Optimization of Process Parameters for Improving Performance in Electrical Discharge Machining

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***Abstract*---** The correct selection of manufacturing condition is one of the most important aspects to take into consideration in the majority of manufacturing processes and, particularly, in processes related to Electrical Discharge Machining (EDM). It is a capable of machining geometrically complex or hard material components.

From the point of view of industrial applications, SS 410 is a very important material and that's why for the purpose of experimentation SS 410 with copper electrode and EDM oil as dielectric fluid has been used. In this present work various input parameters are selected such as discharge current, pulse on time and pulse off time. The experiment was done using PRESS-MACH EDM machine. Three level approach of full factorial design of experiment was applied to design the experimental and the data was analyzed by using analysis of variance (ANOVA). It is found that discharge current and pulse on time was the most significant factor affecting the SR and discharge current was the most significant factor affecting the MRR. Genetic algorithm is used for finding out the optimal condition for surface roughness and material removal rate for EDM.

Keywords: - EDM machine, Full Factorial method, ANOVA Analysis, Minitab@16 software, Genetic algorithm, MATLAB R2010a, Surface Roughness, Material Removal Rate.

I. Introduction

A. *Introduction Of Electric Discharge Machining*

Electrical discharge machining (EDM) is one of the most extensively used nonconventional material removal processes. In this process the material is removed by a succession of electrical discharges, which occur between the electrode and the workpiece. There is no direct contact between the electrode tool and the workpiece. These are submersed in a dielectric liquid such as kerosene or deionised water. Its unique feature of using thermal energy to machine electrically conductive parts regardless of hardness has been its distinctive advantage. The electrical discharge machining process is widely used in the aerospace, automobile, die manufacturing and moulds industries to machine hard metals and its alloy.

B. *Principle of Electric Discharge Machining*

In this process the metal is removing from the work piece due to erosion case by rapidly recurring spark discharge taking place between the tool and work piece. Show the mechanical set up and electrical set up and electrical circuit for electro discharge machining. A thin gap about 0.025mm is maintained between the tool and work piece by a servo system shown in fig 1.1. Both tool and work piece are submerged in a dielectric fluid Kerosene/EDM oil/deionized water is very common type of liquid dielectric although gaseous dielectrics are also used in certain cases.Figure1. 1 Set up of Electric discharge machining

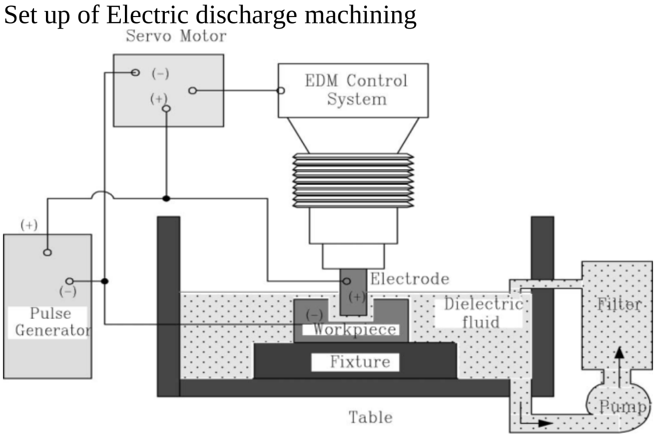

Fig. 1: Setup of The Electric Discharge Machining [1]

C. *Important parameters of EDM*

1) *Spark On-time (Pulse time or Ton):* The duration of time (µs) the current is allowed to flow per cycle. Material removal is directly proportional to the amount of energy applied during this on-time. This energy is really controlled by the peak current and the length of the on-time.

2) *Spark Off-time (Pause time or Toff):* The duration of time (µs) between the sparks (that is to say, on-time). This time allows the molten material to solidify and to be wash out of the arc gap. This parameter is to affect the speed and the stability of the cut. Thus, if the off-time is too short, it will cause sparks to be unstable.

3) *Arc Gap (or gap):* The Arc gap is distance between the electrode and workpiece during the process of EDM. It may be called as spark gap. Spark gap can be maintained by servo system

4) *Discharge Current (Current Ip):* Current is measured in amp Allowed to per cycle. Discharge current is directly proportional to the Material removal rate.

5) *Duty Cycle (τ):* It is a percentage of the on-time relative to the total cycle time. This parameter is calculated by dividing the on-time by the total cycle time (on-time pulse off-time).

τ = (Pulse on time/Pulse off time + Pulse on time) (1.1)

6) *Voltage (V):* It is a potential that can be measure by volt it is also effect to the material removal rate and allowed to per cycle.

7) *Over Cut :* It is a clearance per side between the electrode and the workpiece after the marching operation.

II. Design Of Experiment

Table:1 Factors and Their levels in EDM

Process parameter	Process designation	Level 1	Level 2	Level 3
Discharge current(Amp)	A	5	10	15
Pulse on time (µs)	B	50	200	1000
Pulse off time (µs)	C	50	100	500

Table: 2 Design of Experimental

Sr No.	Discharge Current(Amp)	Pulse on Time (µs)	Pulse off Time (µs)	Surface Roughness(µm)	MRR (mm^3/min)
1	5	50	50	3.01	4.2971
2	5	50	100	1.99	1.6795
3	5	50	500	1.06	3.0387
4	5	200	50	5.63	5.7971
5	5	200	100	4.36	6.0723
6	5	200	500	5.69	5.9715
7	5	1000	50	5.37	6.2795
8	5	1000	100	5	5.9795
9	5	1000	500	4.48	5.3211
10	10	50	50	4.48	13.5037
11	10	50	100	4.05	9.9279
12	10	50	500	2.61	7.9511
13	10	200	50	6.72	16.279
14	10	200	100	5.8	19.1214
15	10	200	500	5.83	17.1059
16	10	1000	50	6.73	14.5643
17	10	1000	100	7.1	14.1519
18	10	1000	500	6.47	17.1511
19	15	50	50	6.21	25.8733
20	15	50	100	5.35	26.9281
21	15	50	500	5.84	27.2157
22	15	200	50	6.95	43.4772
23	15	200	100	6.85	37.2137
24	15	200	500	7.43	26.4529
25	15	1000	50	7.22	32.033
26	15	1000	100	7.51	22.9374
27	15	1000	500	7.85	21.347

III. EXPERIMENTAL WORK

A. Experimental Set up

In order to achieve the goal of this experimental work the cutting tests were carried out in PRESS MACH Die sinker EDM at OM PRECISION INDUSTRIES, AHMEDABAD. The Die sinker EDM has 2-2000 µs pulse on/off capacity and a maximal machining weight of 100 kg, maximal working current 25 Amp and maximal reservoir capacity 60 liters.

B. Technical Specification

1. Model: PRESS MACH EDM
2. Workpiece : Max Height : 150 mm
   Max Weight : 100 kg
3. Dielectric System: Reservoir Capacity : 60 litrs
   Filteration Level : 10 microns
4. Pulse Generator: Working Current : 25 Amp
   Power Consumption : 3 kw
   Pulse on/off Time : 2-2000 µs
5. Table Travel : X axis : 220 mm
   Y axis : 130 mm
6. Servo Head : Quill Stroke : 200 mm
   Electrode Platten size : 100 X 100 mm
   Max Electrode Weight : 20 kg

C. workpiece material

1. Stainless Steel AISI 410 or SS410.
2. Dimension for material is 50 mm X 50 mm X 8 mm.

IV. ANALYSIS OF VARIANCE (ANOVA)

1. For SR analysis shows the percentage contribution of individual parameters on surface roughness. The percentage contribution of discharge current is 42.23 %, pulse on time of 44.88 % and pulse off time of 2.07 % and the error is of 10.80 %. This error is due to human ineffectiveness and machine vibration.
2. For MRR analysis shows the percentage contribution of individual parameters on Material removal rate. The percentage contribution of discharge current is 83.67 %, pulse on time of 5.78 % and pulse off time of 1.81 % and the error is of 8.92 %. This error is due to human ineffectiveness and machine vibration.

A. Main Effect Plots Analysis

The analysis is made with the help of a software package MINITAB 16. The main effect plots are shown in Fig.5.1 and Fig.5.2. These show the variation of individual response with the three parameters i.e. discharge current, pulse on time and pulse off time separately. In the plots, the x-axis indicates the value of each process parameter at three level and y-axis the response value. Horizontal line indicates the mean value of the response. The main effects plots are used to determine the optimal design conditions to obtain the optimum surface finish.

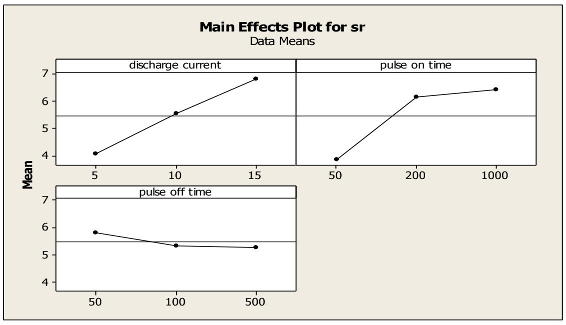

Fig. 2: Main effect plot for Surface Roughness

According to this main effect plot fig.4.1, the optimal conditions for minimum surface roughness are:

1. Discharge Current at level 1 (5 Amp)
2. Pulse on Time at level 1 (50 µs)
3. Pulse off Time at level 3 (500 µs)

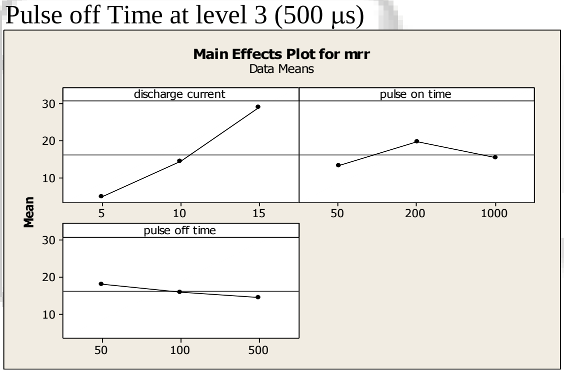

Fig. 3: Main Effect Plot for Material Removal Rate

Fig. 4.2 shows the main effect plot for material removal rate. According to this main effect plot, the optimal conditions for maximum material removal rate are:

1. Discharge Current at level 3 (15 Amp)
2. Pulse on Time at level 2 (200 µs)
3. Pulse off Time at level 1 (50 µs)

V. OPTIMIZATION

A. Genetic Algorithm

In 1975, Holland developed this idea in his book Adaptation in natural and artificial systems. He described how to apply the principles of natural evolution to optimization problems and built the first Genetic Algorithms. Holland's theory has been further developed and now Genetic Algorithms (GAs) stand up as a powerful tool for solving search and optimization problems. Genetic algorithms are based on the principle of genetics and evolution [20]. Goldberg, 1989 gives an excellent introductory discussion on GA, as well as some more advanced topics. Genetic algorithms are a probabilistic search approach which is founded on the ideas of evolutionary processes. The GA procedure is based on the Darwinian principle of survival of the fittest. An initial population is created containing a predefined number of individuals (or solutions), each represented by a genetic string (incorporating the variable information). Each individual has an associated fitness measure, typically representing an objective value. The concept that fittest (or best) individuals in a population will pro-duce fitter offspring is then implemented in order to reproduce the next population. Selected individuals are chosen for reproduction (or crossover) at each generation, with an appropriate mutation factor to randomly modify the genes of an individual, in order to develop the new population. The result is another set of individuals based on the original subjects leading to subsequent populations with better (min. or max.) Individual fitness. Therefore, the algorithm identifies the individuals with the optimizing fitness values, and those with lower fitness will naturally get discarded from the population. Ultimately this search procedure finds a set of variables that optimizes the fitness of an individual and/or of the whole population. As a result, the GA technique has advantages over traditional nonlinear solution techniques that cannot always achieve an optimal solution. For the genetic algorithm, the population encompasses a range of possible outcomes. Solutions are identified purely on a fitness level, and therefore local optima are not distinguished from other equally fit individuals. Those solutions closer to the global optimum will thus have higher fitness values. Successive generations improve the fitness of individuals in the population until the optimization convergence criterion is met. Due to this probabilistic nature GA tends to the global optimum, however for the same reasons GA models cannot guarantee finding the optimal solution. The GA consists of four main stages: evaluation, selection, crossover and mutation.

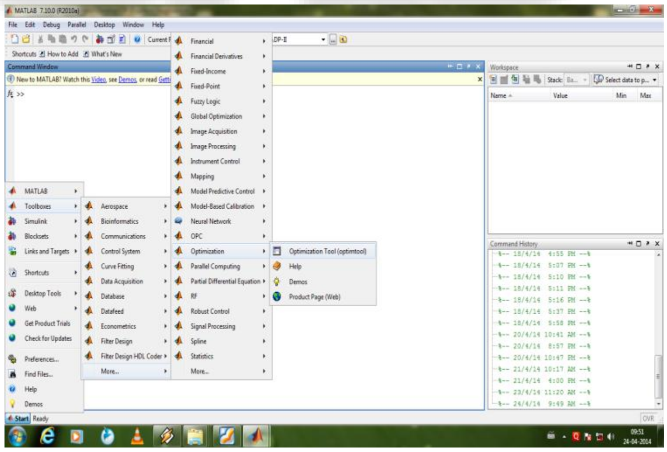

Fig. 4: MATLAB Tool Selection Window

B. Regression Equations

Regression equations were formed using MINITAB 16 software for material removal rate and surface roughness Ra

The regression equation for surface roughness (SR) is

SR = 2.43 + 0.251 discharge current + 0.00224 pulse on time - 0.00337 pulse off time - 0.000054 discharge current * pulse on time + 0.000210 discharge current *pulse off time + 0.000001 pulse on time *pulse off time (6.1)

The regression equation for material removal rate (MRR) is

MRR = - 12.8 + 3.06 discharge current + 0.00639 pulse on time + 0.0083 pulse off time - 0.000711 discharge current * pulse on time - 0.00152 discharge current * pulse off time + 0.000002 pulse on time* pulse off time (6.2)

In genetic algorithm (GA) these equations are written in the form of

The regression equation for surface roughness (SR) is

Function y = surface_roughness(x)

SR = (2.43 + 0.251 * (x(1)) + 0.00224 * (x(2)) - 0.00337 * (x(3)) - 0.000054 * (x(1) * x(2)) + 0.000210 * (x(1) * x(3)) + 0.000001 * (x(2) * x(3))); (6.3)

The regression equation for material removal rate (MRR) is

Function y = removal_rate(x)

MRR = - 12.8 + 3.06 discharge current + 0.00639 pulse on time + 0.0083 pulse off time - 0.000711 discharge current * pulse on time - 0.00152 discharge current * pulse off time + 0.000002 pulse on time * pulse off time (6.4)

C. Genetic Algorithm Result For Sr And Mrr

1) Minimization Of Surface Roughness

Best fitness for minimization of surface roughness is shown in below using genetic algorithm tool. Population size 100, current iteration 51.

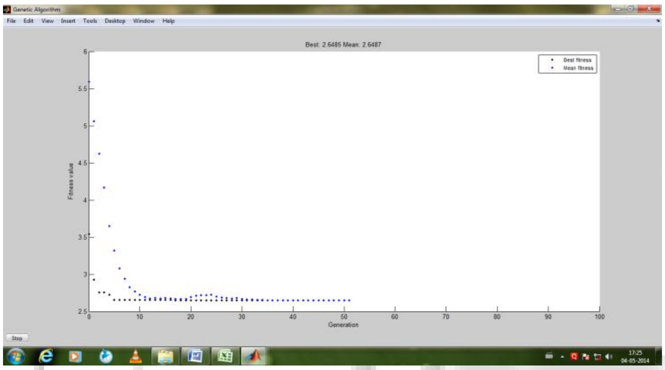

Fig. 5: Graph for Surface Roughness

Discharge current = 5.0 amp, Pulse on time = 50.0 µs and Pulse off time = 499.999965 µs

Best fitness for minimization of surface roughness is 2.648500077359856 µm.

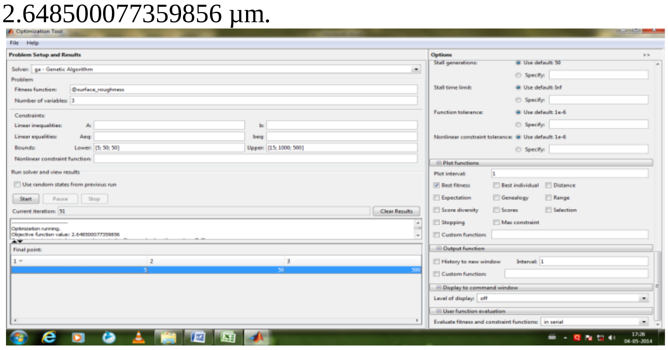

Fig. 6: GA Toolbox in MATLAB Environment for SR

D. Maximization Of Material Removal Rate

Best fitness for maximization of material removal rate is shown in below using genetic algorithm tool. Population size 100, current iteration 51

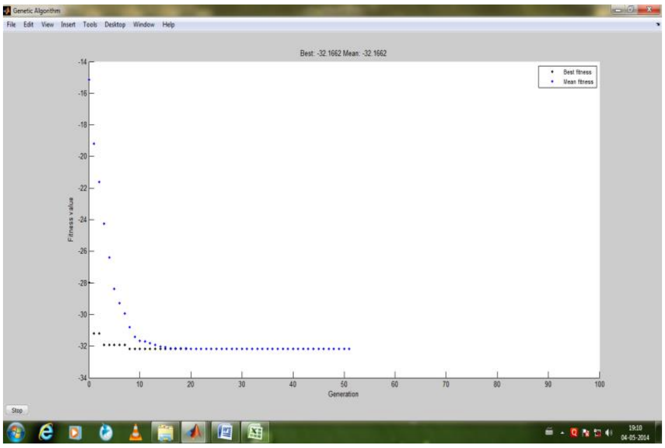

Fig. 7: Graph for Material Removal Rate

Discharge current =14.99999975 Amp, Pulse on time = 50.0 µs and Pulse off time = 50.0 µs

Best fitness for maximization of material removal rate is 32.16624928392038 mm^3/min.

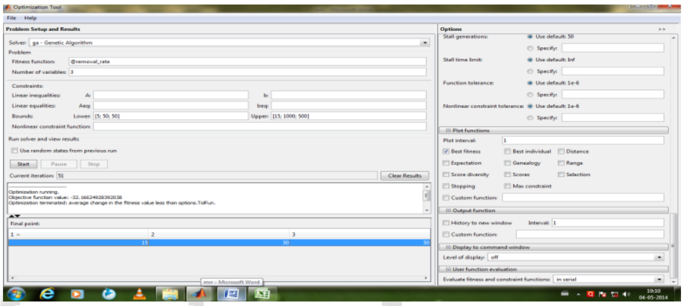

Fig. 8: GA Toolbox in MATLAB Environment for MRR

VI. CONCLUSION

In this dissertation work, various EDM parameters like, Discharge current, Pulse on time and Pulse off time have been evaluated to investigate their influence on surface roughness and material removal rate for EDM operation. Based on the result obtained, it can be concluded as follows:

A. Surface Roughness

1. Discharge current, pulse on time and pulse off time significantly effect on surface roughness.
2. Pulse on time and Discharge current are found the most significant effect on surface roughness. Increase in Pulse on time and Discharge current, value of surface roughness is increases.
3. Pulse off time is found to have effect on surface roughness. Increase in pulse off time value of surface roughness is decreases.
4. The percentage contribution of discharge current is 42.23 %, pulse on time of 44.88 % and pulse off time of 2.07 % on surface roughness for EDM operation.
5. From the ANOVA, it is concluded that the pulse on time and discharge current is significant parameter which contributes more to surface roughness.
6. In multi response optimization, the optimum cutting parameter combination is- Discharge current-5.0 Amp, Pulse on time-50 µs and Pulse off time -499.999965 µs. Surface roughness - 2.648500077 µm.
7. In multi response optimization the optimum cutting parameter combination is meeting with parameter combination value is 0.200 mm depth of cut, 209.99

m/min cutting speed and 0.14 mm/rev feed rate surface roughness is 0.7429609811393024 µm.

B. Material Removal Rate

1. The volume of material removed can be achieved better when machining is done at high Discharge current.
2. Discharge current is found the most significant effect on material removal rate. Increase in Discharge current, value of material removal rate is increases.
3. The percentage contribution of discharge current is 83.67 %, pulse on time of 5.78 % and pulse off time of 1.81 % on material removal rate for EDM operation.
4. From the ANOVA, it is concluded that the discharge current is most significant parameter which contributes more to material removal rate.
5. In multi response optimization, the optimum cutting parameters combination is Discharge current-14.99999975 Amp, Pulse on time-50.0 µs and Pulse off time -50 µs. material removal rate-32.16624928 mm^3/min.

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