ISSN: 0975-766X
CODEN: IJPTFI
Available Online through
Research Article
www.ijptonline.com

MULTI-ATTRIBUTE DECISION MAKING OF ELECTRIC DISCHARGE MACHINING ON AISI-D2 STEEL USING TOPSIS METHOD

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Received on: 19-01-2018 *Accepted on: 28-02-2018*

Abstract:

This paper aims to solve a multi-response parametric optimization problem of Electric discharge machine (EDM) using TOPSIS method. EDM is a non-conventional manufacturing process which is used to obtain a desired shape using electric discharges.L18 orthogonal array (OA) was used to optimize the process parameters in EDM. The various input parameters considered are discharge current (Ip), Pulse-on-time (Ton), Duty cycle (Tau), Voltage (V) and the performance measures include Material Removal rate (MRR), Surface Roughness (Ra).Multi-attribute decision making methods (MADM) namely Technique for order preference by similarity to ideal solution(TOPSIS) is used to solve the multi-objective optimization in EDM process. The optimal parameters obtained by using TOPSIS method can be used by the manufacturing companies to improve their productivity and quality to compete in the world market.

Keywords: Electric Discharge Machine, Multi-attribute decision making methods, TOPSIS, Material Removal rate, Surface Roughness.

1. Introduction:

Electric Discharge machining (EDM) is one of the most important non-conventional machining process which is used to manufacture desired shapes using electrical discharges. It is used mainly for hard materials that are difficult to machine like tungsten, carbides, nickel based alloys, tool steels etc. It is mainly used in mould making, die-making, medical & surgical, optical, automotive and aerospace industries (Froes, 1994). An important step in EDM process is the selection of optimum process parameters, otherwise it may lead to serious problems. Single optimization methods fail to recommend optimum input parameters in Electric discharge machining hence multi-objective optimizing techniques are used.

Methods like artificial neural network(ANN), response surface methodology(RSM), genetic algorithm(GA), Taguchis method, Technique for order preference by similarity to ideal solution(TOPSIS), grey-relational analysis (GRA) etc.

Multi-attribute decision making (MADM) methods are quite simpler and can be easily implemented according to Gadakh(2012). In solving multi criteria evaluation methods are used widely nowadays in solving both theoretical and practical problems Edmundas Zavadskas, Turskis et al., (2010). The main advantage of these MADM methods is to merge both the maximizing and minimizing problems into one single criterion. The integration method is called as normalization. It is basically a relative measure, so that the quantities are comparable. In the present study L18 orthogonal array (OA) approach was used for the experiments and TOPSIS method was applied to rank the alternatives.

2. Literature review:

A robust high-speed Electric discharge machining parameters with better machining capacity and high accuracy was proposed by Tzeng and Chen(2007) using a Taguchis approach. ANOVA was used to check the validity & reliability of the results. To study the impact of various shapes of copper electrodes on the response measures was studied by Sengottuvel et al.,(2013). A number of EDM modeling and optimization tools relating the process variables and output variables have been established in the past few decades.

Inspite of modeling EDM process to improve MRR and Surface roughness, still it is challenging and is restricted in expanding its application in technology by Wang. et.al.(1981)To optimize the process parameters in EDM process Fenggou and Dayong(2004) used Back propagation Neural network(BPNN) along with Genetic Algorithm (GA).Desirability approach was used to find the various optimal process parameters to get desired response, later ANOVA is done to check the significance of each parameter. To check the validity and accuracy Fuzzy logic model (FLM) was used. Using a rotary tool Aliakbari and Baseri(2012) applied Taguchis method for finding optimal parametric values. The significant parameters which affected MRR, Ra & electrode wear rate are current, tool geometry, pulse-on-time and tool rotation. Optimization of performance measures like surface roughness and material removal rate by RSM-GA approach was used by R.Das(2014). Gadakh(2012) solved a multi-objective optimization problem in Wire cut EDM using TOPSIS model. Fuzzy TOPSIS model was used by Maity and Chakraborty(2013)to solve grinding wheel abrasive material based on various process parameters. Analytical hierarchy process(AHP) and TOPSIS method were used to find the relative welding process parameters and evaluating various welding processes under high pressure by Jafarian and Vahdat (2012).Multi response optimization in green EDM process using a combination of Taguchis and TOPSIS method was developed by Sivipirakasam et al.(2011). For the Wire EDM (WEDM) the optimal process parameters using AHP and TOPSIS method was applied by Nayak et al.(2013).To find the weights for the input parameters AHP model was used, later the optimum input values were determined using the TOPSIS method. Ravi kumar kanwar and Mukesh Dubey(2016) used TOPSIS method to find optimum process parameters in EDM using ZrB2-SiC as the work-piece. Multi response optimization of process parameters in turning of GFRP using TOPSIS method was conducted by Arun Kumar Parida and Bharath Chandra Routar(2014). Tzeng(2008) used taguchis method for developing a robust high-speed Electric discharge machine process parameters. Tripathy and TripathyD.K(2015) used a combination of taguchis method ,TOPSIS and Grey relational analysis (GRA) to evaluate the effectiveness of optimizing multiple performance measures. Senthil et al.,(2014) applied TOPSIS method to solve a multi criteria optimization in EDM process.

3. Experimental Setup:

Experiments were conducted to optimize various process parameters on Surface roughness (Ra) and material removal rate (MRR). The work-piece chosen for this experiment is AISI D2 (DIN 1.2379) tool steel which is mostly used in the field to manufacture moulds. Copper electrode with a positive polarity is used. Electronica Electraplus PS 50ZNC die sinking machine is used to conduct the experiment. An electrolytic pure copper with a diameter of 30 mm was used as a tool electrode (positive polarity) and work piece materials used were steel square plates of dimensions 15 ×15 mm^2 and of thickness 4 mm. The dielectric fluid used is the Commercial grade EDM oil (specific gravity = 0.763, freezing point = 94˚C) . Side flushing with a pressure of 0.3 kgf/cm^2 was used. The machining time is 15 min.

Various inputs their units and levels are shown in table no.1

Figure 1: Electronica Electraplus PS 50ZNC.

Table-1: Input parameters, units and their levels.

Parameters	Units	Levels 1	Level 2	Level 3
Ip	A	5	10	15
Ton	μs	50	75	100
Tau		50	75	83
V	V	40	45	50

4. TOPSIS method:

TOPSIS method was developed in the year 1981 by Hwang and Yoon. It is a ranking method which attempts to choose the alternatives such that there is a shortest distance from the positive ideal solution and at the same time maintains farthest distance from the negative ideal solution. The positive ideal maximizes the benefits and minimizes the cost whereas the negative ideal maximizes the cost and minimizes the benefits. The steps in TOPSIS method are

Step 1:

Normalize the decision matrix using the formula:

$$rij = \frac{xij}{\sqrt{\sum_{i=1}^{m} xij^{2}}} \qquad (1)$$

Where i = 1,2...m and j= 1,2,…n.

xij represents the actual value of the i^{th} value of j^{th} experimental data and rij represents the corresponding normalized value.

Step 2: Calculate the weight for each response.

Step 3: Calculate the weighted normalized weighted decision matrix by multiplying the normalized matrix with the corresponding weights. The normalized weighted decision matrix is given by

$$Vij = W\boldsymbol{i}\, X\, rij \qquad (2)$$

Where i = 1,2…m and j= 1,2,…n. wj represents the weight of the j^{th} attribute.

Step 4 : Find the positive ideal solution and Negative ideal solution using the formula

$$V^{+} = (v_1^{+}, v_2^{+}, v_3^{+}, \ldots v_n^{+}) \text{ maximum values} \qquad (3)$$

$$V^{-} = (v_1^{-}, v_2^{-}, v_3^{-}, \ldots v_n^{-}) \text{ minimum values} \qquad (4)$$

Step 5 : Calculate the separation of each alternative from the positive ideal solution and negative ideal solution

$$S_i^{+} = \sqrt{\sum_{j=1}^{m} (V_{ij} - V_j^{+})^2} \qquad (5)$$

$$S_i^{-} = \sqrt{\sum_{j=1}^{m} (V_{ij} - V_j^{-})^2} \qquad (6)$$

where i= 1,2 3, …n

Step 6:

Calculate the closeness coefficient of each alternative (CCi) using the formula

$$CCi = \frac{S_i^{-}}{S_i^{+} + S_i^{-}} \qquad (7)$$

Table-2: Experimental data of the input parameters and response variables.

	Ip	Ton	tau	V	MRR	Ra
1	1	1	3	2	6.95346	8.049686
2	1	3	3	1	7.399165	8.539989
3	1	3	1	2	3.562573	3.64816
4	1	1	1	2	3.081959	3.301918

5	2	3	1	3	11.42434	3.991154
6	2	3	3	3	9.349651	8.461258
7	2	3	1	1	12.71239	7.180543
8	2	2	3	1	8.350307	8.556103
9	3	3	2	2	37.42504	7.880962
10	3	3	3	1	31.751	8.022454
11	3	3	1	3	47.43441	5.782782
12	3	2	3	3	27.93577	8.093774
13	3	1	1	1	36.12899	7.335341
14	3	2	2	2	30.90478	8.024015
15	2	2	1	1	9.738354	6.574
16	2	3	1	1	12.71239	7.180543
17	3	2	3	3	27.93577	8.093774
18	3	1	1	3	36.36999	4.436296

The experiment was conducted to find out the relationship between various input parameters and response measures. The input parameters include Discharge current (Ip), Pulse-on-time (Ton), Duty cycle(Tau), Voltage(V) and the output variables include Material removal rate (MRR) and Surface Roughness(Ra). A large number of experiments were conducted with the process parameters at different levels.

A small set of experiment were performed using Taguchis method which includes four input parameters at three different levels using L_{18} method. The set of response variables obtained using experimental data were recorded and applied for ordering using TOPSIS method. This method converts the multiple responses into a single response value.

The procedure of TOPSIS is as follows:

The objective is to evaluate 18 alternatives for MRR and Ra. In this problem, MRR is considered as the beneficial attribute (maximizing) and Ra is considered as non-beneficial (minimizing)

Table-3: Output parameters.

MRR	Ra
6.95346	8.049686
7.399165	8.539989
3.562573	3.64816
3.081959	3.301918
11.42434	3.991154
9.349651	8.461258
12.71239	7.180543
8.350307	8.556103
37.42504	7.880962
31.751	8.022454
47.43441	5.782782
27.93577	8.093774
36.12899	7.335341
30.90478	8.024015
9.738354	6.574
12.71239	7.180543
27.93577	8.093774
36.36999	4.436296

Step 1: Normalize the decision matrix using formula (1)

$$\begin{pmatrix} 0.040458 & 0.10746 \\ 0.017932 & 0.044079 \\ 0.020729 & 0.048701 \\ 0.017932 & 0.044079 \\ 0.066472 & 0.05328 \\ 0.054401 & 0.112954 \\ 0.073966 & 0.095857 \\ 0.048586 & 0.114221 \\ 0.217756 & 0.105208 \\ 0.184742 & 0.107097 \\ 0.275995 & 0.077198 \\ 0.217756 & 0.105208 \\ 0.210215 & 0.097924 \\ 0.179818 & 0.107117 \\ 0.056662 & 0.08776 \\ 0.073966 & 0.095857 \\ 0.162543 & 0.108049 \\ 0.211617 & 0.059223 \end{pmatrix}$$

Step 2 : Calculate the weight for each response. The relative importance of each attribute is assigned a value and the weights (Wij) which are considered are MRR= 0.6 and Ra = 0.4.

The weights are assigned based on the relative importance of each attribute, but the sum of weights should be unity.

Step 3: Calculate the weighted normalized weighted decision matrix using formula (2).

$$\begin{pmatrix} 0.040458 & 0.10746 \\ 0.017932 & 0.044079 \\ 0.020729 & 0.048701 \\ 0.017932 & 0.044079 \\ 0.066472 & 0.05328 \\ 0.054401 & 0.112954 \\ 0.073966 & 0.095857 \\ 0.048586 & 0.114221 \\ 0.217756 & 0.105208 \\ 0.184742 & 0.107097 \\ 0.275995 & 0.077198 \\ 0.217756 & 0.105208 \\ 0.210215 & 0.097924 \\ 0.179818 & 0.107117 \\ 0.056662 & 0.08776 \\ 0.073966 & 0.095857 \\ 0.162543 & 0.108049 \\ 0.211617 & 0.059223 \end{pmatrix}$$

Step 4: Find the positive ideal solution and Negative ideal solution using the formula (3) & (4)

Table-4: Positive ideal solution.

Positive ideal solution		
	MRR	Ra
V^+	0.275995	0.044079

Table-5: Negative ideal solution.

Negative ideal solution		
	MRR	Ra
V^-	0.017932	0.114221

Step 5: Calculate the separation of each alternative from the positive ideal solution and negative ideal solution using formula (5) & (6)

Table 6: Separation of each alternative from negative the positive ideal solution.

S_1^+	0.243915
S_2^+	0.258063
S_3^+	0.255308
S_4^+	0.258063
S_5^+	0.209725
S_6^+	0.232052
S_7^+	0.208558
S_8^+	0.237981
S_9^+	0.084431
S_{10}^+	0.110898
S_{11}^+	0.033119
S_{12}^+	0.084431
S_{13}^+	0.085008
S_{14}^+	0.114995
S_{15}^+	0.22364
S_{16}^+	0.208558
S_{17}^+	0.130244
S_{18}^+	0.066135

Table 7: Separation of each alternative from the ideal solution.

S_1^-	0.162168
S_2^-	0.012614
S_3^-	0.018243
S_4^-	0.012614
S_5^-	0.094775
S_6^-	0.183221
S_7^-	0.163794
S_8^-	0.182561
S_9^-	0.375715
S_{10}^-	0.328103
S_{11}^-	0.449023
S_{12}^-	0.375715
S_{13}^-	0.357156
S_{14}^-	0.320898
S_{15}^-	0.130061
S_{16}^-	0.163794
S_{17}^-	0.297154
S_{18}^-	0.336469

Step 6: Calculate the closeness coefficient of each alternative (CCi) using the formula (7)

Table 8: Closeness coefficient of each alternative

Closeness Coefficient	$Ci = Si^{-}/(Si^{+} + Si^{-})$	Rank
C_1	0.3993	13
C_2	0.0466	17
C_3	0.0667	16
C_4	0.0466	18
C_5	0.3112	15
C_6	0.4412	9
C_7	0.4399	10
C_8	0.4341	12
C_9	0.8165	3
C_{10}	0.7474	6
C_{11}	0.9313	1
C_{12}	0.8165	4
C_{13}	0.8077	5
C_{14}	0.7362	7
C_{15}	0.3677	14
C_{16}	0.4399	11
C_{17}	0.6953	8
C_{18}	0.8357	2

The relative closeness to ideal solutions are arranged in descending order for each alternative. The best values of input parameters are orderly arranged with reference to the performance measures.

5. Result and Discussion:

The relative closeness to ideal solutions are arranged in descending order. This can be arranged as 11-18-9-12-13-10-14-17-6-7-16-8-1-15-5-3-2-4. From the above table, it is clear that 11 is the first correct choice, 18 is the second choice, 9 is the third choice and 4 is the last choice of alternatives under the given conditions. The optimal choice of process parameters in EDM are Discharge current –15A, Pulse on time- 100μs, Duty cycle-50, Voltage-50 V and performance measures are MRR -47.4344103mm^3/min, Ra- 5.782782 μm.

Table 9: Optimum values of input-output parameters.

Ip	Ton	tau	V	MRR	Ra
15	100	50	50	47.4344103	5.782782

6. Conclusion:

In the present study the selection of optimal parameter settings is done in AISI D2 steel using TOPSIS method. Three levels of input parameters were taken for conducting the experiment by using L_{18} OA rather than conducting a lot of experiments Multiple parametric values were considered as a single performance measures using TOPSIS method. The results of TOPSIS for various experiments are shown in table 10.

Table 10: Ordered results from TOPSIS method.

Experiment no.	Levels of input parameters (Ip	Ton	Tau	V)
11	3	3	1	3
18	3	1	1	3
9	3	3	2	2
12	3	2	3	3
13	3	1	1	1
10	3	3	3	1
14	3	2	2	2
17	3	2	3	3

6	2	3	3	3
7	2	3	1	1
16	2	3	1	1
8	2	2	3	1
1	1	1	3	2
15	2	2	1	1
5	2	3	1	3
3	1	3	1	2
2	1	3	3	1
4	1	1	1	2

The results suggest that higher values of Discharge current, Pulse on-time, Voltage and low value of Duty cycle will yield optimal result for experiment no. 11. TOPSIS method is found be effective and had practical tendency. TOPSIS method considers all the attributes based on their relative importance. Manufacturing industries can achieve higher productivity and better quality considering the optimum input parameters, which would help them to compete in the world market.

Conflict of Interest: The authors do not have any conflict of interest.

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