Parametric optimization of electric discharge machining of SCM415 alloy steel material using Taguchi Technique

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Abstract*:* - In the present study objective of this research work is to analyze the effects of the input parameters (Pulse-on-time (T-on), Duty cycle (DC),Peak current (I_p), Electrode material) of the Electrical discharge machining (EDM) duringmachining of SCM415 alloy steel. Machining experiments were conducted based on Taguchi technique. In order to achieve the maximum material Removal rate and minimum tool wear rate, to obtain the desire results six levels of peak current, three levels of duty cycle, three levels of pulse on time and three different tool material are used. The result of studies indicates that peak current hasa greater impact on both TWR and MRR than other control parameters.

Keywords-Electrical Discharge Machine (EDM), Material Removal Rate(MRR),Tool Wear Rate(TWR). Duty Cycle(DC),Peak Current(I_p), Pulse on time(T-on)

1. INTRODUCTION

Electrical discharge machining (EDM)is a non conventionalmachining technique.This EDM is widely used for producing moulds, dies, and finishing parts for aerospace, automotive, and surgical components.In this desired shape is obtained due to electrical discharges, based on Thermo-electric energy between the workpiece and tool in a liquid dielectric medium. The performance of Electrical Discharge Machining mainly founds out on the basis of Material Removal Rate (MRR), Surface Roughness (SR), Overcut (OC), and Tool Wear Rate (TWR).. The important machining parameters of EDM machining which affecting on the performance are current, pulse on time, pulse off time, arc gap, flushing pressure, voltage and duty cycle. The workpiece material, manufacturing and design method of the electrodes also affect the performance of the process.For optimum performance, Selecting suitable combination of machining parameters is an important task.Majorly, the machining parameters are selected on the basis of the raw data provided by the EDM manufactures or by the operator's experience.Dueto number of machining variables and gentle changes in a single parameter significantly difficult the Optimization of process parameters on EDM. Thus, it is essential to understand the importance of various factors in EDM process. Statistical and Analytical methods are used to choose the best combination of process parameters for the optimum machining performance. A different combination of process parameters was used by different Authors. Some more methods used by different authors for deduction of data related to Optimization of process parameters on Electrical Discharge Machining (EDM) are Regression analysis, Grey Relational Analysis (GRA), Fuzzy clustering, Response Surface Methodology (RSM), Central Composite Design (CCD) and Genetic Algorithm (GA).

2. EXPERIMENTATION

2.1. Work piece material Detail:-

The material used in this work is SCM415 of 14mm thickness and 39 mm diameter. SCM415 is a chromium-molybdenum alloy which is commonly intended for high temperature and high pressure services

Table.1Chemical Composition of the Workpiece (SCM415).

Material	C%	Mn%	Si%	S%	P%	Cr%	Mo%
SCM 415	0.13-0.18	0.60-0.90	0.15-0.35	.030	0.03	0.90-1.20	0.15-0.30

Table.2 Mechanical Properties of Workpiece (SCM 415)

Quantity	Value	Unit
Young's modulus	200000 – 200000	MPa
Tensile strength	650 – 880	MPa
Elongation	8 – 25	%
Fatigue	275 – 275	MPa
Yield strength	350 – 550	MPa

Table.3Physical properties of Workpiece (SCM 415)

Quantity	Value	Unit
Thermal Expansion	10 - 10	e-6/K
Thermal Conductivity	25 - 25	W/m.K
Specific Heat	460 - 460	J/kg.K
Melting Temperature	1450 - 1510	°C
Density	7700 - 7700	Kg/m^3
Resistivity	0.55 - 0.55	$Ohm.mm^2/m$

2.2. Tool material

In spark machining, supper conductor tools, such as graphite,copper, brass, copper and tungsten alloys are used. The mostimportant parameters in choosing tools are cost of material,machining conditions, tool wear rate, melting point, andcost of building and repair of tool [16]. In this study, copper, Aluminium and Brasselectrode were chosen as the tool, to avoid any errors,its diameter and its face was machined and was polished.

Table.4 Physical and mechanical properties of tools

Quantity	Material			Unit
	Copper	Aluminium	Brass	
Electrical resistivity	1.724×10^{-8}	2.65×10^{-8}	5.9×10^{-8}	Ω m
Thermal conductivity	386	204	109	W/mK
Melting point	1083	659	927	Celsius
Specific heat	0.0923	0.215	0.092	cal/g◦C
Specific gravity	8930	2560 – 2640	8400 - 8700	Kg/m³

2.3. Dielectric

Different dielectric fluids can use in EDM, including kerosene, oil and deionized water, The purpose of using dielectric fluid is to cool down tools and workpiece, also ensure the eroded material is completed removed from the job and dielectric should have a very high flash point and low prices also not create a fire hazard [18]. In this experiment, IPOL SEO 450 spark erosion oilis used as the dielectric

3. Experimental Setup and Procedure:

3.1. Setup of the Experiment

The experiments are conducted using the ELECTRONICA C3820 EDM machine (die sinking type) which having a servo control system for feed. The machine has different current setting range from 1-20A, the polarity of workpiece is set as positive, while that of tool as negative. IPOL SEO 450 SPARK EROSION oil is used as the dielectric which ensure the eroded material is completed removed from the job and the temperature of the dielectric is maintained by the cooling unit during the machining process.

3.2. Principle of Taguchi

Taguchi Method is used in the method which is used to improve the quality of product, it is one of the new engineering design optimization methodology that improves the quality of existing processes and products and also simultaneously reduces their costs very rapidly. The Taguchi Method achieves this by making the process or product performance "insensitive" to variations in factors such as workmanship, operating conditions, materials and manufacturing equipment. Taguchi's philosophy is set up on the following three major very simple and fundamental concepts (Ross, 1988; Roy, 1990): Quality is optimally achieved by minimizing the variation from the target; Quality should be created into the product and not inspected into it. The process or product should be so designed that it is protected to uncontrollable environmental variables

3.3. Design of Experiments

In the present study objective of this research work is to study MRR and TWR, the design variables which are taken as input parameters can be summarized as follows:
a) Six levels of peak current to be used.
b) Three levels of the Electrode Material have been used.
c) Three levels of pulse on-time to be used.
d) Three levels of duty cycle to be used.

Out of the above listed design variables, The orthogonal array was to be selected for four design variables which would constitute the orthogonal array. MRR and TWR have been as response parameters for this research work. Taguchi method is used to find out the optimum machining condition and the percentage contribution of each factor to the response factor.
Machining parameters and their level taken in the present study are following

Table.5 Machining parameters and their level

Machining Parameters	Level					
	1	2	3	4	5	6
Peak Current(amp)	3	6	9	12	15	18
Pulse on time (µ.sec)	52	55	58	---	---	---
Duty Cycle	3	5	7	---	---	---
Electrode Material	Copper	Aluminium	Brass	---	---	---

Depending upon the selection of the input parameters and their level anL18 Orthogonal Array created with the help of Taguchi methodand all the experiments performed according to the L18 Orthogonal Array

4. Result and discussion

The 18 different experiments were conducted for 10 min. each with tool 12mm diameter tool. After conducting the 18 different experiments according to the Taguchi method by using the machining set up and control parameters, MRR and TWR is being calculated in grams/min.

4.1. Material removal rate (MRR) and Tool wear rate (TWR) :

MRR and TWR is measured by dividing the difference of initial and final Weight of work-piece and tool respectively by the time taken to machine. And they aremeasured in gram/min.

$$\mathrm{MRR} = \frac{W_{jb} - W_{ja}}{t}$$

$$\mathrm{TWR} = \frac{W_{tb} - W_{ta}}{t}$$

Where

Wjb = Weight of work piece before machining.
Wja = Weight of work piece after machining.
Wtb = Weight of the tool before machining.
Wta = Weight of the tool after machining.
t = Machining time = 10 min.

4.2. Effect of input parameters of Material Removal Rate:

In the present study after conducting 18 different experiments, the effect of different process parameters on MRR is observed and plotted as the process parameters change from one level to another. The MRR is calculated along with S/N ratio, which is given in table 7. The response table for S/N ratio and mean created in the Taguchi are

Table.6Experimental Results of EDM

Runs	Peak Current	T-on	Duty Cycle	Electrode Material	MRR	TWR	S/N ratio for MRR	S/N ratio for TWR
1	3	52	3	Copper	0.0079	0.0024	-42.0475	52.3958
2	3	55	5	Aluminium	0.0031	0.0052	-50.1728	45.6799
3	3	58	7	Brass	0.0109	0.0079	-39.2515	42.0475
4	6	52	3	Aluminium	0.0494	0.0098	-26.1255	40.1755
5	6	55	5	Brass	0.0147	0.0146	-36.6537	36.7129
6	6	58	7	Copper	0.0621	0.0039	-24.1382	48.1787
7	9	52	5	Copper	0.1569	0.0064	-16.0875	43.8764
8	9	55	7	Aluminium	0.1543	0.0147	-16.2327	36.6537
9	9	58	3	Brass	0.0265	0.0198	-31.5351	34.0667
10	12	52	7	Brass	0.0354	0.0460	-29.0199	26.7448
11	12	55	3	Copper	0.2423	0.0074	-12.3129	42.6154
12	12	58	5	Aluminium	0.2836	0.0126	-10.9459	37.9926
13	15	52	5	Brass	0.0756	0.0614	-22.4296	24.2366
14	15	55	7	Copper	0.3624	0.0157	-8.8162	36.0820
15	15	58	3	Aluminium	0.3461	0.0192	-9.2160	34.3340
16	18	52	7	Aluminium	0.3688	0.0498	-8.6642	26.0554
17	18	55	3	Brass	0.1614	0.0761	-15.8419	22.3723
18	18	58	5	Copper	0.3928	0.0196	-8.1166	34.1549

Table.7Response for Signal to Noise Ratio for MRR (Larger is better)

Level	Peak Current	Pulse on Time	Duty Cycle	Electrode Material
1.	-43.82	-24.06	-22.85	-20.23
2.	-28.97	-23.34	-24.07	-29.12
3.	-21.29	-20.53	-21.02	-18.59
4.	-17.43	--------	--------	--------
5.	-13.49	--------	--------	--------
6.	-10.87	--------	--------	--------
Delta	33.95	3.53	3.05	10.54
Rank	1	3	4	2

The effect of Peak current, t-on, duty cycle and electrode material is shown in the effect plot for a S/N ratio of MRR. The plot of the present study of 18 different experiments indicates that the value of MRR increases with the increase of the peak current and peak current is a major significant factor which effect the MRR in the study, the second most significant factor is tool material, from the three different tool material copper is more effective than aluminium and brass. From the S/N plot study, we found out that brass is less effective than other tools used in study, the third effective parameter is DUTY CYCLE, MRR value is maximum for 7 and list for the 5, and Pulse on Time is ranked fourth in the plot, the value of MRR increase with the increase in the value of the Pulse on Time.

Table.8 Optimized Results for MRR

Sr. No	Peak Current (Ampere)	Electrode Material	Pulse on Time (μ Sec)	Duty Cycle
1.	18	Copper	58	7

The above table signifies the optimized value of various parameters selected for the study work for providing maximum material removal rate.

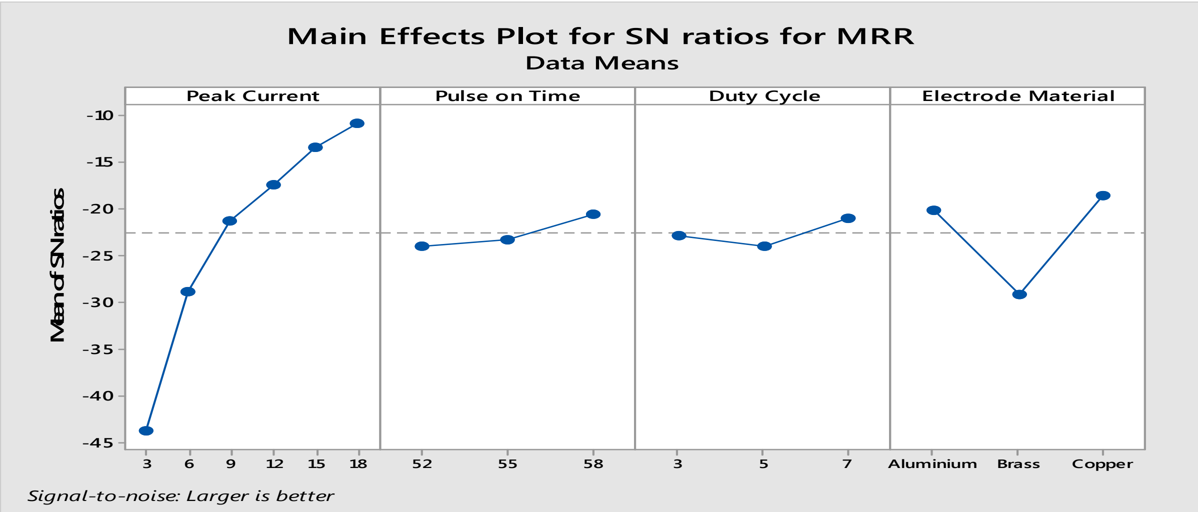

Figure 1: Main Effects Plot for S/N ratio for MRR

4.3. Effect of Input parameters on Tool wear rate

In the present study after conducting 18 different experiments,the effect of different process parameters on TWR is observed and plotted as the process parameters change from one level to another. The TWR is calculated along with S/N ratio, which is given in table 9. The response table for S/N ratio and mean created in the Taguchi are

Table.9 Response for Signal to Noise ratio for TWR (Smaller is better)

Level	Current	Pulse on Time	Duty Cycle	Electrode material
1.	46.71	35.58	37.66	36.82
2.	41.69	36.69	37.11	31.03
3.	38.20	38.46	35.96	42.88
4.	35.78	--------	--------	--------
5.	31.55	--------	-------	--------
6.	27.53	--------	--------	--------
Delta	19.18	2.88	1.70	11.85

The effect of current, ton, duty cycle and electrode material is shown in the effect plot for a S/N ratioof TWR. The plot of the present study of 18 different experiments indicates that the value of TWR decreases with the increase of the peak current and peak current is a major significant factor which effect the TWR in the study, the second most significant factor is tool material, from the three different tool material brass is more effective than aluminium and copper. From the S/N plot study, we found out that copper is less effective than other tools used in study, the third effective parameter is Pulse on Time, TWR value ismaximum for 58 and list for the 52, and Duty Cycle is ranked fourth in the plot, the value of MRR increase with the increase in the value of the Pulse on Time

Table.10 Optimized Results for TWR

Sr. No	Current (Ampere)	Electrode Material	Pulse on Time (μ Sec)	Duty Cycle
1.	18	Brass	52	7

The above table signifies the optimized value of various parameters selected for the study work for providing minimum tool wear rate.

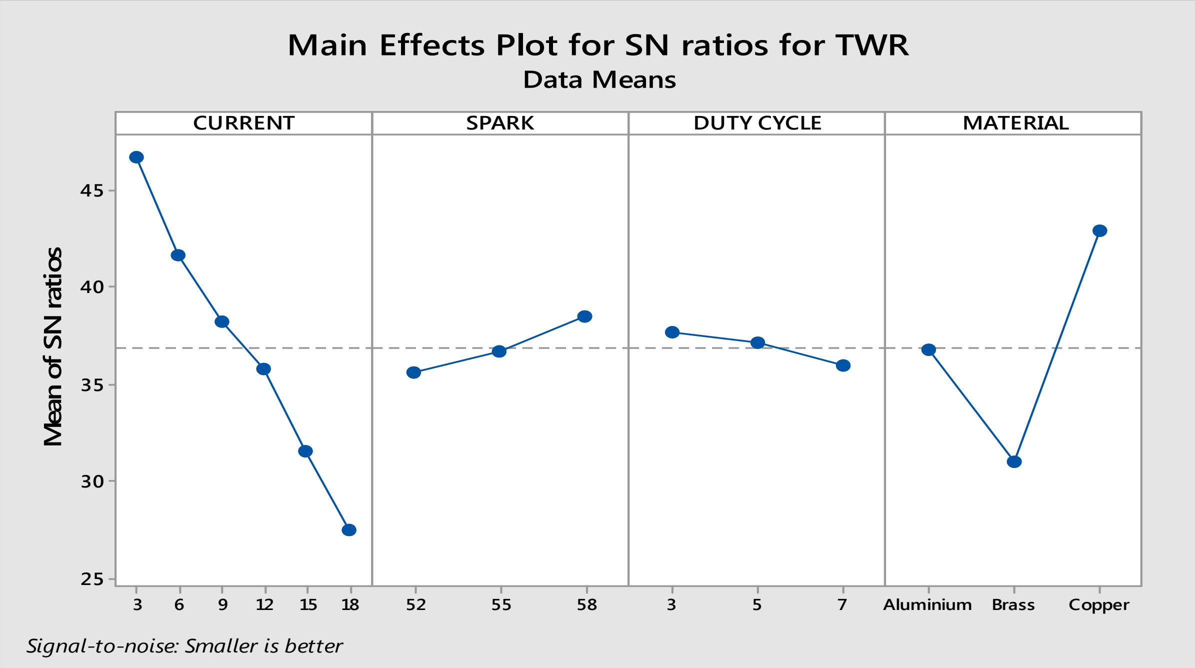

Figure 2: Main Effects Plot for S/N ratios for TWR.

5. CONCLUSION

From the experiments study it can be concluded that the input parameters have an enormous effect on the output responses during machining using an electric discharge machine (EDM). The most important conclusions of the study are:

- Current has the highest effect on the material removal rate. The material removal rate increases with the increase in the current.
- The pulse on time has a small effect on the material removal rate and Duty Cycle on tool wear rate.
- Optimal cutting parameters for material removal rate are obtained as current 18 ampere, electrode material as copper, pulse on time at 58 µs and duty cycle at 7.
- Optimal cutting parameters for tool wear rate are obtained as current 18 ampere, electrode material as Brass, pulse on time at 52 µs and duty cycle at 7.

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