Multi-Response Optimization of Process Parameters of WEDM using TOPSIS Approach

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Abstract: Present study deals with multi response optimization of process parameters during wire EDM of EN31. In this study, process parameters like pulse on time (TON), pulse off time (TOFF) and peak current (IP) are taken into consideration. Taguchi method is used for designing the experiment. In order to optimize the multiple responses like machining time and surface roughness, Technique for order preference by similarity to ideal solution (TOPSIS) method is used to get optimum parametric combination. Finally conformity test is performed to check the validity of the proposed approach.

Keywords: TOPSIS, Optimization, Taguchi

1. INTRODUCTION

Wire electrical discharge machining is a non-traditional machining process which is based on material removal from a work piece by means of series of repeated electrical discharge between electrode and the work piece in the presence of dielectric fluid. A continuous travelling wire electrode which is controlled by the computer to follow a predefined path to cut a slot through the work piece to produce the required shape. High frequency alternating current is discharged from the wire to the work piece with very small gap through an insulated dielectric fluid. The heat of each electrical spark erodes away the material. These particles are flushed away from the cut with a stream of dielectric fluid with the help of nozzle. This dielectric also prevents the heat buildup in the work piece.

In the past several years researchers have used different methods to improve the machining characteristics during wire EDM of several materials. Amitesh Goswamiet.al. used Taguchi based GRA method to investigate surface integrity, MRR and wire wear ratio for WEDM of Nimonic 80A. [1]. Neeraj Sharma et.al. used Response Surface Methodology to optimize process parameters for WEDM of HSLA steel. [2]. J.B. saedonet.al. applied Taguchi based GRA method to perform multi objective response optimization for WEDM of titanium alloy. [3]. Brajesh Kumar Lodhiet.al. used Taguchi technique to optimize machining parameters in WEDM of AISI D3 steel. [4]. Bijaya Bijeta Nayaket.al. proposed Artificial Neural Network to investigate and optimize process parameters during WEDM of cryo treated Inconel 718. [5]. Neeraj Sharma et.al. used RSM with the help of Genetic Algorithm to optimize the process parameters during WEDM of HSLA steel. [6]. Ashish Goyal used ANOVA to optimize the process parameters during WEDM of Inconel 625 using cryo treated wire electrode. [7]. J.F. Oberholzeret.al. optimized the process parameters during WEDM of Aluminium 7075-T6 using ANOVA. [8]. Neeraj Sharma et.al. optimized the process parameters for cryogenic treated D-2 Tool steel by using RSM and Genetic Algorithm. [9]. D. Sudhakara et.al. applied Taguchi method to optimize the process parameters during WEDM of P/M cold worked Tool Steel. [10]. Vikaset.al. used Taguchi method to optimize process parameters during WEDM of EN19 & EN41. [11]. V. Kavimaniet.al. used Taguchi based GRA method to optimize process parameters of magnesium composites. [12]. G. Shrinivasraoet.al. used desirability approach to optimize process parameters during WEDM of 0-α-β Titanium alloy. [13]. Sachin Sonawaneet.al. used principal component analysis integrated Taguchi method to optimize process parameters during WEDM of Nimonic-75 alloy. [14]. G. Harinath Gowdet.al. used NSGA algorithm to optimize process parameters during WEDM of SS304 steel. [15]. Somvir Singh nainet.al. used particle swarm optimization to optimize the parameters during the WEDM of Udiment 605 alloy. [16]. Rupesh Chalisgaonkaret.al. used utility concept methodology to optimize the parameters during WEDM of pure titanium. [17]. R. Ramkrishnanet.al. developed ANN model to optimize parameters of Inconel 718. [18]. Bijo Mathew et.al. Taguchi GRA method to optimize the parameters during WEDM of AISI 304 steel. [19].
BikashChoudhari et al. used fuzzy logic methodology to optimize process parameters during WEDM of H21 tool steel. [20]. R. Soundararajan et al. used RSM to optimize the parameters during WEDM of squeeze casted A413 alloy. [21]. Divyareddy et al. used GRA method to optimize the parameters during WEDM of Ti50Ni48Co2 alloy. [22]. K. Dayakar et al. used Taguchi method to optimize the parameters during WEDM of maraging steel 350. [23]. Siva Prasad Arikatla et al. used simulated annealing to optimize the parameters during WEDM of Inconel 718. [26]

Past study reveals that WEDM involves large number of input parameters that affect the quality characteristics, it is worthwhile to investigate the relative importance between the input and output parameters. Due to the complexity and nonlinearity involved in this process, good functional relationship with reasonable accuracy between performance characteristics and process parameters is difficult to obtain. To address this issue, the present study proposes Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) model to determine the relationship between input parameters and performance characteristics. Most of the researchers have used Taguchi and GRA approach to optimize the process parameters. Multi attribute decision making techniques like TOPSIS, PROMETHEE have not been used to find the optimal setting of the parameters for EN31. Thus, the analysis of improvement in the process using multi attribute decision making techniques is desirable. In the present work, an attempt has been made to find out the optimum parameters through multi response optimization using TOPSIS to achieve minimum Machining Time (MT) and minimum surface roughness.

2. EXPERIMENTAL DETAILS AND METHODOLOGY

2.1 Setup:
Experiments were performed on Electronica supercut 734. Alloy Steel 300 of 200mm*200mm*7.5mm size has been used as a work piece material. Brass wire of 0.25 mm diameter is used as an electrode material.

2.2 Design of Experiments:
For present study Taguchi parameter design approach is used for design of experiment. Six process parameters are selected as control factors and other factors are kept constant.

Table 1 List of controlled and constant parameters

<table>
<thead>
<tr>
<th>Controlled Parameters</th>
<th>Constant Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pulse on Time</td>
<td>Work piece material ;  Alloy Steel 300</td>
</tr>
<tr>
<td>Pulse off Time</td>
<td>Work piece Thickness; 7.5 mm</td>
</tr>
<tr>
<td>Peak current</td>
<td>Wire Electrode ; Zinc coated Brass wire 0.25mm diameter</td>
</tr>
<tr>
<td>Servo Feed</td>
<td>2120mm/Min.</td>
</tr>
</tbody>
</table>

By referring orthogonal arrays table, L9 array is selected for the present study. Parameteric combination for experimentation is tabulated as follows.

Table 2 Levels of controlled parameters

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Level 1</th>
<th>Level 2</th>
<th>Level 3</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>A Pulse on Time TOFF</td>
<td>70</td>
<td>150</td>
<td>230</td>
<td>Volt</td>
</tr>
<tr>
<td>B Pulse off Time IP</td>
<td>108</td>
<td>116</td>
<td>124</td>
<td>µSec</td>
</tr>
</tbody>
</table>

TOPSIS helps to determine the most suitable alternative from the given sets. The technique used in TOPSIS is that the selected solution should be nearest from the positive ideal solution and farthest from the negative ideal solution. In order to obtain the desired output with minimum usage of resources it is important to follow the optimum combination of process parameters. The optimum parameter combination for one response may be unfavorable for other responses. Therefore multi-objective optimization is necessary to obtain the optimum combination of parameters.

3.1 TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution)

TOPSIS helps to determine the most suitable alternative from the given sets. The technique used in TOPSIS is that the selected solution should be nearest from the positive best solution and farthest from the negative best solution.

3.1.1 Step I
The normalized matrix is obtained by the following expression

\[ R_{ij} = \frac{q_{ij} - \min q_{ij}}{\max q_{ij} - \min q_{ij}} \]

where \( j = 1, 2, 3 \ldots \)
3.1.2 Step2
The weight of each attribute was assumed to be \( w_j \) (j=1, 2, 3...) The weighted normalized matrix can be obtained by
\[
U = w_j \rightarrow \sum_j w_j = 1
\]

3.1.3 Step3
The positive and negative ideal solutions are obtained from following expressions.
\[
U_+ = \{ (\sum_{i=1}^{m} u_{ij}) \in J, \sum_{i=1}^{m} u_{ij} \}_{i=1, 2, m} = \{ u_1^+, u_2^+, u_3^+, ..., u_n^+ \}
\]
\[
U_- = \{ (\sum_{i=1}^{m} u_{ij}) \in J, \sum_{i=1}^{m} u_{ij} \}_{i=1, 2, m} = \{ u_1^-, u_2^-, u_3^-, ..., u_n^- \}
\]

3.1.4 Step4
Separation between alternatives from positive ideal solution is expressed as
\[
S_+^i = \sqrt{\sum_{j=1}^{m} (u_{ij} - u_j^+)^2}, \quad i=1, 2, 3, ... m
\]
Separation between alternatives from negative ideal solution is expressed as
\[
S_-^i = \sqrt{\sum_{j=1}^{m} (u_{ij} - u_j^-)^2}, \quad i=1, 2, 3, ... m
\]

Table 5 Normalized matrix

<table>
<thead>
<tr>
<th>Expt.No.</th>
<th>Surface Roughness in (µ)</th>
<th>Material Removal Rate (mm³/Min.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.094349</td>
<td>0.276399</td>
</tr>
<tr>
<td>2</td>
<td>0.125168</td>
<td>0.265722</td>
</tr>
<tr>
<td>3</td>
<td>0.091923</td>
<td>0.214373</td>
</tr>
<tr>
<td>4</td>
<td>0.193407</td>
<td>0.359246</td>
</tr>
<tr>
<td>5</td>
<td>0.187</td>
<td>0.397734</td>
</tr>
<tr>
<td>6</td>
<td>0.111530</td>
<td>0.274846</td>
</tr>
<tr>
<td>7</td>
<td>0.153561</td>
<td>0.407392</td>
</tr>
<tr>
<td>8</td>
<td>0.195057</td>
<td>0.421418</td>
</tr>
<tr>
<td>9</td>
<td>0.185544</td>
<td>0.317313</td>
</tr>
</tbody>
</table>

Table 6 Weighted Normalized matrix

<table>
<thead>
<tr>
<th>Expt.No.</th>
<th>Surface Roughness in (µ)</th>
<th>Machining Time (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.047175</td>
<td>0.1382</td>
</tr>
<tr>
<td>2</td>
<td>0.062584</td>
<td>0.132861</td>
</tr>
<tr>
<td>3</td>
<td>0.045961</td>
<td>0.107187</td>
</tr>
<tr>
<td>4</td>
<td>0.096703</td>
<td>0.179623</td>
</tr>
<tr>
<td>5</td>
<td>0.0935</td>
<td>0.198867</td>
</tr>
<tr>
<td>6</td>
<td>0.055765</td>
<td>0.137423</td>
</tr>
<tr>
<td>7</td>
<td>0.07678</td>
<td>0.203696</td>
</tr>
<tr>
<td>8</td>
<td>0.097528</td>
<td>0.210709</td>
</tr>
<tr>
<td>9</td>
<td>0.092772</td>
<td>0.158657</td>
</tr>
</tbody>
</table>

3.1.5 Step5
Relative closeness of the alternative to the positive ideal solution is given by
\[
Pi = \frac{S_+^i}{S_+^i + S_-^i}, \quad i=1, 2, ... m
\]

Table 7 Closeness co-efficient

<table>
<thead>
<tr>
<th>Expt.No.</th>
<th>Pi</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.739876</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>0.736141</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>0.260142</td>
<td>6</td>
</tr>
<tr>
<td>5</td>
<td>0.108037</td>
<td>8</td>
</tr>
<tr>
<td>6</td>
<td>0.726304</td>
<td>4</td>
</tr>
<tr>
<td>7</td>
<td>0.177754</td>
<td>7</td>
</tr>
<tr>
<td>8</td>
<td>0</td>
<td>9</td>
</tr>
<tr>
<td>9</td>
<td>0.428991</td>
<td>5</td>
</tr>
</tbody>
</table>

From the analysis it is clear that experiment no. 7 is the best multiple performance characteristics having highest preference order followed by expt. No.4 and expt.no.5 The optimum parametric combination can be determined by considering the higher values of preference order.

4. CONCLUSION
In the present investigation multi response optimization technique is used to optimize the process parameters during WEDM of EN31. The optimum combination of parameters using TOPSIS approach are TON3 TOFF1 IP3 (i.e. third level of TON, first level of TOFF, third level of IP) for experiment no. 7. The machining time and surface roughness is 6.25 min. and 3.3 micron respectively at optimum levels. It can be stated that TOPSIS approach can be useful to optimize multi-response characteristics for any manufacturing process.

5. REFERENCES


