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# Optimization of EDM Process Parameters in Machining through Hole making of 17-4 PH Stainless Steel by using Grey Taguchi Technique

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***Abstract: In a number of industries, hard and brittle materials find a diversity of applications. With the enhancement and developments in imaginative technologies, low mass- high potency, high confrontation to temperature. Materials have been produced to congregate the industry desires. The High Strength Temperature Resistance Materials are not easy to machine in traditional machining process for such cases either the tool can undergoes great wear /spoil or the work material will be spoilt. To overcome on top of problems there is a need for advanced machining process. In non-conventional machining process EDM process acting very important role in metal cutting applications with high precise and outstanding machining capabilities. The main aim of this work is to optimization of multiple responses of Electric discharge machining (EDM) using orthogonal array coupled with Grey Taguchi is endeavoured. The work piece material was 17-4 PH Stainless Steel and a cylindrical copper electrode with side impulse flushing was used. The effect of machining parameters, i.e., discharge current, pulse on time, discharge voltage and pulse off time on the Material Removal Rate (MRR), Tool Wear Rate and Surface Roughness (Ra) in EDM were examined. L9 orthogonal array was used to design the experiment and the effect of the factors on the outputs were studied. As the outputs are contradictory in nature, factors of a single combination will not be treated as best machining performance for all responses. The multiple responses were converted into a normalised S/N ratio by this grey relational coefficient and grey relation grade is obtained through this the output responses before optimization and after optimization are confirmed.***

**Keywords**:EDM, Discharge Current, Voltage, Pulse on Time ,Pulse off time, MRR, Surface Roughness, Tool Wear Rate and Grey Taguchi

## Introduction

The English Scientist named Joseph Priestly was initiated process in the 1770's. He seen that in his experiments that electrical discharges had removed material from the two electrodes[1,2] such as work piece and tool. Even though it was formerly noticed by Priestly, the EDM was indistinguishable and riddle from failures. The quality of a product is the main thing for viewing growth of a industry. The quality of the work product largely depends on the type of material to be used and input parameters of the process. Optimization technique plays a vital role to raise the excellent quality of the product [3, 4]. EDM is an electro-thermal un-traditional machining process and where thermal spark is created by using electrical power energy and material removal mainly occurs due to thermal energy of the spark. Mainly the EDM is used to machine those which are difficult to cut on conventional machining process [5, 6]. It is the wide and effectively applied machining process for a variety of work piece materials which are electrically conductive. With the development of mechanization skill manufacturers[7, 8] have more passion in the processing and developing of components by these costly and tough materials. Electrical discharge machining have spread since few decades from a innovation to a manufacturing process[9,10]. Entirely many research attempts have been made on EDM for improving output responses. Still getting better results of MRR and quality of surface finish are demanding troubles that confine the prolonged application of the process [11, 12].

## 1. Methodology

To finish the aim of the present work, different concepts, methods and procedures like Design of Experiments (DOE) [13] and Grey Taguchi [13, 8] have been used in this paper. The methodology adopted for this present work is shown in Figure.1:

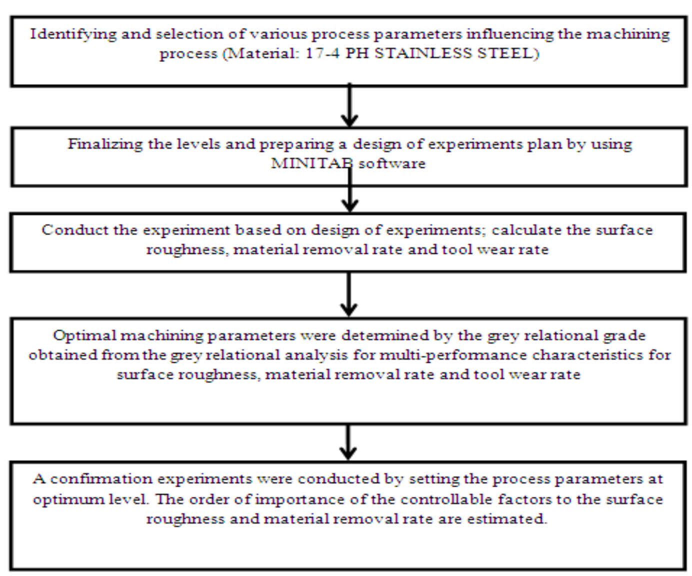


Figure.1: Experimental Flow Chart

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In this work the material selected was 17-4 PH stainless steel having outstanding mechanical and electrical properties. This material has high rust resistance and rigidity, high tiredness with good quality of formability which is extensively adopted in aerospace applications with light mass to high potency, substance dispensation equipment, heat exchangers, power boilers, and superheated tubes. The tool used in this work was copper rod with 10 mm diameter. In EDM process the responses were affected by a number of inputs such as discharge current, pulse duration, pulse on time, pulse off time, voltage, inter electrode gap, duty factor , intensity, pulse frequency, type of dielectric fluids and flushing pressure. Among in this individuals for this work Discharge current, voltage, pulse on time and inter electrode gap are chosen as input parameters with 3 levels. The assortment of number of levels is selected based on the influence of act of parameter suitable to different level settings. If the performance process parameter is a linear function of the self-governing variable, then the number of level setting shall be two. However, if the independent variable is nonlinear related, then one might go for 3, 4 or higher levels depending on whether the connection is quadratic, cubic or higher order[13]. After analyzing the experimental data, one can decide whether the statement of level setting is right or not based on the percent role and the error calculations. To decide a suitable orthogonal array for the experiments, the calculation of total degrees of freedom is essential. In this work, only 9 experiments are required to study the entire machining parameter using the L9 orthogonal array based on DOF. The degree of freedom can be calculated by using following formula.

Degree of freedom = {(L-1)*f} +1; [13]

L= number of levels, f= number of factors

= {(3-1)*4}+1

= 9 i.e. orthogonal Array selected was L9

The process parameter values were selected based on specifications of EDM machine to be used and another influenced factor is properties of tool and work materials.

## 2. Experimental Work

The experiments are conducted on EDM machine based on experimental layout generated by design of experiments [13]. The process parameters table as shown in Table.1:

Table.1: Process Parameter and their Levels

| Symbol | Machining parameter | Units | Level1 | Level2 | Level3 |
|---|---|---|---|---|---|
| P | Discharge Current | Amp | 8 | 14 | 20 |
| Q | Pulse On Time | μsec | 400 | 500 | 600 |
| R | Voltage | volts | 40 | 50 | 60 |
| S | Inter Electrode Gap | μm | 100 | 150 | 250 |

The orthogonal array for above process parameters and their levels [13] as shown in Table.2:

Table.2: $L_9$ Orthogonal Array

| S.No. | Discharge Current | voltage | Pulse on time | Pulse off time |
|---|---|---|---|---|
| 1 | 7 | 40 | 200 | 40 |
| 2 | 7 | 50 | 300 | 60 |
| 3 | 7 | 60 | 400 | 80 |
| 4 | 14 | 40 | 300 | 80 |
| 5 | 14 | 50 | 400 | 40 |
| 6 | 14 | 60 | 200 | 60 |
| 7 | 21 | 40 | 400 | 60 |
| 8 | 21 | 50 | 200 | 80 |
| 9 | 21 | 60 | 300 | 40 |

Experiments have been accompanied on work piece based on above experimental layout by taking machining time as 10 minutes for each individual experiment [13]. The work piece and tool images are shown below Figure.2:

(a)

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(b)

(c)

Figure .2: (a) Before machining of work piece
(b) After machining of work piece
(c) Copper electrode

## 3. Results and Discussion

This is linked the evidence about before and after machining of Work piece and tool weights, made of drilled hole diameter and tool diameter values are measured with digital weighing machine and digital venire'scallipers. The following Table.3: shown the information about before and after machining of Work piece and tool weights.

**Table.3: Before and after machining of Work piece and Tool weights**

| S.No | Discharge Current (Amp) | voltage (v) | Pulse On Time (μ Sec) | Pulse off Time (μ Sec) | Work piece weight (gms) | | Tool weight (gms) | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Weight before machining | Weight after machining | Weight before machining | Weight after machining |
| 1 | 7 | 40 | 200 | 40 | 1845 | 1844.67 | 1300.82 | 1300.72 |
| 2 | 7 | 50 | 300 | 60 | 1844.67 | 1844.25 | 1300.72 | 1300.55 |
| 3 | 7 | 60 | 400 | 80 | 1844.25 | 1843.88 | 1300.55 | 1300.44 |
| 4 | 14 | 40 | 300 | 80 | 1843.88 | 1843.41 | 1300.44 | 1300.22 |
| 5 | 14 | 50 | 400 | 40 | 1843.41 | 1842.84 | 1300.22 | 1299.89 |
| 6 | 14 | 60 | 200 | 60 | 1842.84 | 1842.23 | 1299.89 | 1299.54 |
| 7 | 21 | 40 | 400 | 60 | 1842.23 | 1841.67 | 1299.54 | 1299.24 |
| 8 | 21 | 50 | 200 | 80 | 1841.67 | 1840.85 | 1299.24 | 1298.71 |
| 9 | 21 | 60 | 300 | 40 | 1840.85 | 1840.09 | 1298.71 | 1298.29 |

This is linked about the effect of Material removal Rate, Tool Wear Rate and Surface Roughness are finding the result which combination of the factors discharge current, pulse on time, voltage and pulse off time [13].The work piece weights were measured with digital weighing machine and surface roughness values were measured with talysurf surface roughness tester. The experimental output values are as recorded in Table 4: below.

**Table.4: Calculated Experimental Response values**

| S.No | Discharge Current (Amp) | voltage (v) | Pulse On Time (μ Sec) | Pulse off Time (μ Sec) | MRR ($mm^3$/min) | Surface roughness (μm) | TWR (gm/min) |
|---|---|---|---|---|---|---|---|
| 1 | 7 | 40 | 200 | 40 | 4.1750 | 1.9760 | 0.0100 |
| 2 | 7 | 50 | 300 | 60 | 5.3000 | 1.8570 | 0.0170 |
| 3 | 7 | 60 | 400 | 80 | 4.6250 | 2.7410 | 0.0110 |
| 4 | 14 | 40 | 300 | 80 | 6.0620 | 3.1680 | 0.0220 |
| 5 | 14 | 50 | 400 | 40 | 7.2870 | 2.6270 | 0.0330 |
| 6 | 14 | 60 | 200 | 60 | 7.8250 | 2.7250 | 0.0350 |
| 7 | 21 | 40 | 400 | 60 | 7.1620 | 4.2400 | 0.0300 |
| 8 | 21 | 50 | 200 | 80 | 10.4500 | 2.8950 | 0.0530 |
| 9 | 21 | 60 | 300 | 40 | 9.7370 | 4.4780 | 0.0420 |

Here MRR calculated by using below formula

$$MRR = \frac{Workpieceremovalrate}{Time \times Densityofworkpiece}, \ mm^3/min$$

$$TWR = \frac{Initialweight - Finalweight}{Time} \text{ , gm /min}$$

Here normalization required to minimises the computational time so the following are the normalization formulas

For larger is better = $x_i = \frac{xi(k) - \min xi\ (k)}{\max xi\ (k) - \min xi(k)}$ ;

where k is the output value

For smaller is better = $x_i = \frac{\max\ xi\ (k) - xi(k)}{\max xi\ (k) - \min xi(k)}$

Table.5: Calculated Normalised Values for Experimental Response Values

| S.No | Normalization values for Material Removal Rate (mm³/min) | Normalization values for Surface roughness (µm) | Normalization values for Tool Wear Rate (gm/min) |
|---|---|---|---|
| 1 | 0 | 0.9547 | 1 |
| 2 | 0.1793 | 1 | 0.8373 |
| 3 | 0.0718 | 0.6628 | 0.9768 |
| 4 | 0.3008 | 0.4999 | 0.7300 |
| 5 | 0.4961 | 0.7063 | 0.4652 |
| 6 | 0.5817 | 0.6689 | 0.4187 |
| 7 | 0.4762 | 0.0909 | 0.5349 |
| 8 | 1 | 0.6040 | 0 |
| 9 | 0.8865 | 0 | 0.2559 |

Then deviation sequences are required to apply grey taguchi method so the deviation sequences can be calculated as given below.

$$\Delta_{01}(1) = |\ x_o^*(1) - x_1^*(1)\ | = |\ 1 - 0\ | = 1$$

$$\Delta_{01}(2) = |\ x_0^*(2) - x_1^*(2)\ | = |\ 1 - 0.9547\ | = 0.0453$$

$$\Delta_{01}(3) = |\ x_0^*(3) - x_1^*(3)\ | = |\ 1 - 1\ | = 0$$

$\Delta_{01}(1)$ For Material Removal Rate

$\Delta_{01}(2)$ For Surface roughness

$\Delta_{01}(3)$ For Tool Wear Rate

Table.6: Calculated Deviation Sequences for Experimental Response Values

| S.No | Deviation sequences for Material Removal Rate (mm³/min) | Deviation sequences for Surface roughness (µm) | Deviation sequences for Tool Wear Rate (gm/min) |
|---|---|---|---|
| 1 | 1 | 0.0453 | 0 |
| 2 | 0.8207 | 0 | 0.1627 |
| 3 | 0.9282 | 0.3372 | 0.0232 |
| 4 | 0.6992 | 0.5001 | 0.27 |
| 5 | 0.5039 | 0.2937 | 0.5348 |
| 6 | 0.4183 | 0.3311 | 0.5813 |
| 7 | 0.5238 | 0.9091 | 0.4651 |
| 8 | 0 | 0.396 | 1 |
| 9 | 0.1135 | 1 | 0.7441 |

Then calculate the grey relational coefficient for material removal rate, surface roughness and tool wear rate. The formula used to calculate grey relational coefficient as given below

Grey Relational Coefficient = $\xi_i(k) = \frac{\Delta \min + \delta\Delta \max}{\Delta x_i(k) + \delta\Delta \max}$ ;

the values can be calculated as follows

Here $\delta$ is the distinguishing coefficient stuck between 0 and 1. Normally, the distinguishing coefficient fix to 0.5 and $\xi$ is the Grey relational coefficient.

For Material Removal Rate = $\frac{0 + 0.5 * 1}{1 + 0.5 * 1} = 0.33$

For Surface Roughness = $\frac{0 + 0.5 * 1}{0.0453 + 0.5 * 1} = 0.92$

For Surface Roughness = $\frac{0 + 0.5 * 1}{0 + 0.5 * 1} = 1$

Table.7: Calculated Grey Relational Coefficient for Experimental Response Values

| S.No | Grey Relational Coefficient for Material Removal Rate ($mm^3/min$) | Grey Relational Coefficient for Surface roughness (µm) | Grey Relational Coefficient for Tool Wear Rate (gm/min) |
|---|---|---|---|
| 1 | 0.33 | 0.92 | 1.00 |
| 2 | 0.38 | 1.00 | 0.75 |
| 3 | 0.35 | 0.60 | 0.96 |
| 4 | 0.42 | 0.50 | 0.65 |
| 5 | 0.50 | 0.63 | 0.48 |
| 6 | 0.54 | 0.60 | 0.46 |
| 7 | 0.49 | 0.35 | 0.52 |
| 8 | 1.00 | 0.56 | 0.33 |
| 9 | 0.81 | 0.33 | 0.40 |

After calculating Grey Relational coefficients, it is essential to multiply these values with grade weight values. The following are the grey weight values for material removal rate, surface roughness and tool wear rate.

Table.8: Preferred Values for Outputs by Analytic Hierarchy Process

| | MRR | Ra | TWR |
|---|---|---|---|
| MRR | 1 | 1/3 | 1/5 |
| Ra | 3 | 1 | 1/3 |
| TWR | 5 | 3 | 1 |

For MRR = $(1+1/3+1/5)^{(1/3)}$ = 0.4054

For $R_a$ = $(3+1+1/3)^{(1/3)}$ = 1

For TWR = $(5+3+1)^{(1/3)}$ = 2.466

Then sum of above values = 0.4054 + 1 +2.466 = 3.871

Weight value for MRR = 0.4054/3.871 = 0.10473

Weight value for $R_a$ = 1/3.871= 0.25333

Weight value for TWR = 2.466/3.871 = 0.63704

Table.9: Calculated Grey Relational Weight Values by Analytic Hierarchy Process

| Name of the output | Grey Weighted Value |
|---|---|
| Material removal rate | 0.10473 |
| Surface Roughness | 0.25333 |
| Tool Wear Rate | 0.63704 |

Then calculate the grey relational grade values with weights for material removal rate, surface roughness and tool wear rate.

Table.10: Calculated Grey Relational Coefficient Values with Weights for Experimental Response Values.

| S. No | Grey Relational Coefficient for Material Removal Rate ($mm^3/min$) | Grey Relational Coefficient for Surface roughness (µm) | Grey Relational Coefficient for Tool Wear Rate (gm/min) |
|---|---|---|---|
| 1 | 0.035 | 0.238 | 0.637 |
| 2 | 0.040 | 0.258 | 0.478 |
| 3 | 0.037 | 0.155 | 0.612 |
| 4 | 0.044 | 0.129 | 0.414 |
| 5 | 0.052 | 0.163 | 0.306 |
| 6 | 0.057 | 0.155 | 0.293 |
| 7 | 0.051 | 0.090 | 0.331 |
| 8 | 0.105 | 0.145 | 0.210 |
| 9 | 0.085 | 0.085 | 0.255 |

Then Grade can be calculated with following formula.

Grey Relational Grade = (1/n)*(Average of output grey relational coefficient values); where 'n' is the number of outputs. Hence Grey Relational Grade= (1/3)*(0.035+0.238+0.637) = 0.303; after calculations need to give ranks for those values. The following table.11 represents grades with ranks.

Table.11: Calculated Grey Relational Grade Values

| S. No. | Grey Relational Grade | Rank |
|---|---|---|
| 1 | 0.303 | 1 |
| 2 | 0.259 | 3 |
| 3 | 0.268 | 2 |
| 4 | 0.196 | 4 |
| 5 | 0.174 | 5 |
| 6 | 0.168 | 6 |
| 7 | 0.157 | 7 |

| | | |
|---|---|---|
| 8 | 0.153 | 8 |
| 9 | 0.142 | 9 |

The grade factor average values are determined and shown in below table.

Table.12: Calculated Average Grey Relational Grade values

| Inputs | Average Grey Relational Grade values maximum-minimum | | |
|---|---|---|---|
| | Level1 | Level2 | Level3 |
| P | 0.2767* 0.1260 | 0.1793 | 0.1507 |
| Q | 0.2187* 0.0260 | 0.1953 | 0.1927 |
| R | 0.2080* 0.0030 | 0.1990 | 0.1997 |
| S | 0.2064* 0.0117 | 0.1947 | 0.2057 |

## 4. Conclusion

The Grey Taguchi method gives an optimum solution as Rank 1 for first experiment. It means that experiment one is better for Material Removal Rate, Surface roughness and Toll Wear Rate. The inputs influences EDM process as follows Discharge Current > Voltage > Pulse off time > Pulse on time by Average Grey Relational Grade values.

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