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Attribute based Coding, Evaluation and Optimum Selection of Parameters for EDM System

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Abstract: *This study presents a methodology for evaluation, ranking and selection of parameters of Electric Discharge Machine by using MADM approach. A three stage selection procedure is used for identification of pertinent attributes and ranking is done with TOPSIS and graphical methods (Line graph and Spider Diagram. Then results of MADM approach are validated by comparing with results of experimental work done with ANOVA. This study also presents methodology for calculating the permanent function and numerical index of EDM system by dividing EDM into four subsystems and interactions between subsystems are represented into matrix form. This study provides a general formula which can be applied to any EDM system.*
Keywords: *EDM, MADM & TOPSIS.*

I. Introduction

Electrical discharge machining (EDM) is a thermal processwith a complex metal-removal mechanism, involvingthe formation of a plasma channel between the tool andworkpiece. It has proved especially valuable in the machiningof super-tough, electrically conductive materials such asthe new space-age alloys that are difficult to machine byconventional methods [1].The wordunconventional is used in sense that the metal like tungsten, hardened stainless steel tantalum,some high strength steel alloys etc. are such that they can’t be machined by conventional methodbut require some special technique . The conventional methods in spite of recent advancementsare inadequate to machine such materials from stand point of economic production [2]. In EDM process there are large number of parameters which affect MRR and TWR. Selection of optimum parameters is very difficult task. For this purpose MADM – TOPSIS approach can be used.It identifiesthe various attributes needing to be considered for the optimum evaluation and selection of parameters of EDM.It also provides a coding system for depicting the various attributes. It recognizesthe need for, and processes the information about, relative importance of attributes for a givenapplication without which inter-attribute comparison is not possible. It presents the result ofthe information processing in terms of a merit value, which is used to rank the parametersin the orderof their suitability for the given application[3]. In recent times a few papers have been published in differentareas using the proposed methodology called multipleattributedecision making (MADM) approach. They areoptimum selection of robots, optimum selection ofcomposite product system ,selection of Mechatronic system, optimum selection of thermal power plants.

II. Indentification Of Attributes

A system consists of various sub system. All these sub system are interdependent and interrelated to each other.[4]. The performance, cost, behavior, etc of product or process depends upon the performance of each sub or sub–sub system. One of the critical factors to evaluate system is the identification of attributes affecting its characteristics performance. [5].Precise identification of attributes is highly critical in comparing, evaluation and selection of systems. When a user goes to a supplier for purchase of a new system the identification of the critical attributes become highly significant.A EDM system consists of various sub systems. All these sub system are interdependent and interrelated to each other. The performance, cost, behavior, etc of product or process depends upon the performance of each sub or sub–sub system. One of the critical factors to evaluate system is the identification of attributes affecting its characteristics performance. Number of attributes related to EDM system are identified and classified into different categories. This is shown with help of cause and effect diagram.

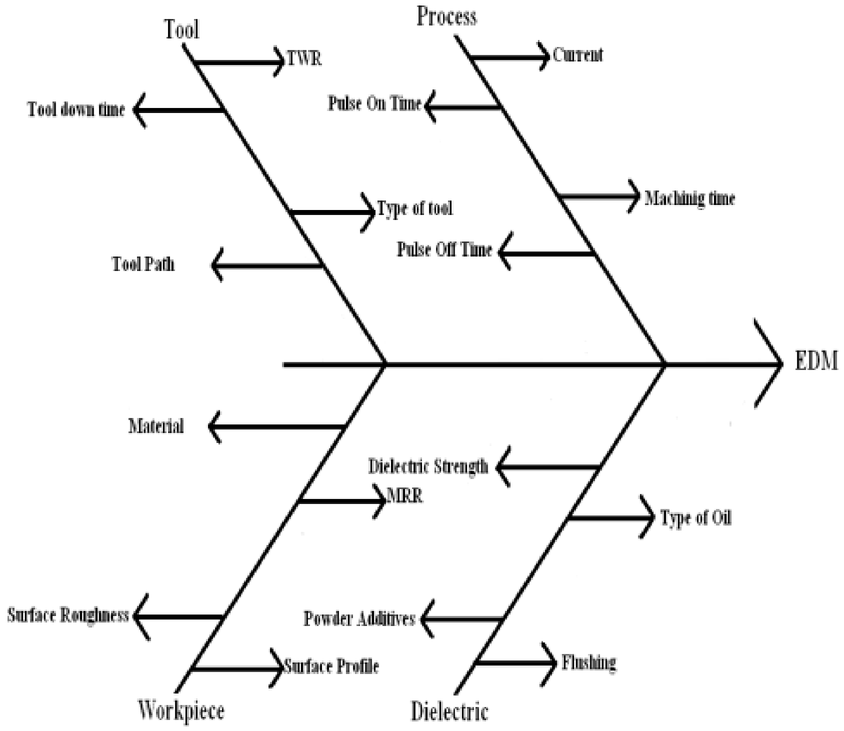

Fig.1. Cause and Effect Diagram

Classification of attributes

All the EDM attributes are broadly classified into five categories:

1. Process based attributes
2. Work piece based attributes
3. Tool and dielectric medium based attributes.
4. Analysis and modeling based attributes
5. General attributes

Usefulness of Identification of attributes

a) Usefulness to the manufacturer

The quantification and monitoring of the attribute magnitudes help the manufacturer to control them closely so that he fulfils the demand of the user precisely. Moreover, he finds out the market trend by observing the attributes magnitudes. It helps the manufacturer to modify his product to suit the future needs of the user. The EDM manufacturer uses these attributes for the SWOT (Strength–Weakness–Opportunity–Threat) analysis of EDM.

b) Usefulness to the designer

For the designer at conceptual design stage, identification helps to generate various alternative designs, which is developed as modular EDM. Using the modular EDM approach, the optimum EDM according to the market requirements is designed in very little time. He identifies the critical attributes, which directly affects the performance. The designer changes these critical attributes and monitors them to control particular parameters so that the required performance obtained from the EDM. Designer use these attributes for cause and effect analysis, where he find out the effects ofmanipulating these attributes on the EDM performance.

c) Usefulness to the user

Identification of the attributes helps the user for the data storage and its retrieval. It generatesthe computerized data, which is used in different formats for different purposes by differentpeople in the organization. It helps the user to select the best possible EDM for theparticular application whenever it is required.

Coding Scheme

After the identification of the attributes the next step is to assign codes to the attributes which is either a numerical value or an alphabet [6]. This is done under the coding scheme which is very important as it gives all the detailed information about the attributes. The attributes are qualitative and quantitative in nature. The qualitative attributes are non-deterministic whereas the quantitative attributes are deterministic in nature. In this study the quantitative attributes are given codes on an interval scale of 0-5, where 0 indicates that no information is available about the attribute and 5 indicates the best information and this attribute is used in experimentation.

Selection Procedure:

In EDM we can use large number of parameters i.e. we can use different current levels, different pulse on time and pulse off time, different work pieces, different tools etc. But the selection of the best possible parameters for a given application is extremely important. The main emphasis is to select set of parameters which would give us maximum MRR, minimum TWR and desired surface finish. So after consideration and evaluation of all the parameters available we have to select best set of parameters for given application. For example in this study we have to select best tool from given three tools (Cu, CuW and Brass) for D3 workpiece. Results for MRR, TWR and Surface roughness are calculated after conducting experiments on EDM machine (Model T- 3822M). The data is taken for the three different tools for the D3 workpiece. In following procedure ranking and selection of tools is done for D3 workpiece.

S.no	Tool	SR (μm	MRR (mm^3/min)	TWR (mm^3/min)
1	Cu	8.7	5.2630	0.337070
2	CuW	7.4	3.0263	0.114280
3	Brass	5.1	0.7890	0.352900

Table1: Data for all three Tools

The procedure for the selection of the tool is as follows:

Step-1: Formation of the decision matrix '**D,** in which the rows of the matrix are candidate tool and the columns are their attribute values.

$$D = \begin{matrix} 8.27 & 5.2630 & 0.337070 \\ 7.40 & 3.0263 & 0.114280 \\ 5.10 & 0.7890 & 0.352900 \end{matrix}$$

Step 2: In this step the normalized specification matrix is calculated which helps to provide the dimensionless elements of the matrix. It is denoted by N**.**

$$N = \begin{matrix} 0.68 & 0.86 & 0.67 \\ 0.61 & 0.49 & 0.23 \\ 0.42 & 0.13 & 0.70 \end{matrix}$$

Step 3: Construction of relative importance matrix from decision matrix. A group of experts and the user will detemine the importance of one attribute over the other. Now for selected application we define this as aij= wi/wj, where this ratio represents the relative importance of ithattribute with respect to the jthattribute corresponding to the particular. Mostly this will be obtain by team of experts by preparing the questionnaires and send it to other team of experts of same area and prepare a database matrix by calculating the average values and put into the relative importance matrix. The relative importance matrix which is formed from the decision matrix is shown here.

$$A = \begin{matrix} 1 & 0.77 & 1.4 \\ 1.28 & 1 & 1.8 \\ 0.71 & 0.55 & 1 \end{matrix}$$

Step 4: Now the maximum eigen value of the relative importance matrix R is to be found out. Therefore (A-λmaxI) is equal to

$$\begin{matrix} 1-\lambda & 0.77 & 1.4 \\ 1.28 & 1-\lambda & 1.8 \end{matrix}$$

0.71 0.55 1-λ

Also, (A-λmaxI) = 0 , On solving the above matrix we have λmax= 2.9898 so take λmax= 3 Therefore, Now (A-λmaxI) =

-2	0.77	1.4
1.28	-2	1.8
0.71	0.55	-2

Step 5: In this step the weights for each attribute using the eigen vector associated with themaximum eigen value are calculated. This can be represented by the equation,

(A - λmaxI) w = 0

-2 0.77 1.4 w_1
1.28 -2 1.8 w_2 = 0
0.71 0.55 -2 w_3

Also we know that, $w_1 + w_2 + w_3 = 1$

On solving this above matrix we have,

$w_1 = 0.35$ $w_2 = 0.39$ $w_3 = 0.26$

Step 6: In this step the weighted normalized specification matrix is calculated. It is denotedby **V.**

V =

0.2108	0.3268	0.1541
0.1891	0.1862	0.0529
0.1302	0.0494	0.1610

The weighted normalized matrix involves both the attribute values and ~~the~~ir relative importance to each other. So this matrix provides a very good basis for the comparison of the attributes with each other and with the benchmark tool.

TOPSIS method for ranking:

The weighted normalized attributes for the positive and negative benchmark tools are obtained which are as follows:

V^+ = (0.2108, 0.3268, 0.1610)

V^- = (0.1302, 0.0494, 0.0529)

Now from the formulas above mentioned in the explanatory part of the TOPSIS method and relative closeness to the ideal solution can be calculated and the values for the same are as follows:

$S_1^+ = 0.0069$ $S_1^- = 0.3060$ $C_1^* = 0.9779$

$S_2^+ = 0.1786$ $S_2^- = 0.1489$ $C_2^* = 0.4546$

$S_3^+ = 0.2888$ $S_3^- = 0.1081$ $C_3^* = 0.2723$

As the C* value of the first tool is the highest therefore it is the best Tool and C* value of third Tool is the lowest so it is the worst tool.

S. no	Tool	Value of C^*	Rank
1	Cu	0.9779	1^{st}
2	CuW	0.4546	2^{nd}
3	Brass	0.2723	3^{rd}

Table2. Ranking using TOPSIS method

As shown in above table Copper is the highest ranked tool so it is the best possible tool for the EDM process and Brass is worst tool for EDM machining.

Graphical technique:

After using the TOPSIS procedure for the ranking and selection of the tool. We also can use two graphical techniques i.e. Line graph and Spider graph for the ranking and thus final selection of the tool.

Line Graph: A graph is drawn for the weighted normalized matrix between the weighted normalized values and the attributes for different tools as shown in fig. The area under the curve in the line diagram for each system is calculated and is further used to calculate COS^{VL} which is used to compare the systems. The system with the highest value of COS^{VL} is ranked highest and the system with the least value of COS^{VL} is ranked last. The COS^{VL} for the line diagram is calculated by the following formulae:

$COS^{VL} = AV_i^{\,L} / AV_{+B}^{\,L}$

$$AV_i^{\,L} = (p_{i,1} + 2\,(p_{i,2} + \_\_ + p_{i,j} + \_\_\, p_{i,n-1}) + p_{i,n}) / 2$$

Where, p i,j– The weighted normalized value of jthattribute in ithsystem

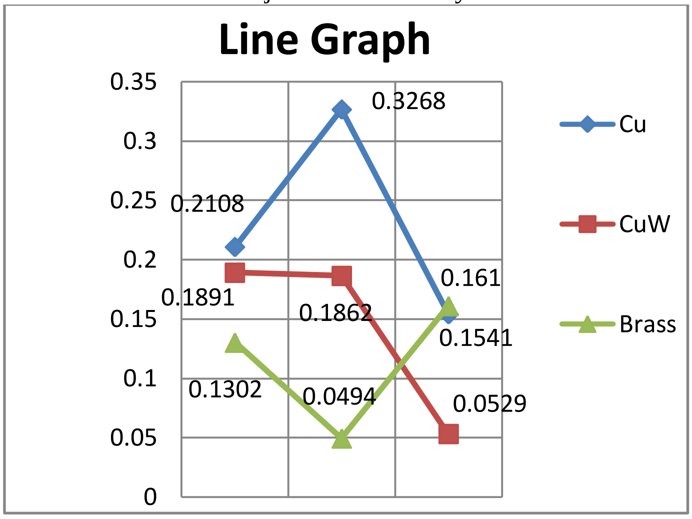

Fig.2. Line Graph of different tools

On the basis of the line diagram shown above the COS^{VL} for each tool is calculated and hence ranking of the three different tools is done.

$$AV_1^{\,L} = 0.5092$$
$$AV_2^{\,L} = 0.3072$$
$$AV_3^{\,L} = 0.1950$$
$$AV_{+B}^{\,L} = 0.5127$$
$$COS_1 = 0.9932$$
$$COS_2 = 0.5991$$
$$COS_3 = 0.3803$$

Ranking based on line graph:

S.no	Name of tool	COS^{VL}	Rank
1.	Cu	0.9932	1^{st}
2.	CuW	0.5991	2^{nd}
3.	Brass	0.3803	3^{rd}

Table 3. Ranking of EDM tools based on the COS in line diagram

We can see from the table that Cu is the highest ranked tool, CuW is the second ranked and Brass is lowest ranked tool. So we can conclude that Cu is best tool and Brass is the worst tool.

Spider graph representation:

The area under the curve for Tools in a spider graph representation is calculated by the following formulae:

$$\text{Area} = (\sin \theta/2) \sum_{j=1}^{n} p_{i,j} \times p_{i,j+1} \text{ where } p_{i,n+1} = p_{i,1} \text{ and } \theta = 360/ n$$

The spider diagram representation for three tools and their attribute values is shown in figure.

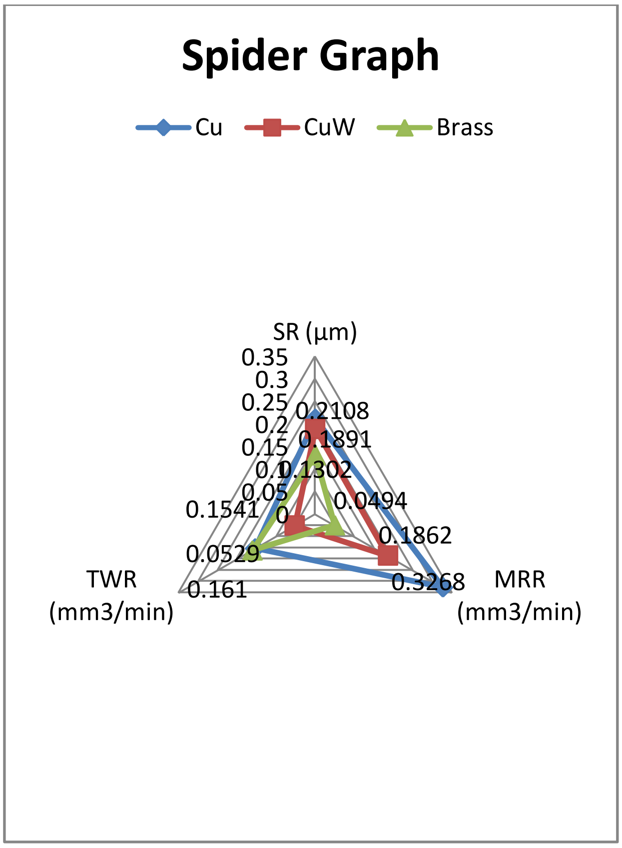

Fig.3. Spider graph for EDM tools.

On the basis of the spider diagram shown above the area under the curve for every Tool is calculated and hence ranking of the three different Tools is done.

Ranking based on spider graph:
Tool which has highest area should be ranked first and tool with lowest area should be ranked last.

S. no	Name of Tool	Area under the curve	Rank
1.	Cu	0.1314	1st
2.	CuW	0.0476	2nd
3.	Brass	0.0306	3rd

Table 4. Ranking of Tools based on the area under the curve in spider diagram

From above table it is clear that Cu is best tool and Brass is the worst tool.

1. Benefits of the proposed methodology

1. This proposed methodology will help in optimization of parameters of EDM system.
2. There are number of parameters and moreover each parameter has number of levels, so selection of best levels of parameter is difficult task. This methodology will help in solving this problem.
3. This methodology will help in validation of results of ANOVA.
4. This methodology will help in increasing MRR and reducing TWR and SR.
5. It provides methodology for evaluation, selection and ranking of parameters of EDM system.

III. Discussion

In this chapter we applied MADM TOPSIS method for evaluation, ranking and selection of Tool for EDM process. As we know that EDM is a advanced machining process which means it is a costlier process so selection of best parameters is very important for economical feasibility of this process. We can use substantial number of parameters for this process like Current level, Pulse on time, pulse off time, type of work pieces and type of tools. So to choose a best set of parameters is a difficult task. To solve this problem we mainly use ANOVA and DOE techniques but these techniques provides us data and graphs from which user has to make decision. But MADM TOPSIS method provide us ranking of different parameters which makes the selection of parameters very easy. As in this study the problem of selection of best tool is solved. Three tools made of copper, copper tungsten and brass are considered and decision matrix is made from experimental data by taking Surface roughness, Material Removal Rate and Tool wear Rate as Attributes corresponding to these three tools. After applying this method Copper proves to be best tool and brass proves to be worst tool.

IV. Results

In this chapter MADM TOPSIS method is applied for evaluation, selection and ranking of tools for EDM process. Ranking is done by TOPSIS C^* values, COS^{VL} values of line graphs and area under the spider diagram. Results of these techniques is shown in tables above in this study. In all three methods of ranking Copper (Cu) proves to be best tool , Copper Tungsten (CuW) got 2^{nd} rank and Brass proves to be worst tool. All three techniques i.e. TOPSIS, Line Graph and Spider Diagram gives same results. This results are validated by applying ANOVA to experimental data used for making decision matrix. ANOVA also gives same trends. So results are unanimous and are correct.

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