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Optimization of Surface Roughness in Electric Discharge Machining on High Carbon High Chromium Steel with Copper Tool

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Abstract: - Electrical discharge machining (EDM) is a nontraditional machining process and it is used to machine hard material components, that are precise and difficult-to-machine such as heat treated tool steels. In die Sinking EDM When sparks are strikes to work piece the metal is heated up so much that it melts and remove the material. This study is focused on optimization of surface roughness on mat lab through genetic algorithm. Experimental data of surface roughness has been collect with five influence parameter such as pulse on time, duty cycle, current, voltage gap and pressure. Design of experiment was done by central composite design.
Key terms: - CCD, mat lab, surface roughness.

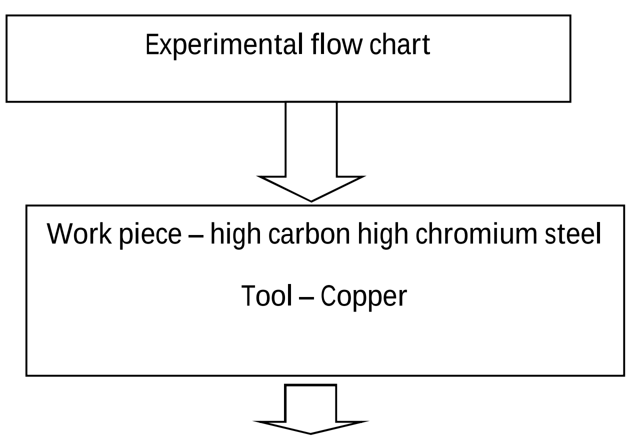
I. INTRODUCTION

In EDM the material is removed by electric spark between both electrode that are work piece and tool electrode.[1] Design of experiment is done through Central composite design which is used for a second-order model. CCD designs are a set of two-level factorial points, axial points and centre point. The factorial points lead to the estimation of linear terms and two-factor interactions. Total numbers of axial points are equal to 2*k. There is 2^k factorial points for a full factorial. There are a number of axial points of 2k and number of factors depends on the number of centre runs.[2] The axial points lie at a distance of $\pm\alpha$ from the centre point (zero level for all factors). The value of α generally varies from 1 to $\sqrt{k}$. By taking $\pm\alpha$ level for one factor and the zero level for all other factors, in the coded space, thus the axial points are obtained.

In optimization of any data select the minimum or maximum of a function by systematically choosing the values of the variables from within set which allowed. Objective functions are those functions which have to be optimized and input variable the variable on which objective function is depends. In addition if there are any constraints then they must also be satisfied by the optimum solution. Mat lab is a optimization tool with different optimization method but in this paper genetic algorithm method is selected for optimized data through mat lab. Real parameter GA has an edge over binary coded GA because of the higher precisions possible through real parameter representations. Also, problems such as hamming cliff are not present in a real parameter GA.

II. METHODOLOGY

A. Flow Chart of Experiment



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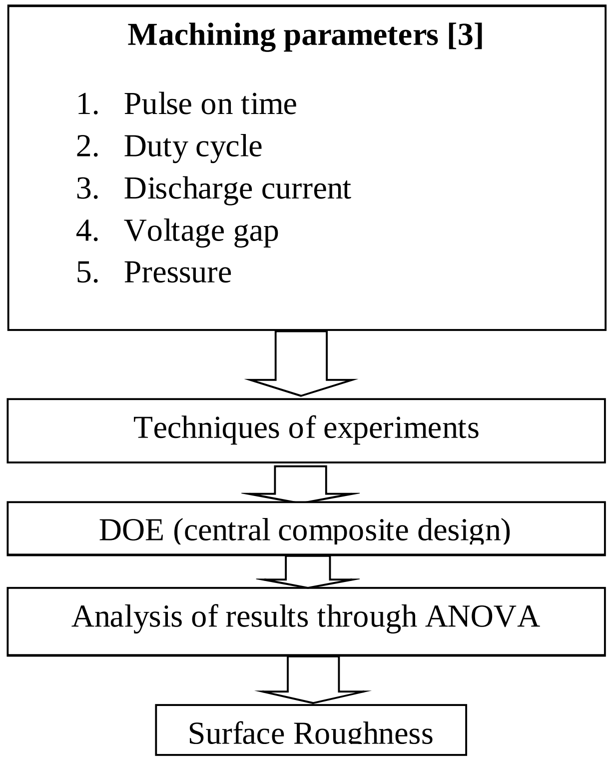

Formulae Used To Calculate Actual Value against the Coded

Table-1

Coded	Actual value
-β (-2)	x_{min}
-1	$\frac{x_{max} + x_{min}}{2} - \frac{x_{max} - x_{min}}{2\alpha(2)}$
0	$\frac{x_{max} + x_{min}}{2}$
+1	$\frac{x_{max} + x_{min}}{2} - \frac{x_{max} - x_{min}}{2\alpha(2)}$
β (+2)	x_{max}

Table-2 EXPERIMENTAL DATA

Run	Ton	Duty Cycle	Ip	Vgap	Fp	Ra Copper
1	0	0	0	0	0	4.8
2	-1	-1	1	-1	-1	5.4
3	-1	1	-1	-1	-1	7.2
4	-1	-1	-1	-1	1	3.8
5	0	0	0	0	0	9.8
6	0	0	0	-2	0	5
7	1	1	-1	1	-1	4.2
8	1	-1	-1	1	1	7
9	-1	-1	1	1	1	10.6
10	1	1	1	-1	-1	14.2
11	2	0	0	0	0	7

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12	0	0	0	2	0	5.2
13	0	0	2	0	0	7.6
14	0	0	0	0	0	6
15	0	0	0	0	-2	6.8
16	-1	1	1	-1	1	6.4
17	-1	1	1	1	-1	10.2
18	-1	1	-1	1	1	7.4
19	0	0	0	0	2	6.6
20	0	0	0	0	0	8.2
21	1	1	1	1	1	6.8
22	-2	0	0	0	0	6
23	1	-1	-1	-1	-1	2
24	1	-1	1	1	-1	5.8
25	0	-2	0	0	0	10.2
26	-1	-1	-1	1	-1	4.6
27	1	1	-1	-1	1	9.4
28	0	0	0	0	0	6
29	1	-1	1	-1	1	7.1
30	0	0	0	0	0	6.1
31	0	2	0	0	0	7.3
32	0	0	-2	0	0	8.4

Analysis of variance - based sequential sum of squares test has been done to select the most appropriate fitted model. ANOVA results are shown in Table-3 , which is come from the Minitab software using experimental result data. In this table lowest P value is 0.005 of interaction model.

Table –3 ANOVA for surface roughness using copper

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Regression	20	221.28	221.28	11.064	2.85	0.015
Linear	5	22.12	13.28	2.656	0.62	0.688
Square	5	20.85	20.85	4.169	0.97	0.475
Interaction	10	178.31	178.31	17.831	4.17	0.005
Residual Error	11	47.09	47.09	4.281		
Lack of fit	6	27.81	27.81	4.363	1.20	0.429
Pure Error	5	19.28	19.28	3.855		
Total	31	268.37				

R- sq= 86.89% , R- sq (adj) = 71.50

According to ANOVA results, Linear interaction fitted model is best fitted model for surface roughness because corresponding to that model P value is very low .The "Lack of Fit F-value" of 1.2 implies that the lack of fit is not significant relative to the pure error. It is good for model because lack of fit is not significant means there are not such type of input process parameters which is much

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affected of model.

Table – 4 Regression coefficients for surface roughness using copper

Term	Coef	SE Coef	T	P
Constant	1.2950	9.8502	0.131	0.897
Ton	-0.0012	0.0036	-0.331	0.745
Dc	0.3693	0.3376	1.094	0.290
Amp	-0.0116	0.2260	-0.051	0.960
Vg	-0.0140	0.0932	-0.151	0.882
Prss	30.8881	23.7928	1.298	0.213
ton*dc	-0.0000	0.0001	- 0.107	0.916
ton*amp	0.0000	0.0001	0.568	0.578
ton*vg	0.0000	0.0000	0.461	0.651
ton*prss	-0.0012	0.0071	-0.170	0.867
dc*amp	0.0202	0.0059	3.426	0.003
dc*vg	-0.0041	0.0024	-1.689	0.111
dc*prss	-2.4452	0.6647	-3.679	0.002
amp*vg	-0.0032	0.0017	-1.902	0.075
amp*prss	-0.7711	0.4579	-1.684	0.112
vg*prss	0.4900	0.1873	2.616	0.019

Table 4 show the regression coefficient and significant factors for surface roughness using copper as a tool electrode. According to this table there are no any single machining parameters which are much affected means significant factors because all machining parameters have high P value. The interactions of two input machining parameters are significant factor in this case because combination of duty cycle (dc) and pressure (F), combination of duty cycle (dc) and discharge current (I_d) are most significant factors for surface roughness using copper electrode.

B. *Final Regression Equation*

Ra = 1.295 - 0.0012*Ton+ 0.3693*dc - 0.0116*amp - 0.140*Vg + 30.888*press - 0.0012*Ton*press+ 0.0202*dc*amp - 0.0041*dc*Vg - 2.4452*dc*press - 0.0032*amp*Vg - 0.7711*amp*press + 0.49*Vg*press

Where, Ra is the surface roughness in µm.This regression equation is obtained from analysis of experimental data through ANOVA on mini tab software. And on the basis of this regression equation is optimized.

C. *Response Optimization*

It is the process of finding the minimum or maximum of a function by systematically choosing the values of the variables from within set which allowed. Objective functions are those functions which have to be optimized and the variables on which the objective function depends are called the input variable. The possible set of values of the parameters forms the search space. In addition if there are any constraints then they must also be satisfied by the optimum solution.[4]

Optimization can be considered to be a 'search' process wherein we are interested in finding that particular solution (out of the entire search space) which makes the objective function minimum or maximum. Classical optimization methods are primarily of

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two types: direct and gradient based search methods. In direct search methods, only objective function and constraint values are used to guide the search strategy, whereas gradient-based methods use the first and/or second-order derivatives of the objective function.

D. Optimization through Genetic Algorithm

Genetic algorithm (GA) is a subclass of population based stochastic search procedure which is closely modeled on the natural process of evolution with emphasis on the survival of the fittest and breeding. The algorithm starts in spite of starting with a single point with a set of initial solutions.[4]
For incorporating the idea of natural evolution GA must have the following essential features:
Solution's encoding- To keep track of favourable solutions
Assigning suitability to a solution: To determine the chances of survival of the solution.
Selection of operator: To select the fit solutions for mating.
Recombination operator: For mixing of traits through mating of two different solutions.
Operator's mutation: Random variations in encoded solutions to obtain new solutions.
These operators are responsible for providing the search direction to a GA. Selection operator selects good solutions and crossover operator recombines good genetic material from two good solutions to (hopefully) form a better solution. Operator's mutation alters a string locally to (hopefully) create a better string. If bad strings are created they are be eliminated by the reproduction operator in the next generation and they are emphasized if they are created.
In real parameter GA, solutions are represented as real numbers instead of using a binary string representation. Real parameter GA has an edge over binary coded GA because of the higher precisions possible through real parameter representations. Also, problems such as hamming cliff are not present in a real parameter GA.[5]
The selection and survivor operators require no modification for real representations. However, modified crossover and mutation operators are necessary to handle real parameters. Simulated binary crossover (SBX) is one of the cross-over operators used for real parameters. SBX imitates the working principle of a binary crossover in real paradigm. The operator produces two children from two parent solutions by generating a random cross-site lying between the two parents. The nearness of the cross-site to the parents is determined by the factor η_c. A large value of η_c produces children nearer to the parents indicating a higher degree of recombination
To Use the GA Tool
Fitness function — the objective function you want to minimize. Enter the fitness function in the form, where fitnessfunn is an M-file that computes the fitness function.
Number of variables — the length of the input vector to the fitness function.
To run the genetic algorithm, click the Start button. The tool displays the results of the optimization in the Status and Results pane.
In order to convert the responses into single characteristic, it is suitably modified. The objective
Objective 1 = Ra =f (1)

IV. RESULTS AND ANALYSIS

A. Optimized Data by GA through MATLAB

Optimization process in matlab through genetic algorithm. First of all I write the objective function in M file of mat lab software after than open the optimization tool and select the genetic algorithm and then fit the objective function then fill the lower limit and upper limit of all process parameters then finally click the button of start and note down the optimization results.

Table:5 Optimum Solution for Surface Roughness using copper

Input parameters	**Value at minimum surface roughness**
Pulse on time (Ton)	100 µs
Duty cycle (dc)	1 %
Current (Ip)	5 amp
Voltage gap (Vg)	10 volt
Pressure (F)	0.116 kgf/cm^2
Response variable	
Surface roughness	3.47 µm

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The above table-5 represent the optimum solution for surface roughness. The optimum value of surface roughness found through mat lab is 3.47µm which is much better surface finish with comparison to experimental results. It prove that the optimum value come at100 µs, 1%, 5 amp, 10 volt and 0.116.

V. CONCLUSIONS

In this paper, parametric analysis of the die- sinking EDM process has been done based on experimental results. Perform the number of nun is based on the Central Composite Design (CCD). Process optimization was then performed using Genetic Algorithms (GA) at Matlab software. Finding from the optimization results, the all optimized value is better over experimental results of surface roughness.

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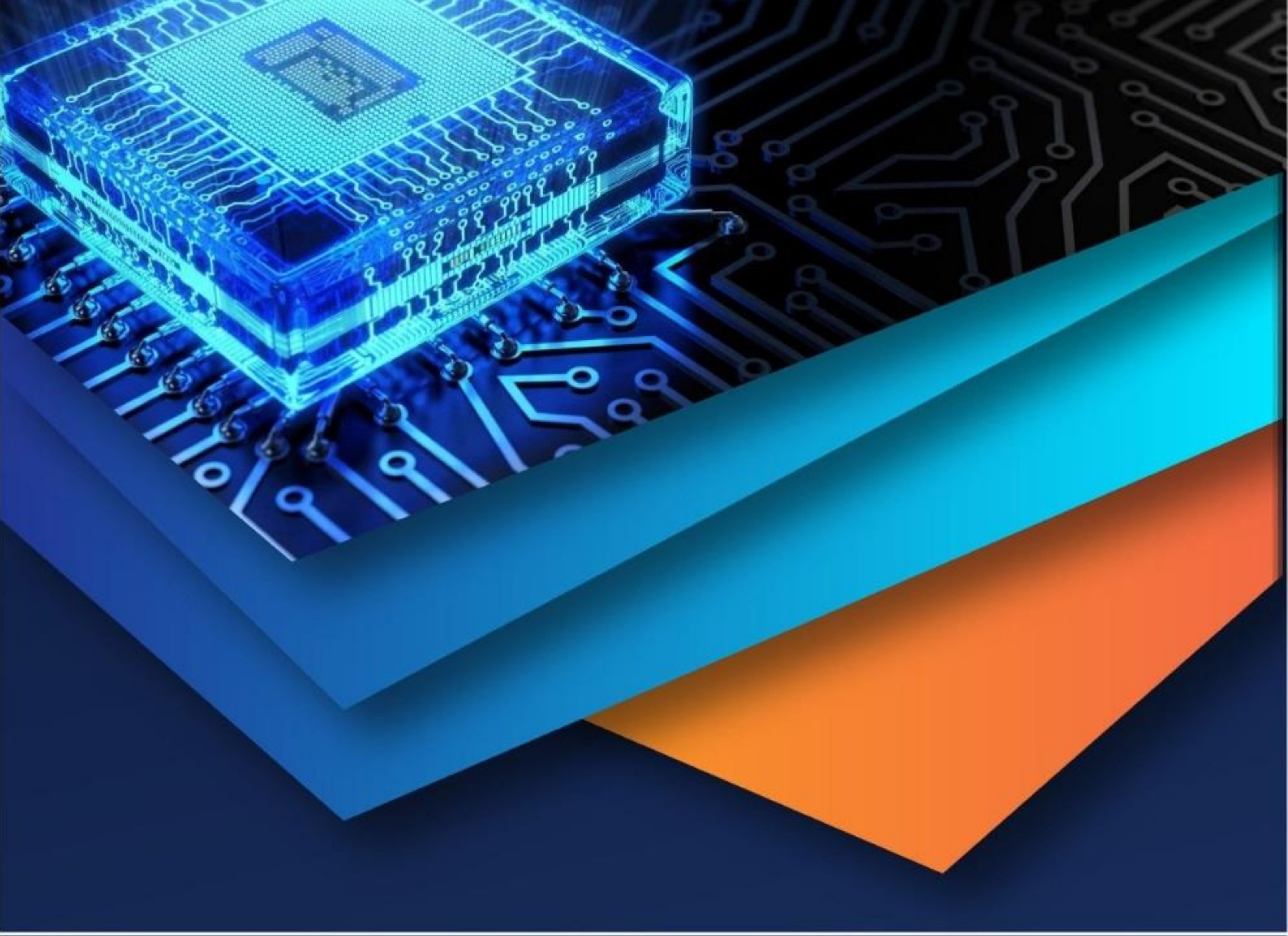

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