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OPTIMIZATION OF MATERIAL REMOVAL RATE IN WIRE ELECTRIC DISCHARGE MACHINING

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ABSTRACT-*With the growth of industries, the need for advanced material has increased. WEDM is a non-conventional machining method that for machining of Special Steel. WEDM is a better choice as to easy control and can machine complex shapes. The aim is to study the effect of WEDM input variables like pulse on and pulse off time, also voltage on the performance variable like MRR.. Taguchi method will be employed for the work. The research work is expected to assist in finding out the optimum output variable that will lead to maximum MRR,*

Keyword: - *WEDM, Pulse on and Pulse off time, Sr.Voltage, MRR.*

1. INTRODUCTION

In WEDM a thin strand metal wire is fed through work piece, typically while in a submerged tank of dielectric fluid . This fluid helps to cool process and cut material is flushed away from work piece. The WEDM process use current to cut material and produce a smooth surface that requires no polishing. This process is used to cut plates and make punch, tool, and die from any material, including hard metals that are too difficult to cut with other methods, like; metal alloys, carbide and diamond. The wire is held between two diamond guides. The guides move in the (X-Y) plane, the upper guide move independently in the (Z-U-V) axis, giving rise to the ability to cut tapered and transitioning shapes and can control axes movements. This gives the WEDM ability to be programmed to cut delicate shapes. WEDM is used when low residual stresses are required. WEDM has no any residual stress because of zero cutting forces. There is slight change in the mechanical properties of a material in WEDM. The cutting wire do not touches the material, the cutting itself is done by the erosion that occurs when a spark occur between wire and raw material. A WEDM process with consist of several pass, moving at various speeds. The first passes are fast moving and lower accuracy to remove large amounts of material. Later, skim passes, will cuts at lower speeds, removing less material and improve the quality of surface and accuracy. In order to have complex cut, a pre-drilled hole through a raw material can be threaded with WEDM and the machine can begin cutting from there. Applications for WEDM include the creation of extrusion die, punch and fabrication.

2. WORKING PRINCIPLE OF WEDM

WEDM is used to cut plates up to thickness of 300mm and make punch, tool, and die from hard material that are complex to perform operation with other methods. EDM is used when low residual stresses are required, because it does not require cutting forces for material removal. If the energy/power per pulse is low then there is a slight change in mechanical properties of a material is occured because of the low residual stresses, although material that has not stress relieved can distort in machining operation. Because of inherent properties of process, WEDM can easily machine complex part and precision component out of hard materials. WEDM is an electro-thermal non-conventional machining process, where electrical energy is used to generate el spark and material removal mainly occurs due to thermal energy of spark. Use current and fine wire to cut materials. The cutting take place while work piece is submerged in deionized water. Deionized water helps to cool the process and flush away the cut material. Cutting wire does not touch the material. Cutting itself is due to the erosion that occurs when a spark forms between the cutting wire and the raw material.

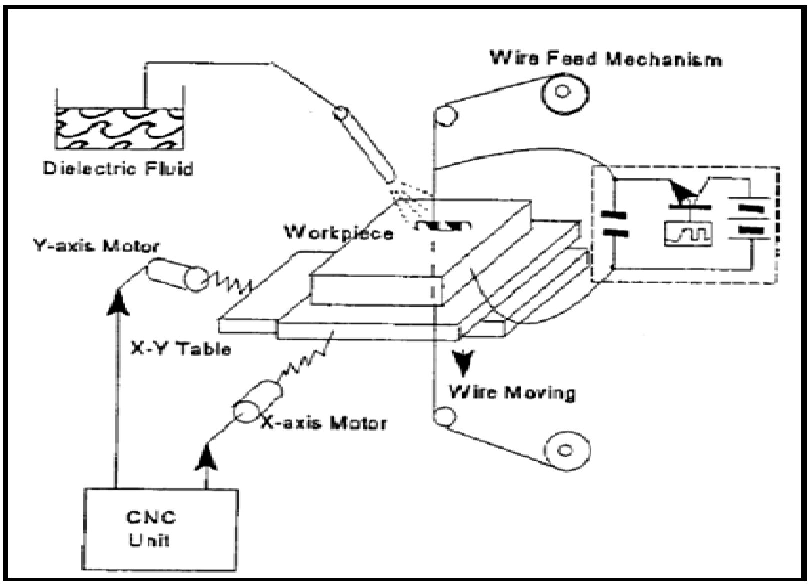

Fig 2.1 Diagram of working of WEDM

3. LITERATURE REVIEW

Using Taguchi technique and RSM in machining of AISI D2 Steel. The objective of present work is to investigate the effects of various WEDM process variables such as pulse on and pulse off time, servo voltage and wire feed rate on the MRR and SR and cutting rate. Secondly, to obtain the optimal settings of machining variables at which the MRR and cutting rate are maximum and the SR is minimum in a range. The experiments were carried out as per design of experiment approach using L27 orthogonal array. AISI D2 steel is machined by using brass wire as electrode and RSM is used for modelling a second-order response surface to estimate the optimum machining condition to produce the best possible response within the experimental constraints. The results from this study will be useful for manufacturing engineers to select appropriate set of process variables to machine AISI D2 steel **[1].**

This study on the development of model and its application to estimation of machining performances using Multiple Regression Analysis (MRA), and Artificial Neural Network (ANN). Experimentation was performed as per Taguchi's L'16 orthogonal array. Each experiment has been performed under different cutting conditions of pulse-on, pulse-off, current and bed speed. Among different process parameters voltage and flush rate were kept constant. Molybdenum wire having diameter of 0.18 mm was used as an electrode. Three responses namely accuracy, surface roughness, volumetric material removal rate have been considered for each experiment **[2].**

They study the properties of EN-31 die-steel after machining with EDM electrodes. A lot of experiments has carried out to find the optimum variables for EDM process. Researchers have also used powder metallurgy electrodes to study their influence on surface properties and output process variables. In this paper, electrodes prepared with different compositions of copper and manganese has used to machine EN-31 die-steel. Comparisons have been made with copper electrode for micro hardness and surface roughness behaviour of work piece and it has been found that copper-manganese (in weight ratio 70-30) composite electrode shows better results than copper-manganese (in weight ratio 80-20) electrode and copper electrode **[3].**

In which they do experimental investigation and optimisation of performance characteristics in EDM of EN-24 alloy steel using Taguchi Method and Grey Relational Analysis. This investigation addresses exploration of EDM process on EN-24 alloy steel using Taguchi robust design approach and multi Objective Grey Relational Grade with four controllable input parameters such as Pulse on time, Pulse off time, Peak current and Flushing pressure for analysis of MRR and Tool wear rate. The design matrixes for experimentation with different treatment conditions are chosen utilising L9 orthogonal array. From detailed study, it is found that different combinations of EDM process parameters are necessary to achieve enhanced MRR and reduced TWR for EN-24 alloy steel. In this study, single objective optimization is established by Taguchi methodology and optimal factor settings for multi objective optimization of two output responses MRR and TWR collectively are identified using Grey relational analysis. Significant contribution of input controllable parameters on output response MRR is also identified statistically **[4].**

They optimise and prediction of MRR in die sinking electro discharge machining of EN45 steel tool. The main aim of this paper is to maximize MRR in die sinking electro-discharge machining of EN45 material using Taguchi method. EN45 is a manganese spring steel with carbon content. EN45 is used in the motor vehicle industry for leaf springs, truncated conical springs, helical springs and spring plates and many applications. The experiments conducted based on the L27 Orthogonal array and results were optimized. Experiment were carried out using four variables viz. current, pulse on time and pulse off time and voltage with three different levels. The effects of input variables and effect of their combination on MRR determined using Taguchi and ANOVA table. It was observed that current and pulse off time are more important factor for MRR **[5].**

Study about effect and optimization of process variables on MRR for EN19 & EN41 materials using taguchi method. The present work deals with the comparison of the MRR for EN19 and EN41 material in a die sinking EDM machine. The various input variables like Pulse ON time, Pulse OFF time, Discharge current and voltage were considered as the input variables, while the MRR is considered as the output. Optimization using Taguchi method was performed to predict combination of inputs towards maximum output. A comparison was done to obtain the effect of these input variables over the MRR for both the material, and simultaneously the impact of the carbon over the MRR was investigated. It was found that the Discharge current in case of the EN41 material and EN19 material had a larger impact as compare to other processing variables on the MRR. A relative study of the carbon composition for both the material was also done **[6].**

In which study of Taguchi method in of preference by similarity to ideal solution (TOPSIS) and Grey Relational Analysis (GRA) have been adopted to evaluate the effectiveness of optimizing multiple performance characteristics for PMEDM of H-11 die steel using copper electrode. The effect of process variables such as powder concentration, peak current, pulse on time (Ton), duty cycle (DC) and gap voltage (Vg) on response parameters such as Material Removal Rate (MRR), Tool Wear Rate (TWR), Electrode Wear Ratio (EWR) and Surface Roughness (SR) have been investigated using chromium powder mixed to the dielectric fluid. Analysis of variance (ANOVA) and F-test were performed to determine the significant parameters at a 95% confidence interval. Predicted results have been verified by confirmatory tests which show an improvement of 0.161689 and 0.2593 in the preference values using TOPSIS and GRA respectively **[7].**

EDM is one of the non-traditional machining processes available, in which the material removal takes place because of melting and vaporisation of electrode materials. Micro Electro-Discharge Machining (μ-EDM) is a variant of EDM, is playing an important role in generation of micro features on difficult to machine conducting materials. In this Paper, authors carried out an extensive literature study to give a complete description on μ-EDM process, its requirements, performance and applications. More than fifty papers were referred and categorized into five major areas, namely, experimental setups and its subsystems, experimental studies and optimization methods, generated micro features, modelling approaches and applications **[8].**

WEDM is a thermal machining process capable of machining parts with varying hardness, which have sharp edges that are very difficult to be machined by other machining processes. This study outlines the development of model and application to estimation of machining performances using Multiple Regression Analysis (MRA), Group Method Data Handling Technique (GMDH) and Artificial Neural Network (ANN). Experimentation was performed as L’16 orthogonal array. Each experiment has been performed under different cutting conditions of pulse-on, pulse-off, current and bed speed. Among different process parameters voltage and flush rate were kept constant **[9].**

In this research, variables such as pulse on and pulse off time, peak current, wire feed, wire tension, and servo voltage has been selected for process capability investigation in WEDM. The process capability index was evaluated for machining characteristics such as machined work-piece dimension and surface roughness. Taguchi’s approach to experiment design and analysis was utilized to study the influence of machining parameters on the process capability index. Single response optimization was performed for both machining characteristics to find out the parametric setting which could optimize WEDM process capability. Surface integrity aspects such as microstructure analysis of the selected machined titanium samples have also been investigated **[10].**

4. OBJECTIVES

- To Study the effect of variable on performance.
- To get the optimum input & output parameters for selected wire & work piece material.
- To study about the MRR in WEDM & its optimization.
- To find out the problems of wire breaking during machining.

5. EXPERIMENTAL SETUP

- **Specification of machine:**

Table 1. Machine specification

SPECIFICATION	DESCRIPTION
Main axes travel	500*300 mm
Max. work piece height	260 mm
Max. work piece weight	500 kg
Aux. axes traverse	100*100 mm
Max. taper angle	35°
Max. cutting speed	250 mm/min
Work table size	810*550 mm
Best surface finish	0.25 µ Ra
Max. wire spool capacity	8 kg
Controlled axes	X,Y,u,v,Z
Di-electric fluid	Di-ionized water

- **Work piece material:** EN–24 tool steel

EN 24 has the wide applications in stamping dies, metal cutting tools or any other industries because of its high strength and heavy weight. In general the edge temperature under expected use is an important determine of both composition and required heat treatment.

Table 2. Chemical composition of work piece material

Chemical composition of EN 24T steel							
C	SI	MN	S	P	Cr	Mo	Ni
0.36/0.44	0.10/0.35	0.45/0.70	0.040 max	0.035 max	1.00/1.40	0.20/0.35	1.30/1.70

- **Wire material:** Hard Brass Zinc Coated Wire

Zinc coated brass wire was the first attempts to present more zinc to the wire's cutting surface. This wire consists of a thin (approximately 5 micron) zinc coating over a core which is one of the standard EDM brass alloys. This wire offers significant increase in cutting speed over plain brass wires, without any sacrifice in any of the other critical properties.

Fig 5.1 Wire electrical discharge machine

Table 3. Factors and Levels

Symbol	Input Parameters	**Level 1**	**Level 2**	**Level 3**
A	Pulse On Time (µs)	**110**	**120**	**130**
B	Pulse Off Time (µs)	**40**	**50**	**60**
C	Voltage (volt)	**110**	**120**	**130**

Output parameter:

- Material Removal Rate: MRR is the most desirable characteristic for WEDM. Its value is measured in mm3/min. In the present experimental work, cutting rate will measured directly from the digital display screen of the machine.

6. RESULTS AND ANALYSIS

Table 4. Results

SR.NO	Pulse on time(μs)	Pulse off time (μs)	Servo Voltage (volts)	MRR (mm^3/min)
1	110	40	110	2.40
2	110	40	110	2.38
3	110	40	110	2.41
4	110	50	120	1.62
5	110	50	120	1.68
6	110	50	120	1.65
7	110	60	130	2.34
8	110	60	130	2.36
9	110	60	130	2.38
10	120	40	110	3.70
11	120	40	110	3.75
12	120	40	110	3.72
13	120	50	120	3.50
14	120	50	120	3.52
15	120	50	120	3.48
16	120	60	130	2.15
17	120	60	130	2.12
18	120	60	130	2.10
19	130	40	110	5.01
20	130	40	110	5.02
21	130	40	110	5.04
22	130	50	120	3.00
23	130	50	120	3.02
24	130	50	120	3.04
25	130	60	130	3.30
26	130	60	130	3.32
27	130	60	130	3.29

A collation of data is accomplished after cutting the EN24T steel material by wire EDM. Machining time has been observed and noted after each experiment and material removal rate have been calculated by applying formula shown in equation. These collected data have been analyzed by using powerful statistical software Minitab 16. In this software, Taguchi method has been considered for analysis of collected values of response parameter.

$$MRR = \frac{l \times h \times k}{t_m} (\frac{mm^3}{minute})$$

Where, l = cutting length, h = cutting thickness, k = kerf of cutting, t_m = machining time

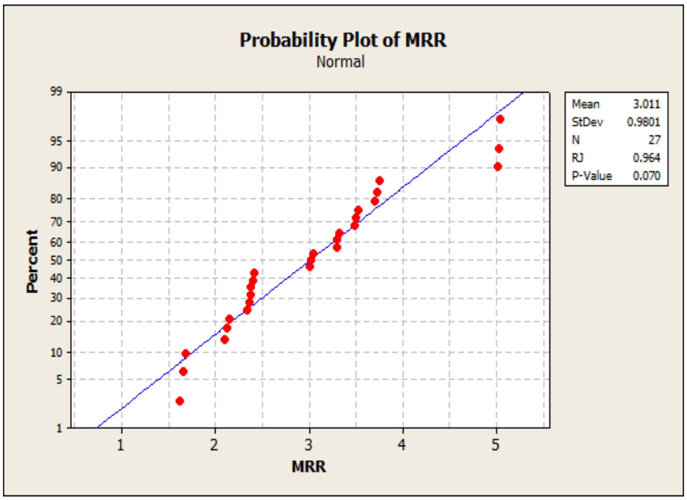

Fig 6.1 probability plot of MRR

Here above fig 6.1 shows probability plot of material removal rate for EN24T steel material for different input values of pulse on time, pulse off time and servo voltage. Here for L27 orthogonal array there are 27 set for input parameter and for that values probability plot as shown in above fig. In which probability value is higher than 0.05 so that, results and probability plot is accurate.

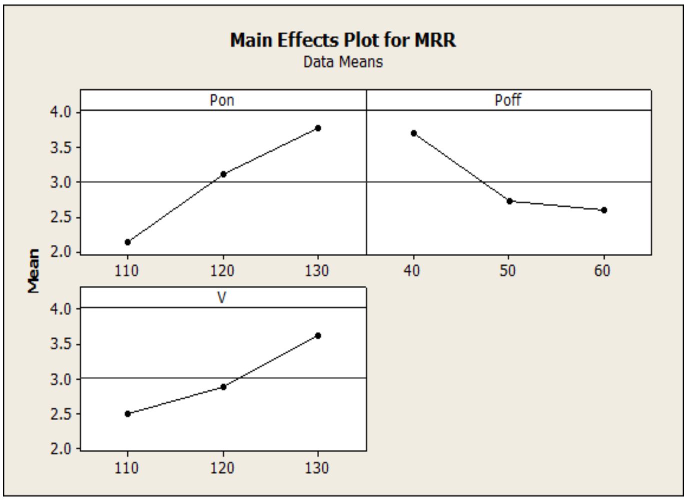

Fig 6.2 Main effect plot for MRR

Here above fig 6.2 shows main effect plot for same material. In which for three input parameter we get different values for material removal rate. In first plot we can see that for the range of pulse on time, removal rate is constantly higher. Same for the pulse off time, for lower value of pulse off time the value of MRR is higher as shown in fig 6.2. But as value increase of pulse off, for that MRR has been decrease. And for voltage same as the pulse on time, as the voltage increase MRR has been increase.

- **Formulation of Problem : Regression Model For MRR**

  Regression Model analysis for MRR:
  The Regression equation is
  MRR = - 10.8 + 0.0823 Pon - 0.0559 Poff + 0.0557 V

Table.5 Regression model

Source	P
Regression	0.000
R-Sq = 93.8%	R-Sq(adi) = 93.3%

- **Optimization Using Genetic Algorithm:**

Table.6 results of optimization using GA

Ext No.	Process variables			Response
	V	Pon	Poff	MRR
Population size : 50				
1	130	130	140	5.07

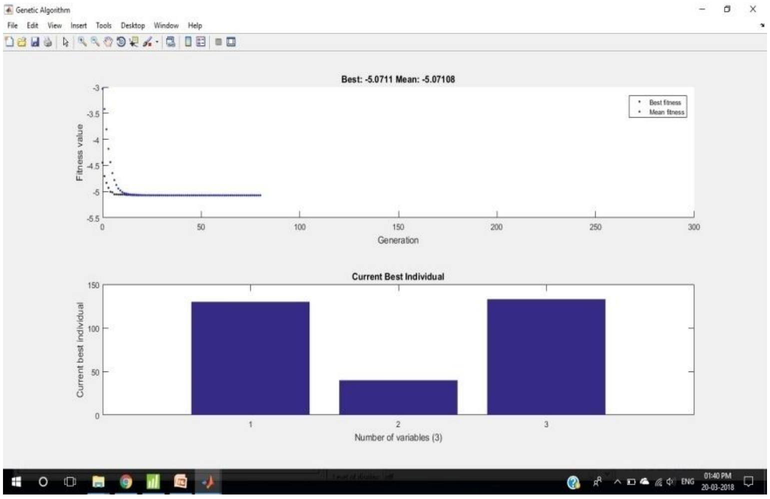

Fig. 6.3 optimization by GA

- **Confirmatory Experiment:**

Table.7 valedictory experiment

Input parameters	Value	Optimized value of MRR	Experimental value of MRR	% Error
Voltage	130	5.07	5.04	-0.59%
Pulse on time	130			
Pulse off time	40			

7. CONCLUSIONS

- **Effect of process parameters on MRR was concluded as under :**

In this experiment as the value of voltage increase, value for material removal rate increase as per the range of given voltage. For pulse on time, when value increase than value of MRR also increase. For pulse off time for some range MRR is increase and further decrease as the pulse off time increase. For the different set of this three input parameter we get different values for material removal rate.

In this paper three input parameter voltage, pulse on time, pulse off time are take different set of three parameters and due to that different values of material removal rate get. Now for the different set of three input variables main effect plot is done as per shown in above figure. And probability graph is also done as per the set of three input parameters.

- **Conclusions from GA optimization:**

The Genetic Algorithm was used for optimization. Following was concluded for the different set of input parameters and for those results in material removal rate. The regression models were subjected to optimization process and have given near about optimal values. Genetic Algorithm was able to reach the optimal solution, after satisfying the constraints. This was validated in present work practically, after performing a confirmatory experiment as per process parameters optimized by GA. Maximum error of 5% was found between the optimized value the experimental value of output parameters of WEDM.

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