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Optimization of Process Parameters in WEDM of EN-31 Alloy Steel using Taguchi Technique and TOPSIS

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ABSTRACT

Optimization of parameters in any process is vital to survive in the present competitive era as it helps to meet out the quality, functional and economical requirement of the product in the best possible way. In this work, TOPSIS (Techniques for Order Preference by Similarity to Ideal Solution) method is combined with Taguchi's technique to solve a multi objective optimization problem in Wire-electrical discharge machining (WEDM) of EN-31 alloy steel. Process information was gathered by Taguchi's L_{27} orthogonal array to study the effect of six input parameters on four responses. TOPSIS has been used to convert multiple responses to a response called as Multi-Performance Characteristic Index (MPCI). This MPCI was then optimized by Taguchi method. ANOVA revealed that pulse off time (41.38%) was the most significant parameter followed by the servo feed (26.80%) and pulse-on-time (15.10%) whereas the effect of wire feed, wire tension and spark gap set voltage is negligible. Further, the confirmation experiment with optimal parameters confirmed that the targeted multi-performance characteristic was significantly improved to achieve more desirable levels.

*Keywords:*WEDM, EN-31, TOPSIS, Taguchi Technique, MRR, Dimensional Deviation.

1.Introduction:

Wire electric discharge machining (WEDM) is a thermo-electrical machining process in which material erodes from the work piece by series of sparks between the work piece and the continuously moving wire electrode. The Wire electrical discharge machining plays a vital role in various manufacturing industries such as aerospace, ordinance and automobile, just to name the few. According to Trezise (1982), the fundamental limit on machining accuracy in WEDM are dimensional consistency of the wire and the positional accuracy of the worktable. Moreover, selection of optimum combination of machining parameter to achieve higher material removal rate, surface finish and dimensional accuracy is a challenging task in WEDM due to large number of process variables and stochastic process mechanism.

A large number of paper reveals that a lot of research work has been carried out on different materials to study the influence of various process parameters on WEDM. The outstanding characteristic of EN-31 steel has led to increased application in various industries especially in the areas of automobile, aerospace, mold and die making industries. EN-31 steel has high strength, toughness and impact resistance and is categorized as "difficult to machine" material posing a major challenge during machining. The optimal parameters for different performance characteristics are different and to select the best set of process parameters for an optimal performance, analytical and statistical techniques are required. In this work, the literature related to EN 31 alloy steel and MCDM has been carried out and presented in the following section.

Hascalyk and Caydas (2004) investigated the machining characteristics of AISI D5 tool steel in WEDM and reported that the intensity of the process energy affects the amount of recast and surface roughness as well as micro cracking, whereas the wire speed and dielectric fluid pressure does not seem to have much influence. Liao et al. (2004) found that the machining voltage, current limiting resistance and capacitance significantly affects the surface roughness in finishing operation. Ramakrishnan and Karunamoorthy (2006) carried out the multi objective optimization of the WEDM process using Taguchi methodology. The effect of pulse on time, wire tension, delay time, wire feed and ignition current intensity was investigated in machining of heat-treated tool steel and it was reported that the pulse on time and ignition current intensity have significant influence over other parameters. The obtained results

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were analyzed to select the optimal set of process parameters for better surface finish. Khan et al. (2006) provided the relations of surface roughness with current and voltage in machining of mild steel, aluminum, cemented carbide, copper and stainless steel with different diameters of brass wire. Jangra et al. (2010) applied Taguchi method and grey analysis to determine optimal parametersfor optimization of multiple performance characteristic (cutting speed, surface roughness and dimensional lag) in WEDM of D-3 Tool steel.

Singh et al. (2011) optimized multiple surface roughness parameters of GFRP polyester composites using TOPSIS method with Taguchi's robust design philosophy. Gadakh (2012) made a case study on optimization of WEDM process parameters using TOPSIS method for solving complex decision making problems. Behzadian et al. (2012) have conducted a state-of-the-art literature survey to taxonomize the research on TOPSIS application and methodologies.Nayak and Mahapatra (2013) conducted experiments on D2 steel in WEDM machining process and optimized the MRR and R_a. TOPSIS method in combination with Taguchi methodology has been adapted to solve the multi-response optimization problem. Parida and Routara (2014) studied the process parameters, cutting speed, feed and depth of cut in turning operation with dry environment. Multi-responseoptimization of process parameters has been done using TOPSIS with Taguchi approach.

The present investigation highlights a multi-objective optimization problem by applying TOPSIS (technique for order preference by similarity to ideal solution) based on Multi-Criteria Decision Making (MCDM) approach in combination with Taguchi's robust design philosophy in machining of EN-31 steel using WEDM Machine.

In the present work, the control factors were based on the pilot experiments conducted with randomly chosen factor combinations, through review of literature and experience. As per best of author's knowledge, no research work has been reported so far in the field of wire electrical discharge machining on simultaneous optimization of responses viz. material removal rate (MRR), surface roughness (R_a), gap current (I_g) and dimensional deviation (DD) in machining of EN-31 alloy steel using TOPSIS method. TOPSIS based MCDM approach has been adopted in combination with Taguchi's robust design philosophy to determine the best combination of cutting parameters namely Pulse on time, Pulse off time, Wire feed, Wire tension, Spark gap set voltage and Servo feed in order to maximize the MRR and Gap current, minimize the surface roughness (R_a) and dimensional deviation (DD) simultaneously.

2. Machining parameters and material details

The experiments were conducted on Electronica Ultra Cut S2 servo control type Wire Cut EDM 5-axis Machine as shown in Figure.1. The process parameters chosen for machining of EN-31 steel are Pulse on Time (T_{on}), Pulse off Time (T_{off}), Wire Feed (WF), Wire Tension (WT), Spark Gap Set Voltage (SV) and Servo Feed (SF). The process variables with their values on different levels are listed in Table 1. The values of T_{on}, T_{off}, WF, WT, SF are given in coded units as per the WEDM technology manual. The actual values of pulse on time (T_{on}) corresponding to 18, 20, 22 units are 1.0 µsec, 1.1 µsec and 1.2 µsec respectively. Similarly the values corresponding to pulse off time of 35, 40 and 45 units are 11.5 µsec, 14 µsec and 18 µsec respectively and for wire tension of 8, 9 and 10 unit are 1250 gm, 1450 gm and 1650 gm respectively. The value of SF 2040, 2060 and 2080 indicates that the machining was performed in constant voltage mode at a feed rate of 4, 6 and 8 mm/min respectively. The de-ionized water was used as dielectric machining fluid with a conductivity value of 20 mho and the water pressure was kept constant throughout the experiment at 10 kg/cm^2. The Zinc coated copper wire (CuZn37 master brass) having tensile strength of 900-920 N/mm^2 and 0.25 mm diameter was used in a vertical position for machining.

In the present study, EN-31 alloy steel was taken as work piece material having following chemical composition: C-1.07; Mn- 0.58; Si-0.32; P-0.04; S- 0.03; Cr-1.12 and Fe- 96.84%. It is rapidly finding its applications in mold and die making industries, automotive industries, manufacturing of jigs and fixtures, press tools etc., where high compressive strength, abrasion resistance and hardness were needed. In theexperimental investigation the thickness of work piece was 20 mm and the cross section of the cut made was 20 mm x 20 mm. The gap between wire and work piece i.e. wire offset was constantly maintained at 0.035 mm by a computer controlled positioning system.

Figure 1 CNC Wire-cut EDM machine (Model: Ultra cut S2)

The most important performance measures in WEDM is Material removal rate (MRR). The material removal rate is the volume of material removed per unit time and it is calculated by using the following equation.
MRR = CR x h x b
Where, MRR = material removal rate (mm^3/min),
CR = Cutting rate (mm/min),
h = thickness of the material (mm).
b = width of cut = $2W_g + d$
Where, W_g= spark gap (wire offset) = 0.035mm
And d= diameter of wire is 0.25mm

The surface roughness (R_a) was measured with Surfcom 130A instrument and the work piece cross section was measured by Mitutoyo Digital Height Master having accuracy of 0.0001mm.The dimensional deviation (DD) of the measured dimension is calculated in percentage using the following expressions:
Dimension Deviation (DD) in % =

$$\frac{\text{Observed value - Actual value}}{\text{Actual value}} \times 100$$

The average gap current (I_g) is a measure of power supplied to the discharge gap. High value of current provides a high pulse energy and leads to formation of deeper discharge craters resulting in increased value of surface roughness. This is the actual value of the gap current required during machining. The amount of gap current drawn during sparking is read on WEDM machine monitor and is expressed in ampere.

Table 1 Process parameters and their levels

S.NO.	Process Parameters	Units	Symbol	Level 1	Level 2	Level 3
1	Pulse on Time (T_{on})	μsec	A	18	20	22
2	Pulse off Time (T_{off})	μsec	B	35	40	45
3	Wire Feed (WF)	m/min	C	8	10	12
4	Wire Tension (WT)	gm.	D	8	9	10
5	Spark Gap Set Voltage (SV)	Volt	E	20	25	30
6	Servo Feed (SF)	mm/min	F	2040	2060	2080

3. Methodology

Generally, the manufacturing industries focus their attention on material removal rate (MRR), dimensional accuracy and surface quality. In order to obtain optimal cutting parameters to achieve the desired results, manufacturing industries refer the machine technology manual and/or depends on operator experience. This traditional practice may lead to high manufacturing cost, low product quality and decrease in the productivity due to sub-optimal use of machining capability. Hence, a systematic approach is required to find out the optimum parametric settings to achieve the best results.

Taguchi method has found extensive applications in parametric optimization as it explores statistically designed experiments. The approach is economic as it requires limited number of experimental runs and results in reliable prediction outcome. Moreover, Taguchi technique allows optimal search at discrete levels of process parameters in the defined domain that can be easily implemented in the experimental setup. The main limitation of Taguchi technique is its incapability to deal with optimization of multiple conflicting objectives. Desirability function was used by Sait et al. (2009) to combine multiples responses into overall desirability value which was finally optimized by Taguchi technique. An alternate way to deal with multi criterion optimization problem in Taguchi technique is by TOPSIS.

TOPSIS is based on the principle that the chosen alternative should have the shortest distance from the ideal solution and the farthest distance from the negative ideal solution. Ideal solution is a solution that maximizes the benefit criteria and minimizes adverse criteria, whereas the negative ideal solution maximizes the adverse criteria and minimizes the benefit criteria. The steps involved in calculating the TOPSIS values are as follows (Singh et al., 2011):

Step 1: In this step a matrix is formed, the row of which is allocated to an alternative and column to an attribute. The decision making matrix thus developed is expressed as follows.

$$D = \begin{array}{c|ccccc|} & C_1 & & C_j & & C_n \\ \hline A_1 & a_{11} & \cdots & a_{1j} & \cdots & a_{1n} \\ \vdots & \vdots & \ddots & \vdots & \ddots & \vdots \\ A_i & a_{i1} & \cdots & a_{ij} & \cdots & a_{in} \\ \vdots & \vdots & \ddots & \vdots & \ddots & \vdots \\ A_m & a_{m1} & \cdots & a_{mj} & \cdots & a_{mn} \end{array}$$

Where, $A_i (i = 1, 2....m)$ represents the possible alternatives; $C_j (j = 1, 2....n)$ represents the attributes related with alternative performances, *j = 1, 2…n* and a_{ij} represents the performance of A_i with respect to attribute C_j.

Step 2: In this step normalized decision matrix is determined by the following relation.

$$r_{ij} = \frac{a_{ij}}{\sqrt{\sum_{i=1}^{m} a_{ij}^2}}$$

Where, r_{ij} is the normalized performance of $A_i$with respect to attribute C_j.

Step 3: Determine the weighted normalized decision matrix, $V = \left[b_{ij} \right] = w_j r_{ij}$

The weight of each attributes is calculated by the standard deviation method and the calculated values are presented in Table 3.The standard deviation method computes the objective weights of the attributes by the following relation.

$$w_j = \frac{\sigma_j}{\sum_{k=1}^{m} \sigma_k}$$

Where $\sum_{j=1}^{n} w_j = 1$

Step 4: The ideal (best) and negative ideal (worst) solutions were determined in this step. The best and worst solution are calculated as:

a) The best solution:

$$A^+ = \left\{ \left(\max_i b_{ij} \,\middle|\, j \in J \right), \left(\min_i b_{ij} \,\middle|\, j \in J^{'} \middle| i = 1,2....m \right) \right\}$$
$$= \left\{ b_1^+ .... \, b_j^+ .... \, b_n^+ \right\}$$

b) The worst solution:

$$A^- = \left\{ \left(\min_i b_{ij} \,\middle|\, j \in J \right), \left(\max_i b_{ij} \,\middle|\, j \in J^{'} \middle| i = 1,2....m \right) \right\}$$
$$= \left\{ b_1^- .... \, b_j^- .... \, b_n^- \right\}$$

$J = \left\{ j = 1,2.....n \middle| j \right\}$ Associated with the beneficial attributes;

$J^{'} = \left\{ j = 1,2.....n \middle| j \right\}$ Associated with non beneficial adverse attributes.

Step 5: The separation distance of each alternative from the ideal solution is determined with the help of following equations.

$$D_i^+ = \sqrt{\sum_{j=1}^{n} (b_{ij} - b_j^+)^2}$$

$$D_i^- = \sqrt{\sum_{j=1}^{n} (b_{ij} - b_j^-)^2}$$

Step 6: The relative closeness to the ideal solution is then calculated by the following relation

$$S_i^+ = \frac{D_i^-}{D_i^+ + D_i^-} \quad i{=}1{,}2....m{:}\ 0 \le S_i^+ \le 1$$

Step 7: The alternatives were finally arranged in the order and the one with largest relative closeness becomes the best choice.

In this work, S_i^+ for each product was used as Multi-Performance Characteristic Index (MPCI) and were optimized by Taguchi method.

The flow chart of entire methodology is presented in Figure 2 which is self-explanatory.

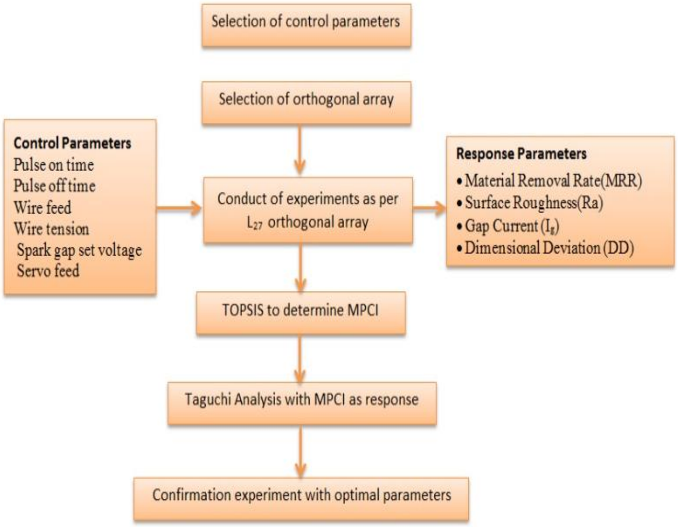

Figure 2 Flow chart of adopted methodology

4. Data Collection, Analysis and Optimization

Twenty seven experiments were conducted as per L_{27} standard orthogonal array to investigate the effect of process parameters on the response characteristics. Each experiment was performed thrice and the average value of the responses were calculated and are presented in Table 2. In the present study, design analysis has been carried out with Minitab statistical software.

The preference value for each experimental combination was determined by TOPSIS method outlined in section 3.

A decision matrix was formed by taking all the attributes of Table 2. Rows of the matrix are allocated to alternatives and columns to attributes. Each response of the matrix were normalized. The normalization is the process of converting the data in the range of zero to one. The reason to perform normalization is that the quality characteristics are often expressed in different units and have entirely different magnitudes because of which a quality characteristic may seem to contribute a lot to the total variability of the system just because its larger magnitudes while the effect of other may be ignored.

The weight for each response were then calculated by standard deviation (SD) method and the obtained values are presented in Table 3. These weights were then multiplied with respective normalized responses and the weighted normalized responses thus obtained are presented in Table 4.

Table 2 Taguchi's L_{27} standard orthogonal array and corresponding values of responses

Exp. No	T_{on}	T_{off}	WF	WT	SV	SF	MRR (mm^3/min)	Ra (μm)	Ig (amp)	DD (%)
1	1	1	1	1	1	1	4.987	1.54	3.5	0.075
2	1	1	1	1	2	2	6.013	1.28	4	0.061
3	1	1	1	1	3	3	7.167	1.13	4.3	0.042
4	1	2	2	2	1	1	3.654	1.49	3.2	0.045
5	1	2	2	2	2	2	3.910	1.22	3.3	0.041
6	1	2	2	2	3	3	5.564	1.13	3.9	0.030
7	1	3	3	3	1	1	1.474	1.31	2.3	0.042
8	1	3	3	3	2	2	1.987	1.16	2.4	0.030
9	1	3	3	3	3	3	3.013	1.02	3	0.020
10	2	1	2	3	1	2	12.859	2.21	5.4	0.075
11	2	1	2	3	2	3	11.846	2.19	5.2	0.071
12	2	1	2	3	3	1	7.936	1.82	4.5	0.055
13	2	2	3	1	1	2	12.474	2.14	5.3	0.085
14	2	2	3	1	2	3	8.449	1.72	4.8	0.065
15	2	2	3	1	3	1	3.333	1.48	3.1	0.053
16	2	3	1	2	1	2	7.936	2.03	4.5	0.075
17	2	3	1	2	2	3	4.603	1.8	3.4	0.064
18	2	3	1	2	3	1	2.628	1.38	2.8	0.043
19	3	1	3	2	1	3	15.872	2.98	5.8	0.120
20	3	1	3	2	2	1	11.974	2.56	5.2	0.098
21	3	1	3	2	3	2	13.949	2.39	5.5	0.085
22	3	2	1	3	1	3	15.038	2.64	5.6	0.110
23	3	2	1	3	2	1	8.641	2.45	4.9	0.095
24	3	2	1	3	3	2	9.923	2.05	5	0.065
25	3	3	2	1	1	3	11.077	2.54	5.1	0.105
26	3	3	2	1	2	1	6.269	2.17	4.2	0.085
27	3	3	2	1	3	2	5.179	1.63	3.7	0.080

Table 3 Weights of responses

Responses	W_j	Weight
MRR	W_1	0.09304
Ra	W_2	0.05552
Ig	W_3	0.04609
DD	W_4	0.06959

The ideal best and ideal worst solution were then determined and are presented in Table 5. A^+ indicates the ideal best value of the considered attribute among the values of the responses for various alternatives. In case of beneficial attributes, A^+ indicates the highest value of the responses whereas for non-beneficial attributes it indicates the lowest value of the responses. A^-indicates the ideal worst value of the considered attribute and the reverse relation of A^+ holds true for negative ideal worst value for beneficial as well as non-beneficial attribute.

Table 4 Weighted Normalized Value of responses

Exp. No	WMRR	Wra	Wig	WDD
1	0.0387	0.0326	0.0271	0.0530
2	0.0466	0.0271	0.0309	0.0431
3	0.0556	0.0239	0.0332	0.0297
4	0.0283	0.0315	0.0247	0.0318
5	0.0303	0.0258	0.0255	0.0289
6	0.0431	0.0239	0.0302	0.0212
7	0.0114	0.0277	0.0178	0.0297
8	0.0154	0.0246	0.0186	0.0212
9	0.0234	0.0216	0.0232	0.0141
10	0.0997	0.0468	0.0418	0.0530
11	0.0918	0.0464	0.0402	0.0501
12	0.0615	0.0385	0.0348	0.0388
13	0.0967	0.0453	0.0410	0.0600
14	0.0655	0.0364	0.0371	0.0459
15	0.0258	0.0313	0.0240	0.0374
16	0.0615	0.0430	0.0348	0.0530
17	0.0357	0.0381	0.0263	0.0452
18	0.0204	0.0292	0.0216	0.0304
19	0.1230	0.0631	0.0448	0.0847
20	0.0928	0.0542	0.0402	0.0692
21	0.1081	0.0506	0.0425	0.0600
22	0.1166	0.0559	0.0433	0.0777
23	0.0670	0.0519	0.0379	0.0671
24	0.0769	0.0434	0.0387	0.0459
25	0.0859	0.0538	0.0394	0.0741
26	0.0486	0.0459	0.0325	0.0600
27	0.0402	0.0345	0.0286	0.0565

Table 5 Ideal (Best) and Negative Ideal (Worst) Solutions for each criterion

Responses	MRR	Ra	Ig	DD
IDEAL BEST (A+)	0.12304	0.0216	0.04484	0.01412
IDEAL WORST (A-)	0.01143	0.0631	0.01778	0.08472

The separation distance of each alternative from the ideal one is determined by n-dimensional Euclidean distance. The calculated D_i^+ and D_i^- are shown in Table 6. The closeness rating (S_i^+) values were then calculated and found to lie between 0 and 1. This S_i^+ has been treated as MPCI (Multi Performance Closeness Index) of the surrogate responses for the proposed multi-response simulation-optimization problem.

Table 6 Ranking table for responses

Exp. No	MRR (mm^3/min)	R_a (µm)	Ig (amp)	DD (%)	D^+	D^-	Closeness (S_i^+)
1	4.987	1.54	3.5	0.075	0.0091	0.0028	0.2338
2	6.013	1.28	4	0.061	0.0069	0.0044	0.3915
3	7.167	1.13	4.3	0.042	0.0049	0.0068	0.5778
4	3.654	1.49	3.2	0.045	0.0098	0.0041	0.2969
5	3.910	1.22	3.3	0.041	0.0092	0.0049	0.3480
6	5.564	1.13	3.9	0.030	0.0067	0.0067	0.5028
7	1.474	1.31	2.3	0.042	0.0135	0.0043	0.2413
8	1.987	1.16	2.4	0.030	0.0123	0.0055	0.3099
9	3.013	1.02	3	0.020	0.0104	0.0069	0.3980
10	12.859	2.21	5.4	0.075	0.0027	0.0096	0.7813
11	11.846	2.19	5.2	0.071	0.0029	0.0084	0.7440
12	7.936	1.82	4.5	0.055	0.0048	0.0055	0.5352
13	12.474	2.14	5.3	0.085	0.0034	0.0087	0.7212
14	8.449	1.72	4.8	0.065	0.0046	0.0055	0.5453
15	3.333	1.48	3.1	0.053	0.0105	0.0035	0.2492
16	7.936	2.03	4.5	0.075	0.0059	0.0042	0.4186
17	4.603	1.8	3.4	0.064	0.0092	0.0028	0.2361
18	2.628	1.38	2.8	0.043	0.0114	0.0042	0.2691
19	15.872	2.98	5.8	0.120	0.0067	0.0132	0.6629
20	11.974	2.56	5.2	0.098	0.0050	0.0074	0.5969
21	13.949	2.39	5.5	0.085	0.0032	0.0107	0.7717
22	15.038	2.64	5.6	0.110	0.0053	0.0118	0.6919
23	8.641	2.45	4.9	0.095	0.0069	0.0039	0.3624
24	9.923	2.05	5	0.065	0.0036	0.0066	0.6446
25	11.077	2.54	5.1	0.105	0.0060	0.0062	0.5066
26	6.269	2.17	4.2	0.085	0.0084	0.0025	0.2296
27	5.179	1.63	3.7	0.080	0.0091	0.0026	0.2194

It is evident from Table 6 that experiment no. 10 corresponding to the factor level (A_2 B_1 $C_2 D_3$ E_1 F_2) has best closeness value among all the responses. Similarly the experiment no.27 corresponding to the factor level (A_3 B_3 C_2 D_1 E_3 F_2) has least closeness value. The best preference has been determined by optimizing MPCI using Taguchi technique. Figure 3 represents optimal parametric combination (A3 B1 C3 D3 E1 F3) evaluated from mean response plot for MPCI. Considering closeness value as representative response, analysis of variance (ANOVA) is then performed. For the appropriate fitting of S_i^+ , the non-significant terms (p-value greater than 0.05) are eliminated during ANOVA. The results of ANOVA for MPCI are presented in Table 7, wherefrom it is evident that the pulse off time (41.38%) is the most significant parameter followed by the servo feed (26.80%) and pulse-on- time (15.10%). Wire feed, wire tension and SV have a negligible effect on MPCI. The coefficient of determination (R^2) which indicates the percentage of total variation in the response explained by the terms in the model is found to be 85.63%.

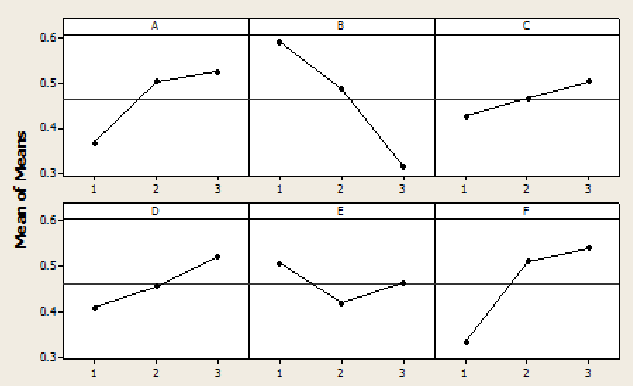

Figure 3 Main effect plot for means

Table 7 Analysis of variance (ANOVA)

Source	DF	Seq SS	Adj MS	F	P	% Contribution
T_{on}	2	0.125774	0.062887	6.44	0.010	15.10
T_{off}	2	0.344660	0.172330	17.65	0.000	41.38
WF	2	0.024970	0.012485	1.28	0.309	3.00
WT	2	0.059994	0.029997	3.07	0.078	7.20
SV	2	0.03475	0.017375	1.78	0.205	4.17
SF	2	0.223174	0.111587	11.43	0.001	26.80
Error	14	0.136710	0.009765			2.34
Total	26	0.950034				

The mean response and main effects in terms of MPCI were calculated and are reported in Table 8 and the main effect of process parameters plotted in Figure 3 shows that the optimal combination of process parameters A3 B1 C3 D3 E1 F3 yields the maximum value of MPCI for the WEDM of EN-31 steel. From the main effect plot, it is observed that the MPCI value increases with increase in T_{on}, SF and decreases with increase in T_{off}.

Table 8 Response table for cutting rate

Level	T_{on}	T_{off}	WF	WT	SV	SF
1	0.3667	0.5883	0.4251	0.4083	0.5061	0.3349
2	0.5000	0.4847	0.4626	0.4559	0.4182	0.5118
3	0.5207	0.3143	0.4996	0.5232	0.4631	0.5406
Delta	0.1540	0.2741	0.0745	0.1149	0.0879	0.2056
Rank	3	1	6	4	5	2

Optimal result has been validated by conducting a confirmatory test. Predicted value of MPCI is 0.7991 which is highest among all entries of MPCIs in Table 6. In confirmatory experiment the value came 0.7963 which is quiet close with the predicted value. So, proposed methodology has improved the quality.

5. Conclusions

The present work utilizes a hybrid of Taguchi technique and TOPSIS for simultaneous optimization of multiple characteristics in Wire EDM of EN-31 alloy. Following conclusions were drawn.

1. The optimal wire EDM parametric combination of T_{on} = 22 µs, T_{off} = 35 µs, WF = 12 m/min, WT = 10 gm., SV = 20 V, SF = 2080 mm/min has been determined by TOPSIS based MCDM approach.
2. ANOVA results revealed that the pulse off time is the most significant parameter followed by the servo feed and pulse-on-time. wire feed, wire tension and spark gap set voltage were found to have negligible effect on MPCI.
3. The entire analysis in this work revealed that Taguchi's quadratic loss function and TOPSIS concept can be efficiently combined towards a compatible multi-response optimization methodology.

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