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Performance Analysis of Wire Cut EDM in AISI 304 and AISI 316 Stainless Steel by Using Taguchi Grey Relational Analysis

P.supraja
[1] *PG Master Student in SV University Department of Mechanical Engineering in Tirupati*

Dr .K.Dharma Reddy
[2] *Asst.prof . Sri Venkateswara University Department of Mechanical Engineering Tirupati, Andhra Pradesh, India,517502*

P.Madhava
[3] *Researcher at Sri Venkateswara University'Mechanical Engineering Department in Tirupati, India.*

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ABSTRACT: To improve the surface roughness, material removal rate, and kerf width using by variety of cutting parameters. Electrode combinations, multiple WEDM approaches are explored in this article. However, while machining, the machining parameters are also useful. In this work, an experiment is conducted to examine the impact of parameters of machining, includes the wire tension (Wt), pulse on time (Toff), pulse off time (Ton).The reactions of MRR, SR and KF. A work materials used for this experiment are AISI 304 and 316 stainless steel, which are used in the production of many items we use on a daily basis. Brass wire that is 0.25mm thick is used for this experiment. This experiment is orthogonal array as L9 was used as the model for the output parameters. This approach uses grey relation analysis to assess the outcomes, which includes L9 as one of the process parameters as discovered by using nine trails as especially, wire tension of 11kg-f,pulse off time130s and pulse on time 40s.

KEYWORDS:
Surface Roughness (SF), Taguchi methods, (KF), (MRR), Wire Edm Machining.

I.INTRODUCTION

The basic electric discharge machining procedure results in production of a spark by electric discharge between two electrodes (solid electric conductor).Usually, the tool electrode which acts as anode is referred to as the electrode and the work piece electrode which acts as cathode is referred to as the work piece. The extreme temperatures ranging from 8,000 to 12,000 °C, is produced by electrical current discharges that happens quickly and repeatedly in a tiny space between the anode and cathode that never make contact with one another. As the electric discharge happens millions of time with in a second, the machine adaptive maintains the constant as the spark gap.

The surface of the material is the only part of the spark that is focused and firmly controlled. Therefore, the Wire EDM process normally has no impact upon that heating happening under this surfaces of either the workpiece and tool, both of which immersed in a non-conductive die-electric fluid, often deionized (di) water.. The spark always happens in the fluid used in die electrics. The precisely controlled conductivity of deionized water makes an ideal setting for the Wire EDM process. Additionally it provides cooling, during the machining process and flushes out the tiny pieces of corroded metal.

Because of vibration issues, this is widely used to replace the traditional machining process in which the parameters difficult as the hard materials. Material used in this are 304 and 316 which are hard materials to process using traditional machining processes. So we use nontraditional machining processes. Here we use wire EDM process. To discover the manner in which Wire electrical discharge machining process parameters. Affect the surface roughness, material removal rate, and kerf width, by varying input parameters. Experimental research is required. The parameters are evaluated in various ways using various approaches. Here, in taguchi software using L9 orthogonal array GRA process is finished as the baseline experiment design. Wire tension, pulse on time, and pulse off time are the cutting parameters considered during this study. Experiments were conducted to determine the output parameters, such as KF, MRR & SF which are calculated by Grey Relational Analysis. The parent metal, AISI 304, was found to have low carbon steel than other metals when processing AISI 316, which was found to have high carbon steel.

II.LITERATURE REVIEW

Selvakumar et.al. Choose the most effective machining parameter combinations for wire electrical discharge machining (WEDM) of the 5083-aluminum alloy using the Taguchi experimental design approach. Wire tension, peak current, and pulse-on and pulse-off timings were all employed as input parameters in various researches. Surface roughness and cutting speed were taken into consideration as replies. It has been discovered that the cutting speed increases as the pulse-on time and peak current increase. Peak current and pulse-on time are increased to complete
the surfaces [1].

Chattopadhyay et.al. Studied rotary EDM using Taguchi's design of experiment (DOE) method using EN8 steel and copper as work piece-tool combinations. Following that, they established empirical relationships between process parameters including tools electrodes, peak current & pulse-on-time, spinning speed and characteristics of performance (MRR and EWR). There is evidence that both the peak current and the speed at which the tool electrode spins have a considerable impact both on response [2].

Mevada et.al. Studied wire wear under various machining circumstances. Using a factorial design with peak current, p on time, and p off time. Three levels govern peak current, pulse on time, and pulse off time. Tool and work piece materials were 0.18 mm molybdenum wire and EN-8 steel. Pulse off time, Peak current, and pulse on time are the three key wire wear characteristics, according to research. Peak current progressively causes wire deterioration. Wire wear rises as pulse length and peak current increased. Pulse off time doesn't affect wire wear rate [3].

In this study, Singh et.al. investigate how the MRR of hot die steel is impacted by the pulse on time, pulse off time, gap voltage, peak current, wire feed and wire tension (H-11). The one variable at a time approach is used to find the optimal set of process parameters in order to raise the MRR [4].

The impact of machining settings on the surface roughness of W-EDM DC53 die steel has been researched by Kanlayasiri et.al. As machining parameters, wire tension, pulse peak current, pulse on time and pulse off time were investigated. The ANOVA findings demonstrate that the wire-EDM DC53 die steel's surface roughness is significantly influenced by the pulse-on time and pulse-peak current [5].

III.MATERIAL SELECTION

Choice of material is determined by the desired weld qualities, which depend on the material's fundamental characteristics such as strength, corrosion or erosion resistance, ductility and toughness. The design procedure must also be taken into account. The properties of the various metallurgical characteristics connected to the temperature cycles experienced throughout the welding operation. The specimens, which measures 120mm by 8mm by 64mm, are ready. In this investigation, stainless steel 304 alloys were used.

Table1AISI 304 Stainless Steel Chemical Compositions

	Si	Cr	P	Mn	C	Ni	N	S
Max	0.17	20.0	0.045	2.0	0.08	12	0.10	0.030

AISI 316 metal is employed as the base metal and filler metal. The steel dimensions are 120 mm by length 10 mm by thickness 64 mm width. This process parameters of these samples are established from the trial and error method as well as Wire cut electric discharge machining is used to cut into different form.

Table 2AISI 316 Stainless Steel Chemical Compositions

	Si	Cr	P	Mn	C	Ni	N	S
Max	0.03	18.0	0.045	2.0	0.08	14.0	0.10	0.30

METHOD OF EXPERIMENT

3.1.1 Taguchi method

The Taguchi methodology is a useful method for developing superior systems. It provides a simple, efficient, and systematic technique for performance, quality, and cost optimization of designs. The Taguchi method's most crucial stage is process parameter optimization. Maintaining low prices while providing high quality. This is owing to the fact that process parameter optimization improve

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characteristics quality. That the obtained optimal process parameters by Minitab taguchi approach are not affected by changes in the environmental conditions or other factors linked to noise. Traditional process parameter design is a difficult and demanding task. By utilizing an inventive design of orthogonal arrays, the Taguchi approach resolves this issue with a constrained number of experiments.

3.1.2 Anova

The findings of the Taguchi method are analysed using the analysis of variance. This gives both effects of the each variable during inquiry and the effects for component interaction. Most significant important insignificant variables were identified, along with their impacts on the response characteristic, using S/N data. For both the raw and S/N data, the major impacts (response curves) were then shown in order to examine impact effects of parametric assumptions on response parameters. The Anova table and response curve analyses are finally used to establish the optimal values of significant process parameters in terms of mean performance parameters.

3.1.3 GRA

The Grey Theory, which was developed in 1982 by Dr. Deng J.L., consists of Grey decision making, Grey relational analysis and Grey modelling prediction, for systems with imperfect information, many inputs, discrete inputs, and inadequate data information.. Where in only part of the information is known and only part of the information is unknown. In order to evaluate the various performance aspects, a grey relational grade is obtained. Only single each grey relational grade. Optimized in GRA in place of difficult multiple performance characteristic optimizations. It is possible to optimize a single grey relational grade by using sophisticated multiple performance characteristic GRA optimization.

3.2 Experiment procedure on wire EDM

The studies were conducted on the Wire Electricdischarge machine at RATNAPARKHI. Thi s wire measured built from vertical on vertical blocks,workpiecewassecured& connected towards t he surface of work the work coordinate system was established using a reference point. The WCS gave the program instruction to be followed. The work item's ground margins served as the point of reference and to work piece's overall dimensions were divided into equal rectangular blocks using the software designed for cutting operations, and a 20 mm x 15.5 mm profile was then generated. When conducting numerous experiments, safety precautions were used in order to reduce error.

When metal is removed via wire electrical machining, it is typically done so by melting and vaporizing the material as a result of a spark discharge caused between the electrodes from a pulsed direct-current power sources. The consequences such as various parameters of wire electric discharge machining. The studies were conducted to ascertain the impact of pulse off time pulse on time and wire tension, the wire is made diameter of 0.25mm the zinc-coated brass wire. Along with objective to calculating the material removal rate's output parameters (MRR). We cut the small pieces of the material 304 stainless steel of the dimensions with regard to surface roughness (SR) and kerf width (KF) (15.5X20.5X8mm). Each rectangular block of the material 316 stainless steels dimensions relates to the composition of the work piece (15.5 X 20.5 X 10mm).The L9 orthogonal array divides each block of rectangular by parameter inputs, where nine tests are conducted as manipulating varied input variables. Here I used in input parameters as wire tension 11kgf, 12kgf, and 13kgf; pulse on time at 130s, 140s, and 150s; and pulse off time at 40s, 50s, and 60s were the three input elements that were taken into account at the three levels. The Taly Surf Method is used to record the cutting time for each rectangular array, and once each block has been cut, both side's surface roughness was calculated.

WIRE ELECTRIC DISCHARGE MACHINING


Fig.1.WEDM MACHINE


Fig.2.AISI 304 RECTANGLE BLOCKS

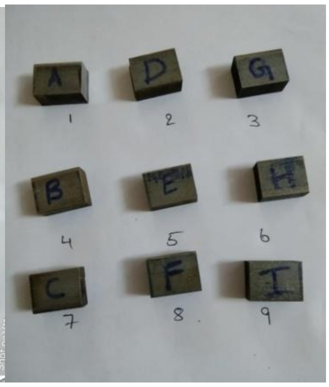
Fig.3.AISI 316 RECTANGLE BLOCKS

Table3 lists the levels of process variables.

Machining variable	L -1	L -2	L -3
Pulse on Time	130	140	150
Pulse off Time	20	30	40
Wire Tension	13	14	15

Through the use of the TAGUCHI approach, the WEDM experiments were find out the investigate as impact variables for the technique on parameters of output and response, such as SR, KF and MRR.

Calculation of output parameters:

$$MRR = \frac{Wja - Wjb}{Þt} \ Mm^3/min$$

Given that,
Wjb is the Work piece's initial weight in grams.
Wja is the after weight in grams.
Þ is the Density in gm/ mm^3.
T is the time in minutes.
The workpiece is weighted both after & before thecutting operation and then it determines the

material removal rate using weighting machining by dividing the difference between the two weights by the machining time divided by the specific gravity. Roughness average is used to measure surface roughness (Ra).Other names for thus metric are arithmetic average, centreline average, and arithmetic mean roughness value. The Taly surf instrument assesses an averaged roughness between the roughness profiles centre line and the roughness profile is directly. After blocks have been machined, each rectangular block's surface roughness as tested. Millimetres are used to measure kerf width.

Measure the quantity of material lost during machining and determines end products dimensional correctness.

IV.RESULT AND DISCUSSIONS

ANALYSIS OF OUTPUT PARAMETERS AISI 304

Were conducted for this study. in this section, the effects of the various processes are discussed. The parameters of cutting speed and surface roughness are discussed for several experimental settings.

The work piece is weighed material removal rate is estimated by dividing between before and aft er machining. The difference between the two weights by the machining time divided by the density.

Roughness average measures surface roughness (Ra). It's also called centerline average, arithmetic mean roughness value and arithmetic average value. Distance between surface roughness profile and its centre line is known as the average roughness when using a Taly surf instrument. It is measured for each rectangular block.

Millimetres' are used to measure kerf width (mm). it determines overall quantity of material consumed during in the machining process and the precision of the completed components dimensions. A digital vernier calliper is used to measure kerf width by deducting the expected width from the actual width.

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Table.4. Experimental Results

Pulse on time(μs)	Pulse off time(μs)	Wire tension (gm)	Material removal rate(mm^3/min)	Surface roughness(μm)	Kerf width(mm)
130	40	11	23.87	1.226	0.05
130	50	12	25.92	0.483	0.019
130	60	13	21.56	0.285	0.22
140	40	12	27.85	0.525	0.230
140	50	13	21.15	1.204	0.09
140	60	11	27.50	0.306	0.59
150	40	13	25.84	1.181	0.040
150	50	11	20.80	0.245	0.55
150	60	12	25.39	1.2184	0.31

EXPERIMENTATION

MRR values in tabular form, as well as SN ratios and graphs, are evaluated using the MINITAB19 programme. Obtained to determine the machining parameter that is most effective

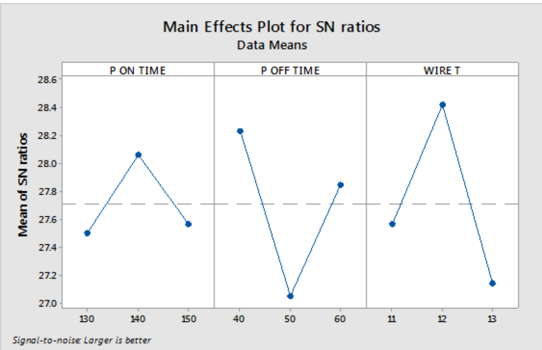

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Figure4.Material removal rate main Effects plot for S/N graphs

The significance of each parameter is illustrated by Material removal rate main Effects plot for SN ratios in figure (4). These plots were built using the "Larger is Better" theory, as demonstrated by the S/N ratio charts. Since the mean of the SN ratios for these parameters has minimal noise, the effective parameter for pulse on time is 140 s, for pulse off time is 40 s, and for wire tension is 12 kg-f. To determine the most effective machining parameter, the tabulated MRR was assessed using MINITAB19 software, and S/N ratios and graphs were produced.

Utilizing the MINITAB19 application, the tabulated surface roughness values are assessed, and graphs and S/N ratios are produced to help select the most efficient machining setting. These stories' central conceit is "Smaller is better."

The wire tension is more effective at 13 kg-f, the pulse off time is more effective at 40 s, and the pulse on time has low noise at 150 s. The Surface roughness main Effects plot for S/N graphs shown

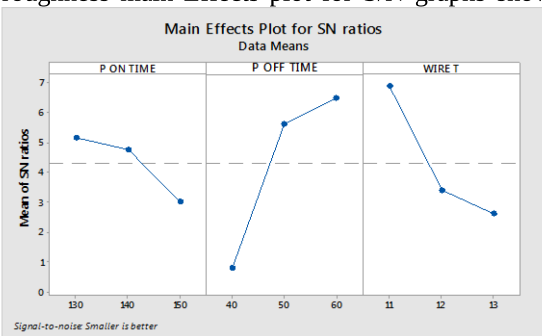

Figure5. Surface roughness main Effects plot for S/N graphs.

in above figure 5 indicates that these are the ideal setoff parameters for surface roughness.

Figure6. Kerf width main Effects plot for S/N graphs. below shows the relevance of each parameter. The S/N ratios are built on the tenet "Smaller is better." The pulse on time of 140 s, the pulse off time of 60 s, and the wire tension of 11 kg-f are the most effective characteristics. The S/N ratio plots were used to identify and predict the optimal settings for a particular variable.

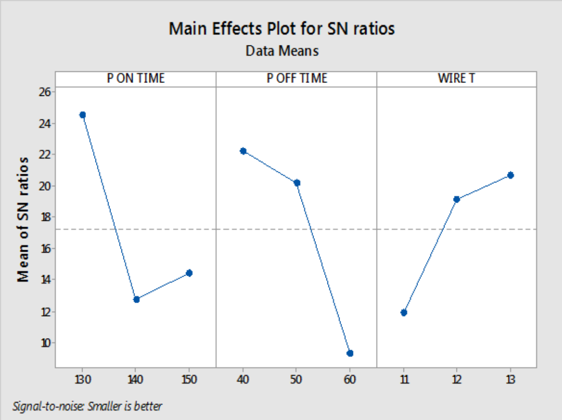

Figure6. Kerf width main Effects plot for S/N graphs

5.1 Empirical modelling

After conducting empirical modelling, regression equations are derived. Calculated R^2 values R-squared (R^2) is a statistical measure that depicts the percentage of variance for a dependent variable in a regression model that is explained by one or more independent variables.

Regression Equastion R^2 = $1 - \frac{\text{unexplained variation}}{\text{total variation}}$ (5.1)

The model summary of Rsq values

MRR = 32.7+ 0.011 P on time - 0.052 P off time – 0.60wiretensions.

R^2 for MRR values is 72.14%

SR= -1.63+ 0.0108 P on time - 0.0187 P off time+ 0.149wiretensions.

R^2 for SR values is 50.07%

KF = -0.18 +0.01018 P on time + 0.01333 P off time -0.1400 wiretension.

R^2 for KF values is 86.07**%**

R^2 for all the three process parameters were found.

GREY RELATIONAL GRADE (GRG) The grey relation coefficients experiments based on desired outcomes, such as high material removal rate, low surface roughness, and low kerf width, are shown in below table 5.

Table5. Grey relational coefficients

Exp No	Pulse on time	Pulse off time	Wire tension	Material removal rate	Surface roughness	Kerf width	GREY RELATIONAL COEFF.		
							MRR Mm^3/min	Surface roughness µm	Kerf width mm
1	130	40	11	23.87	1.226	0.05	0.469	1	0.347
2	130	50	12	25.92	0.483	0.019	0.645	0.397	0.33
3	130	60	13	21.56	0.285	0.22	0.358	0.342	0.438
4	140	40	12	27.85	0.525	0.23	1	0.413	0.44
5	140	50	13	21.15	1.204	0.09	0.344	0.960	0.362
6	140	60	11	27.50	0.306	0.59	0.909	0.349	1
7	150	40	13	25.84	1.181	0.04	0.632	0.92	0.34
8	150	50	11	20.80	0.245	0.55	0.330	0.33	0.86
9	150	60	12	25.39	1.2184	0.31	0.580	0.98	0.505

Table6. Grey relation grade ranking

Exp No	P on Time	P off Time	Wire tension	Material removal rate	Surface roughness	Kerf width	GRG	Rank
1	130	40	11	23.87	1.226	0.05	0.605	**5**
2	130	50	12	25.92	0.483	0.019	0.457	**8**

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3	130	60	13	21.56	0.285	0.22	0.379	**9**
4	140	40	12	27.85	0.525	0.23	0.617	**4**
5	140	50	13	21.15	1.204	0.09	0.550	**6**
6	140	60	11	27.50	0.306	0.59	0.750	**1**
7	150	40	13	25.84	1.181	0.04	0.630	**3**
8	150	50	11	20.80	0.245	0.55	0.501	**7**
9	150	60	12	25.39	1.2184	0.31	0.683	**2**

The gray relation grade and ranking of the tests based on the intended results, i.e., high material removal rate (mm^3/min), low surface roughness (µm), and decreased kerf width (mm), are shown in above the tabular column (6).

CONFIRMATION TEST:
To assess wire EDM's quality attributes, confirmation tests are run for the best parameters and their levels. The work piece's outcomes were confirmed as follows. Comparing the expected values and experiment values in below the tabular column (7)

Table7:Comparision Of Parameters

	Optimal process parameters	
	Predicted	Experiment
Level	A3B3C2	A3B3C2
MRR	25.92	27.50
SR	0.525	0.306
KF	0.50	0.59

ANALYSIS OF OUTPUT PARAMETERS AISI 316:

Table.4. Experimental Results

Pulse on time(µs)	Pulse off time(µs)	Wire tension (gm)	Material removal rate(mm^3/min)	Surface roughness(µm)	Kerf width(mm)
130	40	11	23.87	1.226	0.05
130	50	12	25.92	0.483	0.019
130	60	13	21.56	0.285	0.22
140	40	12	27.85	0.525	0.230
140	50	13	21.15	1.204	0.09
140	60	11	27.50	0.306	0.59
150	40	13	25.84	1.181	0.040
150	50	11	20.80	0.245	0.55
150	60	12	25.39	1.2184	0.31

The tabular material removal rate values, S/N ratios and graphs are evaluated using the MINITAB19 programmer. To obtained to determine the best parameter for machining.

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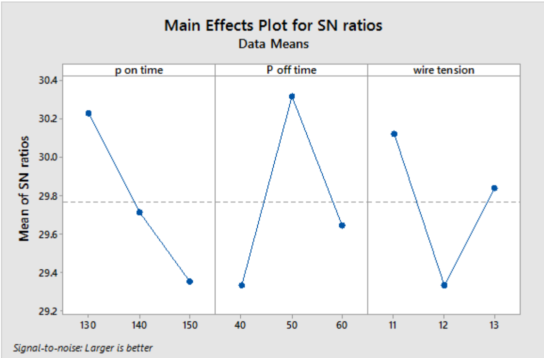

Figure7. Material removal rate main Effects plot for S/N graphs

Significant parameters for the S/N ratios graph for material removal rate include the pulse on time 130 µs, pulse off time 50 µsand wire tension 11 kg-f as shown in below figure(7).

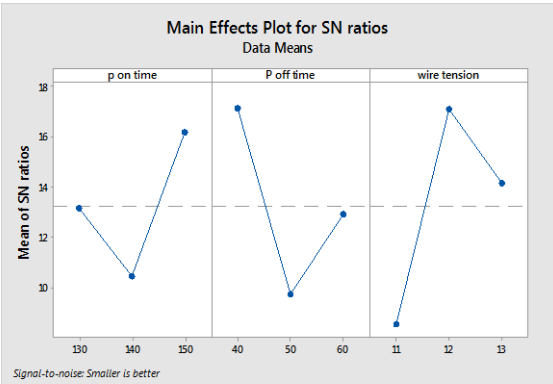

Figure9. Kerf width main Effects plot for S/N graphs.

The above figure(9),which depends the S/N ratio plot for kerf width, indicates that A2B2C1 are the significant parameters with pulse on time130 pulse off time 50 and wire tension 11 kg-f being the ideal set of kerf width parameters

5.2 Empirical modeling

After conducting empirical modelling, regression equations are derived. Calculated R^2 values is a statistical measure that shows how much of a dependent variables variance is explained by one or more independent variables in a regression model.

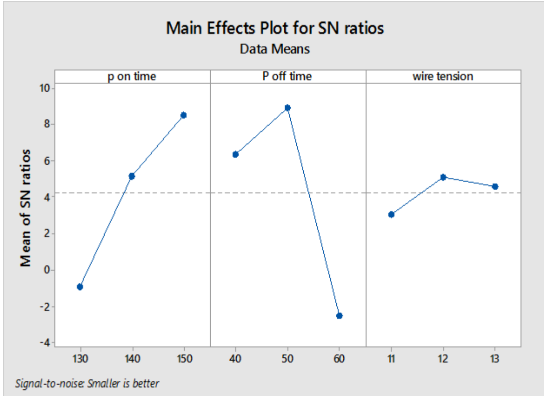

Figure8.Surface roughness main Effects plot for S/N graphs.

The S/N ratio graph for surface roughness has shown in the figure above (8) that A1B3C1 are significant parameters i.e., pulse on time 130µs, pulse off time 60µs, and wire tension 11 kg-f. Are the ideal set of surface roughness parameters.

Table.9. Grey relational coefficients

how much of a dependent variables variance is explained by one or more independent variables in a regression model.

Regression equation $R^2=1-\frac{\text{unexplained variation}}{\text{total variation}}$ (5.2)

(5.2)

The model summary of Rsq values

MRR = 54.6 - 0.150 Pon time + 0.048 Poff time – 0.43 wiretensions.

R^2 for MRR values is 75.12%

SR = 5.67 - 0.0365 Pon time + 0.0297 Poff time- 0.100 wiretensions.

R^2 for SR values is 88.17%

KF = 0.98 - 0.00133 Pon time + 0.00533 Poff time - 0.0667 wiretensions.

R^2 for KF values is 97.57**%**

R^2 for all the three process parameters were found

GREY RELATIONAL GRADE

The grey relation coefficients experiments based on desired outcomes, such as high material removal rate, low surface roughness, and low kerf width, are shown in below tabular column (9)

Exp No	Pulse on time	Pulse off time	Wire tension	Material removal rate	Surface roughness	Kerf width	GREY RELATIONAL COEFF.		
							MRR	Surface	Kerf width

							Mm^3/min	roughness µm	mm
1	130	40	11	33.65	1.802	0.28	0.847	1	0.50
2	130	50	12	30.54	0.453	0.19	0.515	0.375	0.408
3	130	60	13	33.31	1.673	0.20	0.79	0.86	0.416
4	140	40	12	28.56	0.283	0.12	0.414	0.347	0.357
5	140	50	13	34.39	0.559	0.47	1	0.393	0.96
6	140	60	11	29.14	1.071	0.48	0.43	0.520	1
7	150	40	13	26.13	0.218	0.08	0.33	0.338	0.33
8	150	50	11	33.60	0.18	0.39	0.83	0.33	0.68
9	150	60	12	28.79	1.342	0.12	0.423	0.637	0.357

Valve Frequency The grey relational grade tabulation and ranking of the tests based on the desired outcome, i.e., high material removal rate (mm^3/mm), low surface roughness (µs) and decreased kerf width (mm) are shown in below tabular column (10).

Table.10. Grey relation grade and ranking.

Exp no	Pulse on Time µs	Pulse off Time µs	Wire tension kg-f	MRR Mm^3/min	Surface roughness µm	Kerf width mm	GRG	Rank
1	130	40	11	33.65	1.802	0.28	0.780	**2**
2	130	50	12	30.54	0.453	0.19	0.430	**7**
3	130	60	13	33.31	1.673	0.20	0.680	**3**
4	140	40	12	28.56	0.283	0.12	0.370	**8**
5	140	50	13	34.39	0.559	0.47	0.784	**1**
6	140	60	11	29.14	1.071	0.48	0.650	**4**
7	150	40	13	26.13	0.218	0.08	0.330	**9**
8	150	50	11	33.60	0.18	0.39	0.613	**5**
9	150	60	12	28.79	1.342	0.12	0.470	**6**

Confirmation Test:

Table 11 Comparison of process parameters

	Optimal process parameters	
	Predicted	Experiment
Level	A3B3C2	A3B3C2
MRR(mm^3/min)	33.31	34.39
Surface roughness(µm)	1.673	0.559
Kerf width(mm)	0.20	0.47

To access wire electrical discharge machining is quality attributes, conformation tests are run for the best parameters and their levels. The work pieces outcomes were confirmed as follows. comparing the experiments values to the projected values in above tabular column (11).

CONCLUSION

On work Through-hole machining is carried out on work components made of steel with an AISI 304 and AISI 316 grade using a locally developed kind of wire electrical discharge machine. These conclusions come from the study that is described in this article. By adjusting control parameters such pulse on time, pulse off time, and wire tension, through holes are machined on work components with a thickness of 8 mm and electrode wire 0.25 mm^2 in size using deionized water as the dielectric medium. It is thoroughly examined how process parameters affect performance variables such machining time, the resulting constituent findings are given material removal rate, surface roughness and kerf width.

1. The optimal values for the S/N ratio plots, are the pulse on time at 140 µs, pulse off time at 40 µs, and wire tension at 12 kg-f, are classified as $A_2B_1C_2$ for the high material removal rate.
2. The optimum variables identified By examining the curves, the best variables for surface roughness are found to be $A_3B_1C_3$, which suggests that a wire tension of 13 kg-f has a lower surface roughness than pulse on times150 µs and pulse off time40 µs.
3. The best values found by looking at the graphs are $A_3B_3C_3$, which has a lower kerf width and pulse on time of 150µs and pulse off time of 60 µs.
4. After completing a regression analysis, it was established that the kerf width output parameter with the highest R-Sq value, or 86.07%.
5. After performing a grey analysis, it was observed that the best input parameters for all three process parameters were pulse on time of 150 µs, pulse off time of 40 µs, and wire tension of 14 kg-f. These input parameters result in a high material rate, decreased kerf width are surface roughness both are obtained.

The entire AISI 316 material was machined. By adjusting control variables such pulse on time, pulse off time, and wire tension, through holes are machined on a work piece with a thickness of 10 mm and electrode wire that is 0.25 mm^2 in size using deionized water as the dielectric medium. It is thoroughly described how process variables affect performance elements like machining time, material removal rate, surface roughness and kerf width.

1. The analysis of the S/N ratio graphs the ideal pulse on time 140 µs, pulse off time 50 µs and wire tension at 13 kg-f for the material removal rate.
2. The graphs' analysis determined the following optimal parameters $A_1B_3C_1$, which means that the pulse on time should be 130 µs, the pulse off time should be 60 µs, and the wire tension should be 11 kg-f have a lower surface roughness.
3. The graphs show that the best values, as determined by looking at the graphs, are $A_1B_2C_1$ for the kerf width, which means that the pulse on time should be 130 µs and the pulse off time should be 50 µs.
4. After completing a regression analysis, it was discovered that the output parameter with the highest R-Sq value, or 97.57%, was kerf width.
5. After performing a grey analysis, the optimal input values for all three process parameters were determined grey analysis to be pulse on time140 µs, pulse off time50 µs and wire tension 13 kg-f. These input parameters result in a high material rate, decreased kerf width and surface roughness are obtained.

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