Application of TOPSIS for Optimization of Operating Parameters in Micro-EDM

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***Abstract*: The efficiency of a manufacturing process strongly depends on the selection of appropriate process parameters. Most of the machining parameters are determined by human judgements based on experience or hand book values some time. This does not ensure the optimal or near optimal performance. The selection of most suitable cutting parameters is a multi-criteria decision making problem which is based on the several qualitative and even conflicting factors involved. In the present work, Experiments have been conducted by considering three parameters such as discharge current, pulse on time and pulse off time each at three levels for obtaining responses like material removal rate, tool wear rate and overcut. Taguchi L9 orthogonal array is used as it helps to collect information regarding the response parameters with less number of experimental runs. This Current work demonstrates the application of TOPSIS method for determination of suitable machining parameters for making micro holes in Monel 400 Alloy.**

***Keywords*: Optimization, TOPSIS, micro EDM, Process parameters.**

1. Introduction

Micromachining is the most fundamental technology used for the production of miniaturized parts and components [1]. Micro-EDM has been known as one of the indispensible micromachining techniques with obvious advantages of machining complex structures with high aspect ratios, high precision, and accuracy irrespective of workpiece material's hardness and toughness [2]. Choosing the most suitable machining parameters for manufacturing process is the essence of any manufacturing process, in order to make high quality parts at reduced cost for the best performance. An improper parameter selection directly affects the productivity, lead time and cost of the product. Generally, this can be carried out by relying heavily on the operator's experience or crisp technological data provided by the EDM machine manufacturers. The information given by the manufacturers is inadequate and also applicable for regular materials.

The work material used in this study is a Monel 400 alloy which is a most promising and commonly used nickel based alloys due their excellent corrosion resistance and toughness over a wide temperature range. Monel has been widely used in chemical industries, food processing industries, heat exchanger tubing, nuclear reactors, sub marine and ship propellers etc. [3]. Many studies have been carried out previously on optimizing process parameters in the domain of EDM by classical methods [4]-[6]. Multi Criteria Decision Making (MCDM) has found acceptance in areas of operations research and management science and the discipline has created several methodologies. Gadakh [7] presented techniques for order preference by similarity to ideal solution (TOPSIS) method for solving multiple criteria optimization problem in WEDM process. TIWARY [8] used combined approach of response surface methodology and fuzzy technique for order preference by TOPSIS for machining of titanium super alloys. In this study an effort has been taken to select optimum process parameters for making micro hole in a Monel metal specimen.

2. Taguchi Technique

The Taguchi technique integrated with experimental design has been significantly utilized in the different zones of engineering field to enhance the efficiency of the manufacturing processes [9]. Taguchi provides standardized methods for each of these DoE application steps. This method incorporated with unique design of orthogonal arrays to assess the impact of the entire process parameter space with only a minimum number of experiments [10]. The purpose of conducting an orthogonal experiment is to find the optimum level for each factor. The optimal process parameters obtained from the Taguchi method are insensitive to the variation of environmental conditions and other noise factors. However, originally, the Taguchi method was designed to optimize single-performance characteristics. Optimization of multiple performance characteristics is not straight forward and significantly more confused than that of single-performance characteristics. In this study to solve the multiple performance characteristics problems, the Taguchi method is coupled with TOPSIS.

A. TOPSIS Method

TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) is a unique and multiple criteria Decision making method to determine solutions from a limited set of alternatives. It is one of the MCDM methods and initially developed by Hwang and Yoon (1981), and further refined by Hwang, Lai and Liu in 1993[11]. The fundamental principle of

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this method is based on the idea that the selected alternative that has the nearest distance from Positive ideal solution and on the other side the farthest distance from the negative ideal solution. The positive ideal solution maximizes the benefit criteria and minimizes cost criteria or attributes whereas the negative ideal solution maximizes the cost criteria and minimizes the benefit criteria [12]-[13]. In other words, the positive ideal solution is composed of all best values attainable of criteria, whereas the negative ideal solution consists of all worst values attainable of criteria. As our aim of the study is to get maximum material removal rate and minimum tool wear rate. The steps involved in the TOPSIS method are as follows,

$$D = \begin{matrix} A_1 \\ A_2 \\ A_3 \end{matrix} \begin{pmatrix} X_{11} & X_{12} & X_{13} \\ X_{21} & X_{22} & X_{23} \\ X_{31} & X_{32} & X_{33} \end{pmatrix}$$

Step 1: To transform different scales and units among different criteria into common measurable units to permit comparisons across the criteria. Assume f_{ij} to be of the evaluation matrix R of alternative j under evaluation criterion i then an element r_{ij} of the normalized evaluation matrix R can be computed by many standardised methods to achieve this objective.

$$r_{ij} = \frac{f_{ij}}{\sqrt{\sum_{j-1}^{j} f_{ij}^2}} \quad j= 1, 2, 3.....j,\ i= 1,2, 3.....n \qquad (1)$$

Step 2: The weighted normalized decision matrix can be determined by multiplying the normalized evaluation matrix r_{ij} with its associated weight w_i to obtain the result.

$$v_{ij} = w_i * r_{ij} \quad j= 1, 2, 3 ......j,\ i= 1,2, 3.....n \qquad (2)$$

where w_i is given by $\sum_{i-1}^{n} w_i = 1$

Step 3: To determine the positive and negative ideal solutions: the positive ideal solution A^* indicates the most preferable alternative and the negative ideal solution A^- indicate the least preferable alternative.

$$A^* = \{v_i^* .. v_i^*\} = \{(\max v_{ij} \mid i \in I)(\min v_{ij} \mid i \in I)\} \qquad (3)$$

$$A^- = \{v_i^- .. v_i^-\} = \{(\min v_{ij} \mid i \in I)(\max v_{ij} \mid i \in I)\} \qquad (4)$$

Step 4: After determining the ideal solution, the distance from the positive and negative ideal for each alternative can be measured by

$$D_j^* = \sqrt{\sum_{i=1}^{n} (v_{ij} - v_i^*)^2} \quad j= 1, 2, 3, ..J \qquad (5)$$

$$D_j^- = \sqrt{\sum_{i=1}^{n} (v_{ij} - v_i^-)^2} \quad j= 1, 2, 3,......J \qquad (6)$$

Step 5: To find the relative closeness of the i^th^ alternative with respect to ideal solution A+ is defined as

$$CC_j^* = \frac{D_j^-}{D_j^* + D_j^-}, \qquad j= 1, 2, 3, ... J \qquad (7)$$

Step 6: Ranking the priority of alternatives according to the preference value.

3. Experimental Procedure

The process parameters, selected for the present investigation, are Discharge Current, Pulse on time and Pulse off time which have significant influence is on the EDM process performances. Their influence on the Material Removal Rate, Tool wear rate and Over cut are measured through the set of the planned experiments based on L_9 orthogonal array of Taguchi's design of experiments. Table.1 shows the factors and their levels in coded and actual values.

Table 1
Process parameters and their levels

Parameters	Factors	Levels		
		1	2	3
Pulse off time (µs)	A	2	3	4
Discharge current (a)	B	4	5	6
Pulse on time (µs)	C	4	5	6

Fig. 1. Photograph of the experimental apparatus of the EDM

Commercially obtained Monel 400 alloy having thickness of 10mm were used as a work piece material. The chemical composition (weight %) of Monel 400 alloys is as follows: C: 0.047, Si: 0.172, Mn: 1.03, P: 0.012, S: 0.01, Cr: 0.1, Mo: 0.1, Fe: 1.66, V: 0.029, W: 0.1, Cu: 29.24, Al: 0.01, Co: 0.103, Nb: 0.1, Ti: 0.047, Mg: 0.031, and Ni: 67.4. Brass electrode (Cu-61.8%, Zn-37.2% and impurities-1.0%) of Ø 0.5mm was selected to drill holes in the work piece. The output response characteristics (Material Removal Rate, Tool wear rate and Over cut) have been evaluated through the experiments presented in Table 2.

Table 2
Experimental results

Trial Nos	A	B	C	Material Removal Rate (mm^3/sec)	Tool wear rate (mm^3/sec)	Overcut (µm)
1	1	1	1	0.003530	0.019727	9.75
2	1	2	2	0.008750	0.052589	12.33
3	1	3	3	0.010101	0.07985	16.92
4	2	1	2	0.004250	0.034044	8.58
5	2	2	3	0.007760	0.030226	16.41
6	2	3	1	0.006900	0.05934	18.43
7	3	1	3	0.004600	0.035044	12.75
8	3	2	1	0.005100	0.03404	12.35
9	3	3	2	0.007460	0.056247	14.85

4. Results and Discussion

In Taguchi based TOPSIS methodology, the data which is obtained from experiments have been normalized using equation (1), The normalized data are presented in table 3.

Table 3
Normalised decision matrix

Sl. No.	Material Removal Rate	Tool wear rate	Overcut
1	0.172294	0.137195	0.232966
2	0.427076	0.365736	0.294613
3	0.493016	0.55533	0.404286
4	0.207437	0.236765	0.20501
5	0.378755	0.210212	0.3921
6	0.33678	0.41269	0.440366
7	0.22452	0.243719	0.304648
8	0.248924	0.236737	0.29509
9	0.364112	0.391179	0.354825

The weighted normalised decision matrix has been obtained by multiplying the elements of normalised decision matrix with weight. For all the three performance measures, both are given equal weights. By applying equation (3) and (4) the positive ideal solution and negative ideal solution are computed and presented in table 4.

Table 4
Positive and negative ideal solution

Criteria	Material Removal Rate	Tool wear rate	Overcut
Positive ideal solution	0.246508	0.034299	0.023613
Negative ideal solution	0.086147	0.138832	0.157581

The closeness coefficient (CC) for each experimental run is computed by utilizing the equation (7). The Closeness co-efficient is also termed as overall performance Score which has been further optimized by Taguchi method. Finally, the ranking is done according to the overall performance score for each experimental run and presented in table 5.

The Mean response table for overall performance score is presented in table 6.

It is observed that the discharge current is the predominant factor followed by pulse on time and pulse off time. The main effects plot for OPS is shown in figure 2.

Table 5
Calculated separation measures and relative closeness co efficient

S. No.	S_i^*	S'_i	C_i^*	Rank
1	0.164057	0.144207	0.467803	7
2	0.082798	0.159746	0.658627	1
3	0.130104	0.170026	0.566508	3
4	0.147555	0.134005	0.475937	5
5	0.095573	0.147131	0.606215	2
6	0.135368	0.101443	0.428371	9
7	0.146606	0.115671	0.441026	8
8	0.134278	0.121802	0.475641	6
9	0.111458	0.125005	0.528645	4

Table 6
Response table for overall performance score

Level	T_{off}	Current	T_{on}
1	0.5643	0.0825	0.4573
2	0.5035	0.5802	0.5544
3	0.4818	0.5078	0.5379
Delta	0.0825	0.1186	0.0971
Rank	3	1	2

Fig. 2. Main Effects plot for overall performance score

5. Conclusion

This paper demonstrates the application TOPSIS method which helps the process engineers in selecting the most optimum process parameter from a large number of conflicting factors for performing EDM on Monel 400 alloy. Results obtained from the relative closeness to the ideal solutions were used to rank the preference order in the selection of optimum process parameter for machining Monel metal in EDM Process. It is noticed that the best choice of optimum process parameters is Discharge current 5amps, pulse on time 5µs and pulse of time 2µs which gives maximum metal removal rate (0.008750 mm^3/sec), minimum tool wear rate (0.052589 mm^3/sec) and minimum over cut (12.33 µm). It clearly shows the application of TOPSIS is an effective technique in order to provide a more realistic solution to the process of selecting optimum process parameters.

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