"GRAY RELATIONAL BASEDANALYSIS OF TOOL STEEL"

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Abstract -*Nowadays innovative changes in the area of non-traditional machining process are not to be considered as replacements for conventional machining methods of metal working. They also do not offer the best alternative solutions for all machining applications. The traditional metal cutting processes utilize shearing action on the work piece for material removal. However, the non-traditional processes depend on other factors such as chemical properties, melting and vaporization of the material, electrolytic displacement of ions and mechanical erosion. The main reasons for using the non-traditional machining processes are to machine high strength alloys, complex surfaces, difficult geometries, high accuracies surface finish and automation requirements. To carryout experimental investigation and optimization of process parameter for Electro Discharge Machining of tool steel in order to achieve maximum MRR with lowest possible surface roughness. Surface roughness and MRR are very important which rely on many parameters, its need of hour to have the experimental investigation for optimum values by satisfying the desired constraints to achieve particular objective. Taguchi has envisaged a method of conducting the DOE, which are based on well-defined guidelines. To study the entire process parameter space with a small number of experiments only, Taguchi method uses a special design of orthogonal arrays (OA). With this method the number of experiments for evaluation of the influence of control parameters on certain quality, properties or characteristics is markedly reduced compared to a full factorial approach. In this work Gray taguchi methodology is applied for multi objective optimization of tool steel.*

Key Words: **Electro Discharge Machining, MRR, Taguchi Method, Orthogonal Arrays**

1. INTRODUCTION

EDM has been substituting traditional machining operations. Now today EDM is a popular machining operation in several manufacturing productions all over the world's countries. Most of the traditional machining process such as drilling, grinding and milling, etc. are failed to machine geometrically complex or difficult shape and size. Those materials are easily machined by EDM non-traditional machining process which leads to broadly utilized as die in addition to mold assembly industries, making aeronautical parts and nuclear instruments at the minimum cost. Electric Discharge Machining has also established its presence touched on the different subject areas such as make use of sporting things, medicinal and clinical instruments as well as motorized research and development regions[1]

1.1 PROBLEM STATEMENT

The project work focuses on optimization of electro discharge machining considering the various process parameters. The aim is "To carryout experimental investigation and optimization of process parameter for machining of tool steel in order to achieve maximum MRR with lowest possible surface roughness."

1.2. OBJECTIVES

1. To develop mathematical model for surface roughness and MRR of chosen material
2. To investigate the effects of input process parameters (Machining) on the surface finish and material removal rate

1.3. SCOPE

Surface roughness and MRR are very important which rely on many parameters, its need of hour to have the experimental investigation for optimum values by satisfying the desired constraints to achieve particular objective.

2. LITERATURE SURVEY

This chapter sets the background for up-coming sections. It is an assessment of the present state of art of the wide and complex field of optimization of electro discharge machining by design of experiment and its application. In addition, this chapter separately reviews what did in the past in the area of application.

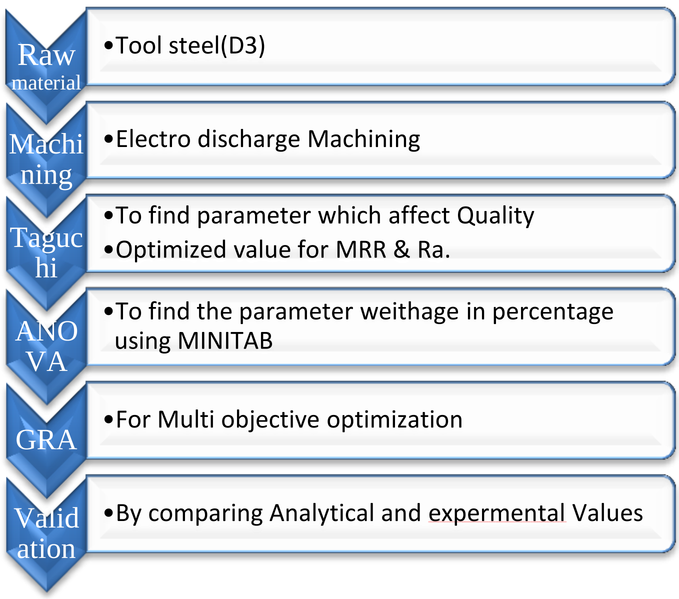
Puri et. al. [2] employed mathematical modeling of white layer depth to correlate the dominant input parameters of the WEDM process, comprising of a rough cut followed by a trim cut In the process, typical die steel (M2 – hardened and annealed) was machined using brass wire as electrode. An experimental plan of rotatable central composite design in RSM consisting of input variable pulse on time during the rough cutting and pulse on time offset and cutting speed during trim cutting has been employed to carry out the experimental study and concluded that the white layer depth increases with increasing pulse on time during the first cut and decreases with increasing pulse on time during trim cutting. With increasing cutting speed in trim cutting, the white layer depth first reduces and then starts increasing. T. A. El-Taweel [3] investigated the relationship of process parameters in EDM of CK-45 steel with novel tool electrode material such as Al-Cu-Si-TiC composite product using powder metallurgy technique. In this study, peak current, dielectric flushing pressure and pulse on time are considered as input process parameters and the process performances such as MRR and TWR were evaluated. The analysis was carried out with the help of response surface methodology. It was concluded that the peak current was found to be the most important factor effecting both the MRR and TWR while dielectric flushing pressure has little effect on both responses.Al-Cu-Si-Tic electrodes were found to be more sensitive to peak current and pulse on time than conventional electrodes. Sohani et. al. [4] presented the application of response surface methodology (RSM) for investigating the effect of tool shapes such as triangular, square, rectangular and circular with size factor consideration along with other process parameters like discharge current, pulse on time, pulse off time and tool area. The investigation revealed that the best tool shape for higher MRR and lower TWR is circular, followed by triangular, rectangular and square cross-sections. Mohd Amri Lajis et. al. [5] investigated the relationship of process parameters in EDM of Tungsten carbide was used as the workpiece material and graphite as electrode. In this study peak current, voltage, pulse on time and pulse off time are considered as input process parameters and the process performances such as metal removal rate (MRR), electrode wear (EWR) and surface roughness (SR). S.H.Tomadi et. al. [6] Investigated the effect of process parameters like Pulse on time, Pulse off time, Supply Voltage, peak current on material removed rate (MRR) and electrode wear (EW). The Tungsten Carbide was used as the workpiece material and Copper Tungsten as electrode. The full factorial design of experiment was used to analysis the optimum condition of machining parameters. K.D. Chattopadhyay et.al.[7] derived an empirical mathematical model for predication of output parameters has been developed using linear regression analysis by applying logarithmic data transformations of non-linear equation. Experiment have been conducted with three machining parameters viz. peak current pulse on time and rotational speed of the electrode and to relate them with process responses viz. material removal rate (MRR), surface roughness (SR) and electrode wear ratio (EWR). Experiment was performed with copper- steel (EN-8) as work piece and copper as electrode. Asif Iqbal et. al. [9] established empirical relations regarding machining parameters and the responses in analyzing the machinability of the stainless steel AISI 304 using copper electrode. The machining factors used were voltage, rotational speed of electrode and feed rate over the responses MRR, EWR and SR. The response surface methodology was used to investigate the relationships and parametric interactions between the three control variables on the MRR, EWR and SR. the developed models show that the voltage and rotary motion of electrode are the most significant machining parameters influencing MRR, EWR and SR. Shailesh Dewangan et. al.[11] investigated the effect of process parameters like Pulse on time, Discharge current and Diameter of electrode on material removal rate (MRR), Tool wear rate (TWR) and over cut. The experiment used AISI P20 tool steel as work piece and U-shaped copper tool as electrode with internal flushing system.

3. EXPERIMENTAL INVESTGATION

In order to satisfy the desired objectives the method of DOE coupled with optimization techniques is identified, extensive literature review is carried out and following workflow to carry out the experimentation is formulated

3.1. Proposed workflow

In order to achieve the desired objective that is minimum surface roughness and maximum material removal rate for the optimization of Tool steel, the method of the design of experiment is identified and the proposed algorithm as follows



3.2. Experimental Setup

The experiment is going to be conducted on the electro discharge machine (EDM) at shreelila engineering services, Ambad, Nashik in following table 1 gives idea about the technical specification of the machines:

Table 1: Machine details

Description	Specification
ELECTRAPULS PS 35	
Table size	750*450mm
Maximum job weight	300 kg
Maximum job height	250mm
Maximum electrode weight	70kg
Maximum working current	60A

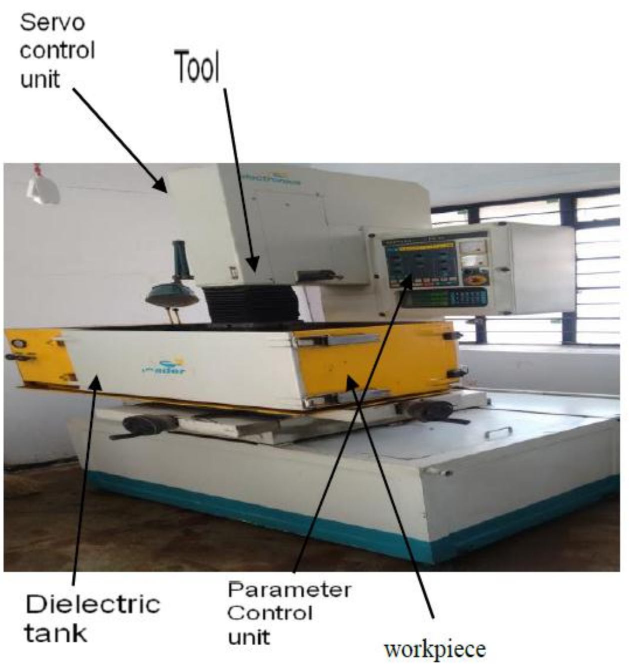


Fig 1: EDM Machine used in Experimentation.

3.3 Selection of Material

The work piece material used in the experiment is 'Tool steel(D3) which has a following properties, the dimension of work piece are selected as 40x40x16mm.

Table 2: Material Properties

Parameter	Specification
Density	7700kg/m^3
melting point	1421^{0}C
Hardness	77HRC
Poisson's ratio	0.28
Coefficient of thermal expansion	12×10^{-6}/C^0

Fig 2: Tool steel work piece of 40×40 mm in dimension.

3.4. Selection of Cutting Tool

It is decided to use the Copper tool having following details.

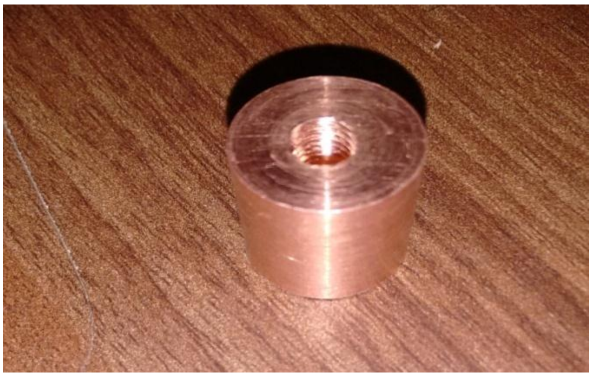


Fig 3: Copper tool of 10mm diameter

4 .GREY BASED TAGUCHI ANALYSIS FOR COMBINE OBJECTIVE.

Grey-relational analysis is mainly used to conduct a relational analysis of the uncertainty of a system model and the incompleteness of information. It can generate discrete sequences for the correlation analysis of such sequences with processing uncertainty, multi-variable input and discrete data. Therefore, grey relational analysis is a measurement method to discuss the consistency of an uncertain discrete sequence and its target. In a given group for grey-relational analysis, all the sequences should comply with the comparability conditions of normalization, S-calling and polarization.

Grey relational analysis was proposed by Deng in 1989 as cited in is widely used for measuring the degree of relationship between sequences by grey relational grade. Grey relational analysis is applied by several researchers to optimize control parameters having multi-responses through grey relational grade. The use of Taguchi method with grey relational analysis to optimize the EDM operations with multiple performance characteristics includes the following steps:

1. Identify the performance characteristics and cutting parameters to be evaluated.
2. Determine the number of levels for the process parameters.
3. Select the appropriate orthogonal array and assign the cutting parameters to the orthogonal array.
4. Conduct the experiments based on the arrangement of the orthogonal array.
5. Normalize the experiment results of MRR and surface roughness.
6. Perform the grey relational generating and calculate the grey relational coefficient.
7. Calculate the grey relational grade by averaging the grey relational coefficient.
8. Analyze the experimental results using the grey relational grade and statistical ANOVA.

9. Select the optimal levels of cutting parameters.
10. Verify the optimal cutting parameters through the confirmation experiment.

4.1 DATA PRE-PROCESSING.

In grey relational analysis, the data pre-processing is the first step performed to normalize the random grey data with different measurement units to transform them to dimensionless parameters. Thus, data pre-processing converts the original sequences to a set of comparable sequences. Different methods are employed to pre-process grey data depending upon the quality characteristics of the original data. The original reference sequence and pre-processed data (comparability sequence) are represented by $xx0\ (0)(kk)$ and $xxii\ (0)(kk)$, i =1,2,….,m; k =1,2,.....,n respectively, where m is the number of experiments and n is the total number of observations of data. Depending upon the quality characteristics, the three main categories for normalizing the original sequence are identified as follows:

If the original sequence data has quality characteristic as 'larger-the-better' then the original data is pre-processed as 'larger-the-best:

$$xi(k) = \frac{\text{yi(k)} - \text{min yi(k)}}{\text{max yi(k)} - \text{min yi(k)}}$$

If the original data has the quality characteristic as 'smaller the better', then original data is pre-processed as 'smaller-the best':

$$xi(k) = \frac{\text{max yi(k)} - \text{yi(k)}}{\text{max yi(k)} - \text{min yi(k)}}$$

Xi=Compatibility sequence

4.2. Sample calculation of compatibility sequence for roughness value Tool steel

$$xi(k) = \frac{\text{Max CT} - \text{First Value of CT}}{\text{Max CT} - \text{Min CT}}$$

$$xi(k) = \frac{5.44147 - 1.9524}{5.44147 - 0.32393}$$

$$\boldsymbol{xi(k) = 0.68178}$$

Table 3: Normalized S/N data (Grey relational generation) for Tool Steel

Sr.No	S/N Ra	S/N MRR	Xi Ra	Xi MRR	Δ Ra	Δ MRR
1	1.9524	26.4692	0.68178	0	0.31822	1
2	2.65	31.38	0.543	0.50	0.456	0.49
3	5.44	35.55	0	0.92	1	0.07
4	2.96	34.91	0.483	0.86	0.516	0.13
5	5.16	33.75	0.054	0.74	0.945	0.25
6	0.32	33.48	1	0.71	0	0.28
7	4.10	36.36	0.260	1	0.739	0
8	1.55	26.70	0.758	0.02	0.244	0.97
9	3.45	32.72	0.387	0.63	0.612	0.36

Similarly all values of compatibility sequence for surface roughness and material removal rate can be calculated. All values are show in Table 3 Where xi (k) is the value after the grey relational generation, min yi (k) is the smallest value ofyi (k) for the k^{th} response, and max yi (k) is the largest value of yi (k) for the k^{th} response.

An ideal sequence is x0(k) (k=1, 2) for two responses. The definition of the grey relational grade in the grey relational analysis is to show the relational degree between the twenty-seven sequences (x0(k) and *xi* (k), i=1, 2 . . . 27; k=1, 2). The grey relational coefficient ξi(k) can be calculated as:

4.3.Sample calculation of grey relation coefficient for Roughness value

$$\xi i(k) = \frac{\min\Delta + \theta * \max\Delta}{\Delta i(k) + \theta * \max\Delta}$$

ξi(k) =The grey relational coefficient

θ is the distinguishing coefficient which is taken as 0.5

$$\xi i(k) = \frac{0 + (0.5 * 1)}{0.456091 + (0.5 * 1)}$$

ξi(k) = for second value = 0.52296

Similarly, all values of grey relation coefficient for roughness and material removal rate are calculated and tabulated in the table given below.

4.4 Sample calculation of grey relation grade for Roughness value and MRR.

After averaging the grey relational coefficients, the grey relational grade γi can be computed as,

$$\boldsymbol{Yi} = \frac{\boldsymbol{1}}{\boldsymbol{n}}\sum_{k=1}^{n} = \text{ξi[k]}$$

$$\boldsymbol{Yi} = \frac{\boldsymbol{1}}{\boldsymbol{2}}(0.3333 + 0.61108)$$

Reading of grey relation grade is, **Yi = 0.47219**

Similarly all values of grey relation grade of nine experiments are carried out and tabulated in table 4 given below, Yi =grey relational grade

Where n = number of process responses.

The higher value of grey relational grade corresponds to intense relational degree between the reference sequence x0 (k) and the given sequence xi (k). The reference sequence x0 (k) represents the best process sequence. Therefore, higher grey relational grade means that the corresponding parameter combination is closer to the optimal.

Table 4: Grey Relation Grade, coefficient and Order

Sr No	GRC For Ra	GRC For MRR	GRG	Gray Order
1	0.61108	0.3333	0.47219	9
2	0.52296	0.50155	0.512255	6
3	0.3333	0.875503	0.6044015	4
4	0.492	0.78511	0.638555	3
5	0.34587	0.66185	0.50386	8
6	1	0.63883	0.819415	1
7	0.40332	1	0.70166	2
8	0.67187	0.33885	0.50536	7
9	0.449502	0.58136	0.515431	5

4.5. Analysis of the combined objective by using Taguchi for Tool steel;

Table 5: Response Table for Taguchi analysis

Sr	Voltage	Current	Pulse On	GRG	S/N
1	60	12	50	0.47219	-6.51766
2	60	15	100	0.512255	-5.81028
3	60	18	150	0.6044015	-4.37349
4	70	12	100	0.638555	-3.89603
5	70	15	150	0.50386	-5.9538
6	**70**	**18**	**50**	**0.819415**	**-1.72992**
7	80	12	150	0.70166	-3.07747
8	80	15	50	0.50536	-5.92798
9	80	18	100	0.515431	-5.75659

4.6. Main Effect plot for combine Objective

Following fig. 4 & 5 are the main effects plots for SN ratio and data means for above data which determine the optimum levels, MINITAB 14 is used to plot these plots considering the S/N ratio as larger is the better.

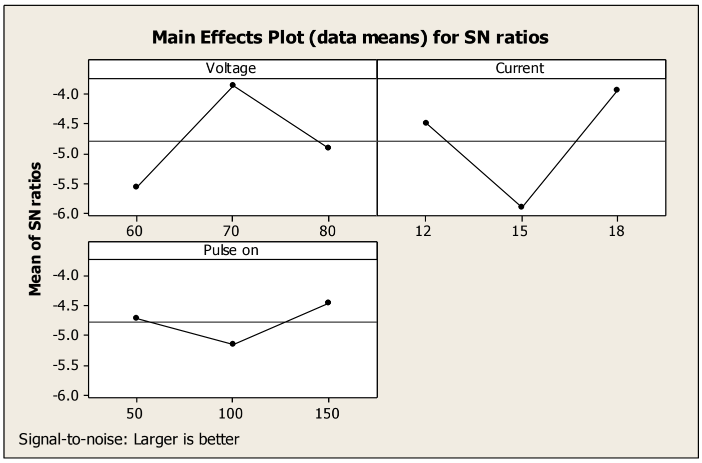


Fig 4: Main effect plot for combined objective S/N ratio

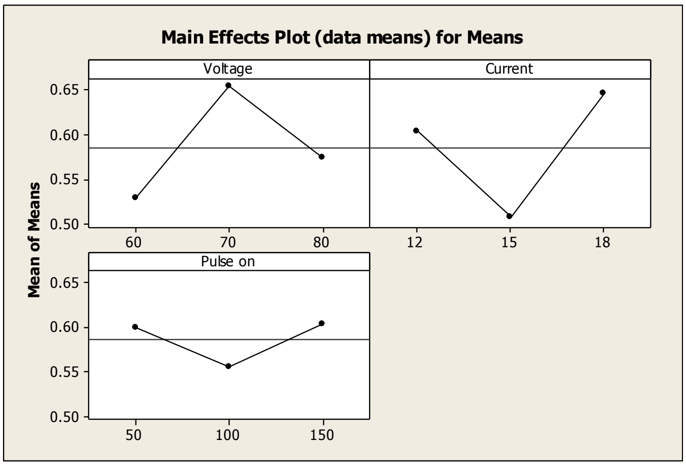


Fig 5: Main effect plot for means of mean

CONCLUSIONS

Existing experiment and its analysis provides following remarkable point

I. Considering the objective like MRR and roughness nine experiments were successfully conducted and then its analysis is done with the help of Minitab software

II. The present work has successfully demonstrated the application of Taguchi based Grey relational analysis for multi objective optimization of process parameters in EDM for tool steel subjected to various conditions.

III. In grey relational analysis higher the grey relational grade of experiment says that the corresponding experimental combination is optimum condition for multi objective optimization and gives better product quality. Also form the basis of the grey relational grade, the factor effect can be estimated and the optimal level for each controllable factor can also be determined.

IV. It is found that experiment no 6 has the best multiple performance characteristic among 9 experiments, because it has the highest grey relational grade of 0.8194 for tool steel

Experiment No	GRC Ra	GRC MRR	GRG	Material
6	1	0.638 83	0.819 4	Tool Steel

V. Thus this experimentation successfully optimize the EDM for two tool steel considering various process parameters, which will help to improve the efficiency by selecting the optimum parameters.

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