Optimization of EDM Process withTaguchi, Grey Relational Analysis and Fuzzy Logic Technique

[1]Mr Ganesh Pandurang Jadhav, [2]Dr. Narendra Narve, [3]Prof. Vyankatesh Mundhe

[1]P.G.Student, [2,3]Professor
Department Of Mechanical engineering
JSPM Bhagwant Institute of Technology, Barshi, Solapur, Maharashtra, India

Abstract- **In this document observed that application of the Taguchi method with fuzzy logic for optimizing the electrical discharge machining process with multiple performance characteristics. A multi-response performance index is used to solve the electrical discharge machining process with multiple performance characteristics. It described the use of the grey-fuzzy logic based on orthogonal array for optimizing the electrical discharge machining process with multi-response has been reported. An orthogonal array, grey relational generating, grey relational coefficient, grey-fuzzy reasoning grade and analysis of variance are applied to study the performance characteristics of the machining process.**

IndexTerms**—GRA (Grey relational analysis), Fuzzy logic, Orthogonal array, EDM**

I. Introduction

In electrical discharge machining, it is important to select machining parameters for achieving optimal machining performance [1]. Usually, the desired machining parameters are determined based on experience or handbook values. However, it does not ensure that the selected machining parameters result in optimal or near optimal machining performance for that particular electrical discharge machine and environment. The Taguchi method can optimize the performance characteristic through the settings of process parameters and reduce the sensitivity of the system performance to sources of variation. As a result, the Taguchi method has become a powerful design of experiment method [2–4].

In electrical discharge machining (EDM), it is important to select machining parameters for achieving optimal machining performance. Usually, the desired machining parameters are determined based on experience or on handbook values. However, this does not ensure that the selected machining parameters result in optimal or near optimal machining performance for that particular electrical discharge machine and environment. It has been shown that the grey-based Taguchi method can optimize the multi-response processes through the settings of the process parameters [5]; but, in this paper, the grey relational analysis is not used for calculating the S/N ratio. This is because grey relational analysis based on the grey system theory [6] is used for solving the complicated interrelationships among the multiple responses. A grey relational grade is then obtained for analysing the relational. The theory of fuzzy logics, initiated by Zadeh in 1965 [7] has proven to be useful for dealing with uncertain and vague information. In fact, the definition of performance characteristics such as lower-the-better, higher-the-better, and nominal-the-better contains a certain degree of uncertainty and vagueness. Therefore, optimization of the performance characteristics with fuzzy logic has been considered in this study. In this study, a fuzzy reasoning of the multiple performance characteristics has been developed based on fuzzy logic. As a result, optimization of complicated multiple performance characteristics can be transformed into the optimization of a single multi-response performance index (MRPI). In this paper, the optimization of the electrical discharge machining process with multiple performance characteristics has been investigated to illustrate this approach.

II.Working principle of EDM

EDM process is carried out in presence of dielectric fluid which creates path for discharge [8]. When potential difference is applied across the two surfaces of work piece and tool, the dielectric gets ionized and an electric spark/discharge is generated across the two terminals. The potential difference is applied by an external direct current power supply connected across the two terminals. The polarity of the tool and work piece can be interchangeable but that will affect the various performance parameters of EDM process. For higher material removal rate (MRR), work piece is generally connected to positive terminal as two third of the total heat generated is generated near the positive terminal. The inter electrode gap has a significant role to the development of discharge. As the work piece remain fixed by the fixture arrangement, tool helps in focusing the discharge or intensity of generated heat at the place of shape impartment. Application of focused heat raises the temperature of work piece in the region of tool position, which subsequently melts and evaporates the metal. In this way the machining process removes small volumes of work piece material by the mechanism of melting and vaporization during a discharge. The volume removed by a single spark is small, in the range of 10^{-6}-10^{-4} mm^3, but this basic process is repeated typically 10,000 times per second [9]. Fig.1.1 shows the layout of EDM process which indicates the working of EDM.

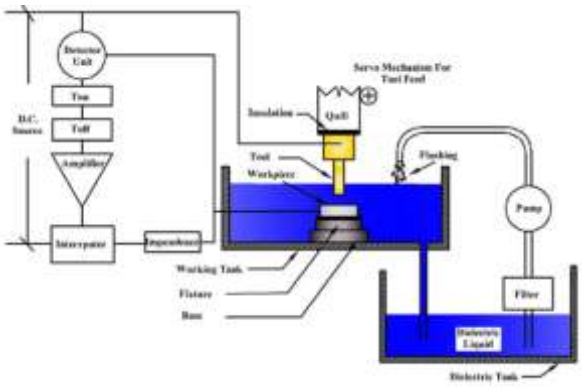

Fig.1 Layout of Electrical Discharge Machining [9]

III. Applicationof Taguchi Method in EDM

Taguchi method involves reducing the variation in a process through robust design of experiments. The overall objective of the method is to produce high quality product at low cost to the manufacturer. Taguchi developed a method for designing experiments to investigate how different parameters affect the mean and variance of a process performance characteristic that defines how well the process is functioning. The experimental design proposed by Taguchi involves using orthogonal arrays to organize the parameters affecting the process and the levels at which they should be varied; it allows for the collection of the necessary data to determine which factors most affect product quality with a minimum amount of experimentation, thus saving time and resources. Taguchi design method is to identify the parameter settings which render the quality of the product or process robust to unavoidable variations in external noise. The relative "quality" of a particular parameter design is evaluated using a generic signalto-noise (S/N) ratio. Depending on the particular design problem, different S/N ratios are applicable, including "lower is better" (LB), "nominal is best" (NB), or "higher is better" (HB). As the objective is to obtain the high material removal rate , low tool wear rate, and best surface finish, it is concerned with obtaining larger value for MRR, smaller value of tool wear rate and smaller value of surface roughness .Hence, the required quality characteristic for high MRR is larger the better, which states that the output must be as large as possible, and for tool wear rate and surface roughness is smaller the better, which states that the output must be as low as possible.

Design of Orthogonal Array

Classical experimental design methods are too complex and are not easy to use. A large number of experiments have to be carried out when the number of process parameters increase. To solve this problem, the Taguchi method uses a special design of orthogonal arrays to study the entire parameter space with only a small number of experiments. Three superplastic forming parameters are considered as controlling factors. They are X, Y and Z. Each parameter has three levels – namely low, medium and high, denoted by 1, 2 and 3 respectively. According to the Taguchi method, if three parameters and 3 levels for each parameters L9 orthogonal array should be employed for the experimentation. Table 5.1 shows parameters and their levels considered for the experimentation.

Table No.1 Process Parameter selection

Process parameters	**Levels**		
	Level 1	**Level 2**	**Level 3**
X – A	5	10	15
Y - B	0.5	1	1.5
Z- C	50	100	150

Orthogonal arrays are special standard experimental design that requires only a small number of experimental trials to find the main factors effects on output. Before selecting an orthogonal array, the minimum number of experiments to be conducted is to be fixed based on the formula below,

N Taguchi = 1+ NV (L – 1)

N Taguchi = Number of experiments to be conducted

NV = Number of parameters

L = Number of levels

In this work NV = 3 and L = 3, Hence

N Taguchi = 1+ 4 (3-1) = 9

Hence at least 9 experiments are to be conducted. Based on this orthogonal array (OA) is to be selected which has at least 9 rows i.e.,9 experimental runs.

The following standard orthogonal arrays are commonly used to design experiments:

2-Level Arrays: L4, L8, L12, L16, L32

3-Level Arrays: L9, L18, L27

4-Level Arrays: L16, L32

Once the orthogonal array is selected, the experiments are selected as per the level combinations. It is important that all experiments are conducted. The performance parameter (output) is noted for each experimental run for analysis.

Table no.2 L9 Orthogonal Array

Experiment Run	X-A	Y-B	Z-C
1	5	0.5	50
2	5	1	100
3	5	1.5	150
4	10	0.5	100
5	10	1	150
6	10	1.5	50
7	15	0.5	150
8	15	1	50
9	15	1.5	100

IVGRA-Grey Relational Analysis Method

Optimization steps using grey relational analysis

Step 1 Calculate S/N ratio for the corresponding responses using the following Category.

i Larger - the – better

This is applied for problem where maximization of the quality characteristic of interest is sought. This is referred as the larger-the-better type problem

ii Smaller - the – better

This is termed as the smaller-the-better type problem where minimization of the characteristic is intended.

iii Nominal - the – best

This is called nominal-the-best type of problem where one tries to minimize the mean squared error around a specific target value. Adjusting the mean on target by any means renders the problem to a constrained optimization problem.[10]

Step 2 Value is normalized to avoid the effect of adopting different units and to reduce the variability. It is necessary to normalize the original data before analysing them with the grey relation theory or any other methodologies. An appropriate value is deducted from the values in the same array to make the value of this array approximate to 1. Since the process of normalization affects the rank, we also analysed the sensitivity of the normalization process on the sequencing results. Thus, we recommend that the S/N ratio value be adopted when normalizing data in grey relation analysis.

Step 3 Calculate the grey relational co-efficient for the normalized S/N ratio values.

Step 4 Generate the grey relational grade.

Step 5 Determine the optimal factor and its level combination.

The higher grey relational grade implies the better product quality; therefore, on the basis of grey relational grade, the factor effect can be estimated and the optimal level for each controllable factor can also be determined.

VFuzzy Logic Optimization Method

Fuzzy logic is a mathematical theory of inexact reasoning that allows modelling of the reasoning process of human in linguistic terms. The fuzzy logic control allows the existence of uncertaintyin handling parameter values [11]. Fuzzy logic system (Mamdani system) comprises of a fuzzifier, membership functions, a fuzzy rule base, an inference engine, and defuzzifier [12]. The fuzzifier uses membership functions to fuzzify

S/N ratios of each performance characteristic are shown in Fig. 1. Next, the inference engine (Mamdani fuzzy inference system) performs fuzzy reasoning on fuzzy rules to generate a fuzzy value. Finally, the defuzzifier converts fuzzy predicted value into a Multi Response Performance Index (MRPI) response that can be used to find the better accuracy of output of the MRPI in EDM using Taguchi L9 processed based.

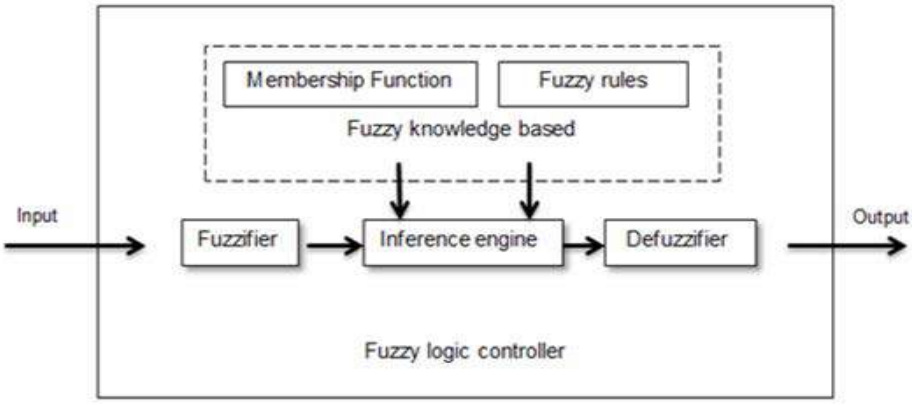

Figure No. 2 Fuzzy Logic Controller

Figure no. 3 representing the membership function of response variable. In this fuzzy subset formation occurs in which the representation of fuzzy subset in many segments like small, medium and large. For more accurate outputs we can divide these sets in more number of member functions like very small, small, medium, large and very large.

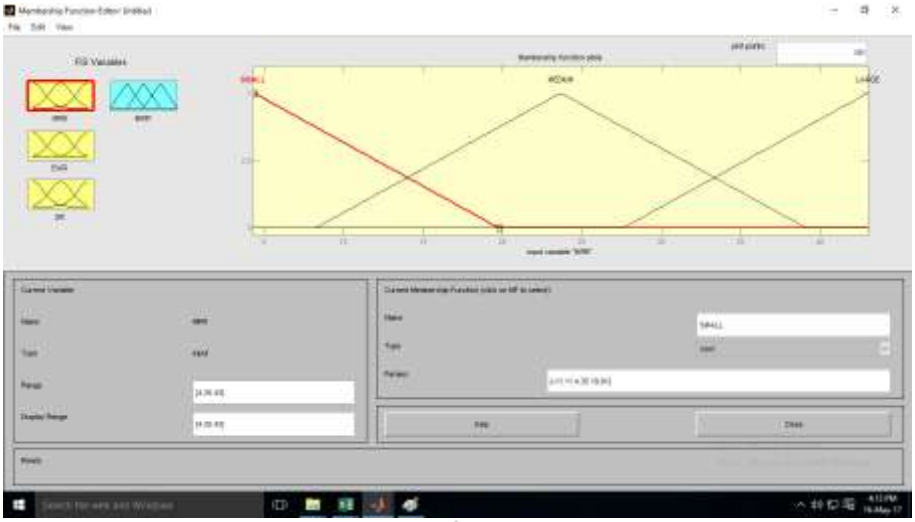

Figure No. 3 Member Function for Response Variables

The next step of fuzzy logic system is If and Then rule application. If and Then rules based on three main factor that are AND, OR and NOT functions. For example X is increases then y increases likewise X increases Y decreases or X increases then may be Y decreases in another case it may possible that X increase then Y may not Changes. Figure No. 4 is representing the three response variable by which we conclude one MRPI. X is small, Y is small and Z also small then MRPI must be very small likewise we apply rule in fuzzy logic system. In sequential manner.

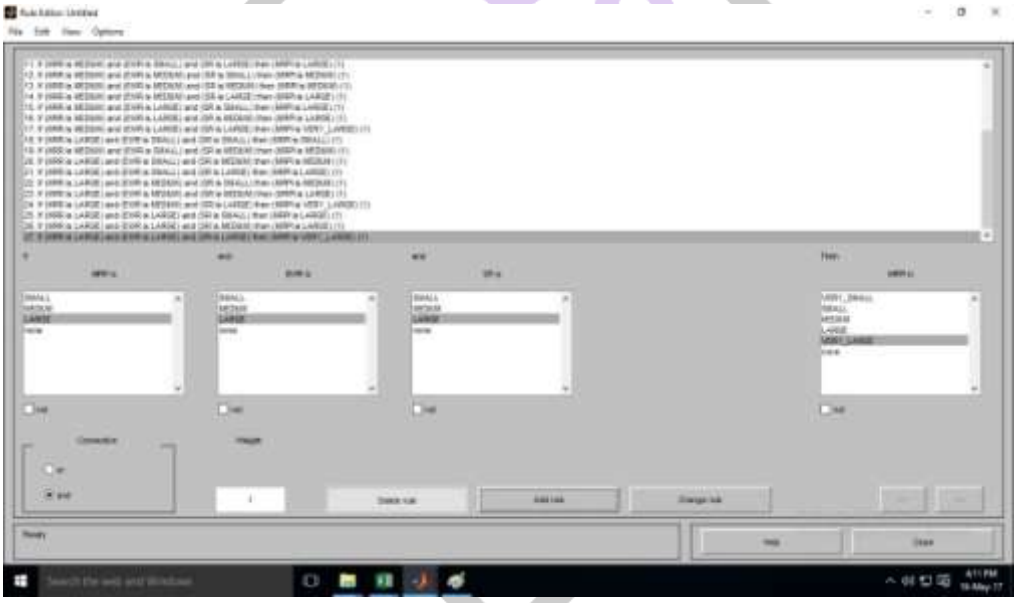

Figure No. 4 If-Then Rule in Fuzzy Logic System

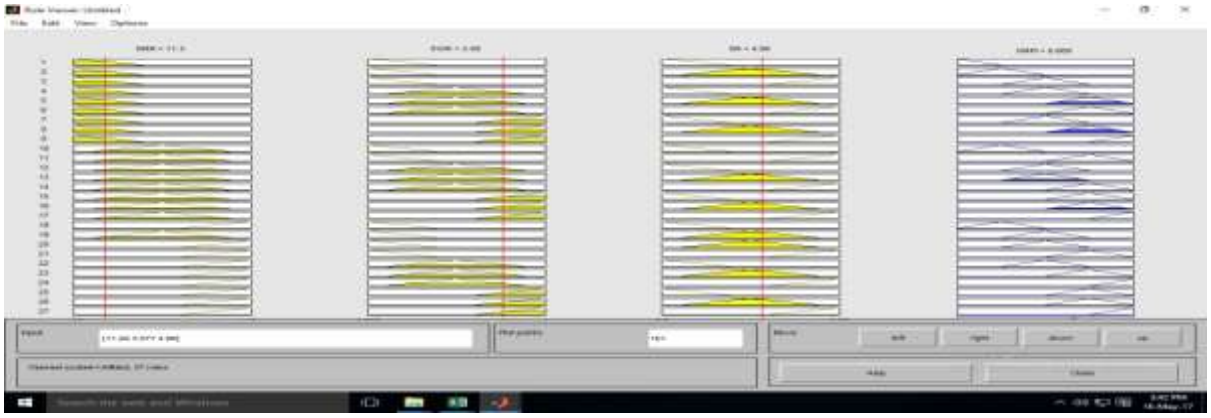

Figure No.5 MRPI by Fuzzy logic

After finding MRPI values for all response variable combinations as per L9 orthogonal array. Finally the optimal parameter is selected by final observation table. Value of maximum MRPI is optimal process parameter value and the reading set for that MRPI is best optimal reading set which gives maximum output.

VIConclusions

Based on the application of GRA and Fuzzy Logic based multi-objective optimizationn methods, the following conclusions are drawn.

- Taguchi method is very much useful for experimental setup design. It helps to minimize trial and run time drastically. Taguchi method very much important in DOE (design of experiment)
- GRA (Grey Relational Analysis) is purely mathematical Optimisation method which highlight importance of numbers and its calculations but fuzzy logic help to use some logic (AND, OR, NOT) and more detail study of response of input parameter in all direction and sense.

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