pp.1-33

[32] Ricky Agarwal(May 2010) "Optimization of process parameters of micro wire edm",pp.1-41

[33] Rohit Garg(May,2010)Effect of process parameters on performance measures of wire electrical discharge machining

[34] Nuran Bradley (2007)The response surface methodology, pp 1-84

[35] Study on Machining Response in Wire EDM OF Fucunel 625; International Journal of Applied Engineering Research ISSN 0973-4562 Volume 13
[36] G. Archanal, Dr.K. Dharma Reddy2, Dr. P.Venkataramaiah3 1,2,3 Department of Mechanical Engineering, Sri Venkateswara University College of Engineering, Tirupati, Andhra Pradesh 517502, India 2018
[37] Analysis of Effects of Cutting Parameters of Wire Electrical Discharge Machining on Material Removal Rate and Surface Integrity, 5th National Conference on Processing and Characterization of Materials; H. R. Tonday, A. M. Tigga Department of Manufacturing
[38] Engineering, National Institute of Technology Jamshedpur, Jamshedpur-31614, Jharkhand, India 2013
[39] Optimization of the machining parameters for EDM wire cutting of Tungsten Carbide MATEC Web of Conferences DOI: 10.1051/57, 03006 (2016) matec 57 conf/2016 0 ICAET 2016-3006 Gaurav Kumar, JS Tiwana, Ashish Singla MATEC Web of Conferences 57, 03006, 2016
[40] Experimental Optimization of Process Parameters with Wire-EDM on Inconel 625 Anoop Kumar, U Ashok Kumar, P Laxminarayana
[41] Parameter study and optimization of WEDM process: A Review IOP Conf. Series: Materials DARSET, 2019
[42] Science and Engineering 404 (2018) 012007 Md Ehaan Aagar, Ajay Kumar Singh Singholi Top Conference Series. Material science and engineering 404, 012007, 2018
[43] A comprehensive review on wire EDM performance evaluation Nadeem Alam, Arshad Noor Siddiquee, Zahid A Khan, Noor Zantan Khan Proceedings of the Institution of Mechanical Engineers, Part E. Journal of Process Mechanical Engineering 236 (4), 1734-1746, 2002
[44] Experimental Optimization of Process Parameters with Wire-EDM on Inconel 625nAnoopKumar, U Ashok Kumar, P Laxmi HARSET, 2019
[45] Wire electrical discharge machining-A review Laurenția Slătincanu, Ouna Dodin, Margareta Coteați, Gheorghe Nagil, Irina Beyliu Băncescu, Adelina Hrituc Machines 8 (4), 69, 2020
[46] Multi-objective optimization of machining parameters in wire EDM for AISI-304 Volume 18, Part 7,2019
[47] Smita P. Bhise, Minakshi Y. Shinde, "Study of Process Parameters Used in Wire Electric Discharge Machining" International Journal for Research in Applied Science & Engineering Technology, Volume 4 Issue X, October 2016, pp. 485-489
[48] Smita P. Bhise Mr. Jadhav Prajwal Sandeep Mr. Kadam Rakesh Anil Mr. Nikam Akshay Tanaji Mr. Pawar Aniket Sunil Experiment Investigation of process parameter of wire electrical discharge machining on tungsten wire tool and Inconel 625 workpiece Mukt Shabd Journal, volume viii, issue vi, June 2024



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