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Optimization of Various Machining Parameters of EDM by using Genetic Algorithm

C.Raghavendra[1],Dr.V.Venugopal Reddy[2],K.Pavan Kumar Reddy[3]

[1]*Mtech student Mechanical Engineering, JNTUCEP.*
[2] *Head and professor Mechanical Engineering, JNTUCEP.*
[3] *Assistant professor Mechanical Engineering, JNTUCEP.*

Abstract- *In present days of the competitive environment, all the companies across the world are trying to reach the market demand and increase the profits without increasing the cost of the product. It can be achieved by reducing the losses with of high productivity and good surface finish. Machining of hard metals, complex shapes with of traditional manufacturing is difficult. So it is replaced by the unconventional machining process. Electric discharge machining is one of the unconventional machining processes used to machining hard metals, complex shapes with of metal erosion technique by using all electro conductive materials as tools. In optimizing process parameters selection is very crucial. Process parameters considered in these discharge current, pulse on time, pulse off time, tool material effects outputs on material removal rate, surface roughness. L27 Orthogonal Array design of experiments is used to do the machining on work pieces. Multiple regression analysis is used to develop the objective function. Genetic Algorithm is used to optimize the process on AISI P20, HE20, C45, and EN47 work materials by Copper, brass, and graphite as tool materials.*

Key words: *Material Removal Rate, Surface Roughness, Genetic Algorithm, EDM, L27 Orthogonal Array.*

I. INTRODUCTION:

EDM is one of the non-traditional manufacturing process used for removal of metal by an electrical spark erosion process. In these, processes electrical spark is used as a tool to remove material from work piece to produce the finished part to the desired shape. The EDM process uses two electrodes such as tool and the work piece both are separated by dielectric fluid. By the metal erosion process, the top surface of the work piece is subsequently re solidified and cools at a high speed manner. The applications of these EDM process mostly used in dies and press tools, plastic moulds, forging dies, aerospace, automotive and in several engineering applications. Kuwar Mausam et al. (2015) investigated the effect of four values of inputs, namely peak current, gap voltage, pulse-on-time and duty cycle in EDM for machining carbon fibre based two phase epoxy composites. Here GA is run for 15 generations using MATLAB 2010. In this work effect of these parameters are calculated on the TWR. MATLAB is used for the better convergence of GA. Final concluded after experimentation gap voltage, pulse-on-time and duty cycle are more influencing on TWR. R.Rajesh et al. (2012) performed the machining on Al alloy with grade HE9 in EDM with electrolytic copper as the tool. In these outputs namely MRR and SR are optimized affected by process parameters are working current, working voltage, oil pressure, spark gap Pulse On Time and Pulse Off Time. Multiple regression analysis and Genetic algorithm optimization technique are used to optimize the out parameters. The conformation runs show that current at 3 A, voltage at 78 V, gap at 0.35, flow rate at 1, pulse ON as 1 and pulse OFF as 8 produced maximum MRR and minimum Surface Roughness. And finally, most influencing factor is current on both the output parameters.

II. EXPERIMENTATION AND OBSERVATION

a) MATERIAL SELECTION

Four different types of work pieces are used to do this experiment (i.e. C45, HE20, EN47, and AISI P20). Three different types of tool materials (i.e. copper, brass, graphite) for the used to machining the process. Chemical compositions of the four different work pieces are as follows. Below table shows the chemical composition of C45, HE20, EN47, AISI P20 steels.

Table1. Chemical composition of c45 steel

Element	C	Mn	Si	S	P
Content %	0.447	0.751	0.318	0.022	0.024

Table2. Chemical composition of HE20 steel

Element	Mg	Si	Fe	Mn	Zn	Cr	Ti
Content%	0.57	0.469	0.249	0.047	0.015	0.006	0.02

Table3. Chemical composition of EN47 steel

Element	C	Mn	Si	S	Fe	Cr
Content%	0.502	0.735	0.49	0.048	97.30	0.969

Table4. Chemical composition of P20 steel

Element	C	Mn	Si	S	P	Cr
Content%	0.39	0.92	0.412	0.01	0.022	1.894

b) *EXPERIMENTAL SETUP*

Experimentation is done on Sporkonix F50 die sinking EDM machine is shown in fig1. and table5 represents specifications of the machine.

TABLE5. Machine Specifications

XY Travel mm	400*300
Z -axis travel mm	250
Tank size mm	1000*600*450
Work Table mm	800*500
Maximum weight of work piece	2000kg
Maximum height of work piece	40mm

Fig.1. EDM machining

Machining parameters for experimentation is considering with of three levels of process parameters for the experiment setting is shown in table6.

Table6. Working conditions

Symbol	Factors	Level 1	Level 2	Level 3
X1	Current	10	15	20
X2	T on	6	7	8
X3	T off	4	5	6
X4	Tool material	Copper	Brass	Graphite

c) *DESIGN OF EXPERIMENTS*

L27 Orthogonal Array (OA) DOE is used to do the machining on work pieces. In the present experimental study, discharge Current, Pulse on Time, Pulse off Time and tool material has been considered as process variables.

Table7. L27 OA table of experiments

S.NO	I(amp)	Ton (µs)	T off (µs)	Tool material
1	10	6	4	Copper
2	10	6	5	Brass
3	10	6	6	Graphite
4	10	7	4	Brass
5	10	7	5	Graphite
6	10	7	6	Copper
7	10	8	4	Graphite
8	10	8	5	Copper
9	10	8	6	Brass
10	15	6	4	Copper
11	15	6	5	Brass
12	15	6	6	Graphite
13	15	7	4	Brass
14	15	7	5	Graphite
15	15	7	6	Copper
16	15	8	4	Graphite
17	15	8	5	Copper
18	20	8	6	Brass
19	20	6	4	Copper
20	20	6	5	Brass
21	20	6	6	Graphite
22	20	7	4	Brass
23	20	7	5	Graphite
24	20	7	6	Copper
25	20	8	4	Graphite
26	20	8	5	Copper
27	20	8	6	Brass

d) *CALCULATION OF MRR AND SR*:

Material removal rate: MRR is calculated by measuring the time of machining. Material removal rate can be calculated using following formula

$$\frac{(W_I - W_F)}{T} = \text{g/minute}$$

W_I: Initial wt of the work piece
W_F: Final wt of the work piece
T: Machining time in minute
Surface roughness: It is a quality of the machining surface related to the geometric irregularities of the surface. Surface roughness R_a arithmetic average height of surface above and below the central line. It is measured by using Mitutoyo SJ-201 Talysurf is shown in below fig.2.

Fig.2.Mitutoyo SJ-201 Talysurf.

By using of multiple regression analysis objective function is developed as follows
Objective function Y1 and Y2
Y 1= constant + a X_1 + b X_2+ c X_3 (1)
Y2 = constant + a X_1 + b X_2+ c X_3 (2)
Y1= Material removal rate (MRR)
Maximize: objective function1
Variables:
X1: Discharge Current
X2: Pulse on time
X3: Pulse off time
a, b, and c are the coefficient of these variables.
Minimize: objective function2
Y2 = Surface roughness
Variables:
X1: Discharge Current
X2: Pulse on time
X3: Pulse off time
a, b, and c is the coefficient of these variables.
Constraints:
X1>= 10, X2<=20
X2>=6, X2<=8
X3>=4, X3<=6
Fitness function
Minimize Y= Y1-Y2

e) GENETIC ALGORITHM

- Perform population initialization:

The main object of a genetic algorithm is optimized the objective function. Initially, size of the population is selected randomly from the total population. Then the selected individual population is converted into genes by using of encoding.

- Perform selection process:

After population initialization, selection is one of the important process. At the end of each production, a new population of solutions is selected to serve as the new population by evaluating the fitness of each individual. Production is to be optimizing the present optimization problem, and Tournament selection has been chosen randomly. Selection selects individual from the population to generate a sub group of the population to specify a tournament size. The amount of fitness of each individual in the subgroup is compared, and the best fitness values are selected. The new population is generated with cross-over, mutation operators.

Cross-over operation generates new children from two selected parents. Crossover process produces a better generation by combining of two parents chosen from the new population. Mutation operation randomly alters the value of genes in a chromosome to increase genetic multiplicity. By mutation will bring better character to increase the probability of survey.

f) Experimental Results:

1. Experimentation result of EN47 steel is shown in the below table8.

Table8. Experimentation result for EN47 steel

S .N O	I amp	Ton (μs)	T off (μs)	Tool material	MRR mg/min	SR μm
1	10	6	4	Copper	0.1281	4.34
2	10	6	5	Brass	0.07407	3.15
3	10	6	6	Graphite	0.2	4.49
4	10	7	4	Brass	0.0555	3.24
5	10	7	5	Graphite	0.175	5.71
6	10	7	6	Copper	0.2	4.98
7	10	8	4	Graphite	0.1272	4.61
8	10	8	5	Copper	0.1818	5.36
9	10	8	6	Brass	0.0666	3.72
10	15	6	4	Copper	0.4	3.56
11	15	6	5	Brass	0.1111	3.48
12	15	6	6	Graphite	0.2333	4.14
13	15	7	4	Brass	0.1666	3.16
14	15	7	5	Graphite	0.175	5.17
15	15	7	6	Copper	0.2.333	4.85
16	15	8	4	Graphite	0.0588	4.42
17	15	8	5	Copper	0.3500	5.20
18	20	8	6	Brass	0.0937	5.07
19	20	6	4	Copper	0.4666	5.20
20	20	6	5	Brass	0.1071	2.53
21	20	6	6	Graphite	0.1000	3.19
22	20	7	4	Brass	0.125	2.14
23	20	7	5	Graphite	0.1428	5.66
24	20	7	6	Copper	0.350	4.54
25	20	8	4	Graphite	0.05	4.48
26	20	8	5	Copper	0.4666	5.68
27	20	8	6	Brass	0.15	2.25

Regression Analysis: MRR versus current, pulse on time, pulse off time is shown in the below table9.

Table9. Analysis of Variance for MRR

Source	DF	Sum of Squares	Mean Squares	F-value	P
Regression	3	0.064677	0.021559	0.88	0.463
I	1	0.031234	0.031233	1.27	0.271
T on	1	0.006076	0.006076	0.25	0.624
T off	1	0.02768	0.027368	1.11	0.303
Error	23	0.565886	0.024604		
Total	26	0.630563			

Regression Equation

MRR = 0.00833 current + 0.0184 pulse on time - 0.0390 pulse off time - 0.240 (3)

Regression Analysis: SR versus current, pulse on time, pulse off time is shown in the below table10.

Table10. Analysis of Variance SR

Source	DF	Sum of Squares	Mean Squares	F-value	P
Regression	3	3.5997	1.1999	1.07	0.379
I	1	0.8581	0.8581	0.77	0.390
T on	1	2.5013	2.5013	2.24	0.148
T off	1	0.2404	0.2404	0.22	0.647
Error	23	25.6823	1.1166		
Total	26	29.2821			

Regression Equation

SR = 1.70 -0.0437 current +0.373 pulse on time +0.116 pulse off time (4)

2. Experimentation results of AISI P20 steel is steel is shown in the below table11.

Table11. Experimentation result for P20 steel

S No	I amp	T on µs	T off µs	TOOL MATERIAL	MRR mg/min	SR µm
1	10	6	4	COPPER	0.08333	4.24
2	10	6	5	BRASS	0.100	2.46
3	10	6	6	GRAPHITE	0.33325	3.32
4	10	7	4	BRASS	0.1200	4.06
5	10	7	5	GRAPHITE	0.1904	3.65
6	10	7	6	COPPER	0.21428	5.16
7	10	8	4	GRAPHITE	0.1108	3.81
8	10	8	5	COPPER	0.1538	3.91
9	10	8	6	BRASS	0.075	4.75
10	15	6	4	COPPER	0.25	5.00
11	15	6	5	BRASS	0.08571	2.95
12	15	6	6	GRAPHITE	0.1666	4.36
13	15	7	4	BRASS	0.15	2.81
14	15	7	5	GRAPHITE	0.14811	4.18
15	15	7	6	COPPER	0.1875	4.81
16	15	8	4	GRAPHITE	0.1025	3.66
17	15	8	5	COPPER	0.300	4.31
18	15	8	6	BRASS	0.05	2.80
19	20	6	4	COPPER	0.200	3.43
20	20	6	5	BRASS	0.06666	2.23
21	20	6	6	GRAPHITE	0.0909	3.27
22	20	7	4	BRASS	0.04166	3.26
23	20	7	5	GRAPHITE	0.2000	4.79
24	20	7	6	COPPER	0.2222	4.09
25	20	8	4	GRAPHITE	0.043478	3.84
26	20	8	5	COPPER	0.14285	4.17
27	20	8	6	BRASS	0.07407	2.1

Regression Analysis: MRR versus current, pulse on time, pulse off time is shown in table12

Table12.Analysis of Variance

Source	DF	Sum of Squares	Mean squares	F-value	P
Regression	3	0.03637	0.01212	1.22	0.326
I	1	0.00375	0.00375	0.38	0.545
T on	1	0.00043	0.00043	0.04	0.836
T off	1	0.03217	0.03217	3.23	0.085
Error	23	0.22892	0.00995		
Total	26	0.26529			

Regression Equation

MRR = -0.043 - 0.00289 current + 0.0049 pulse on time
+ 0.0423 pulse off time (5)

Regression Analysis: surface roughness versus current, pulse on time, pulse off time is shown in the below table13.

Table13.Analysis of Variance

Source	DF	Sum of Squares	Mean Squares	F-value	P
Regression	3	1.2302	0.41006	0.56	0.649
I	1	0.9707	0.97069	1.32	0.263
Ton	1	0.2427	0.24267	0.33	0.572
T off	1	0.0168	0.01681	0.02	0.881
Error	23	16.959	0.73738		
Total	26	18.189			

Regression Equation

SR = 3.49 -0.0464 current +0.116 pulse on time
+ 0.031pulse off time (6)

3. Experimentation results for HE20 steel is shown in the below table14.

Table14. Experimentation result for HE20 steel

S. NO	I Amp	T on µs	T off µs	TOOL MATERIAL	MRR mg/min	SR µm
1	10	6	4	COPPER	0.025	3.27
2	10	6	5	BRASS	0.0571	3.45
3	10	6	6	GRAPHITE	0.0071	3.51
4	10	7	4	BRASS	0.05	3.61
5	10	7	5	GRAPHITE	0.008	4.03
6	10	7	6	COPPER	0.0111	3.60
7	10	8	4	GRAPHITE	0.006	4.21
8	10	8	5	COPPER	0.0083	3.60
9	10	8	6	BRASS	0.0833	3.16
10	15	6	4	COPPER	0.075	5.14
11	15	6	5	BRASS	0.08	3.41
12	15	6	6	GRAPHITE	0.0105	5.09
13	15	7	4	BRASS	0.1	4.08
14	15	7	5	GRAPHITE	0.02	3.91
15	15	7	6	COPPER	0.15	4.00
16	15	8	4	GRAPHITE	0.0285	5.7
17	15	8	5	COPPER	0.0333	4.64
18	15	8	6	BRASS	0.1333	5.4
19	20	6	4	COPPER	0.125	5
20	20	6	5	BRASS	0.15	3.98
21	20	6	6	GRAPHITE	0.0272	5.71

22	20	7	4	BRASS	0.25	4.1
23	20	7	5	GRAPHITE	0.0250	6.54
24	20	7	6	COPPER	0.100	5.06
25	20	8	4	GRAPHITE	0.0166	5.12
26	20	8	5	COPPER	0.200	5.17
27	20	8	6	BRASS	0.3000	4.89

Regression Analysis: MRR versus current, pulse on time, pulse off time is shown in the below table15.

Table15.Analysis of Variance

Source	DF	Sum of Squares	Mean Squares	F-value	P
Regression	3	0.053601	0.01786	3.85	0.023
Current	1	0.048868	0.04886	10.53	0.004
T on	1	0.003542	0.00354	0.76	0.391
T off	1	0.001192	0.00119	0.26	0.617
Error	23	0.106735	0.00464		
Total	26	0.160336			

Regression Equation

MRR = -0.218 + 0.01042 current + 0.0140 pulse on time + 0.0081 pulse off time (7)

Regression Analysis: SR versus current, pulse on time, pulse off time steel is shown in the below table16.

Table16. Analysis of Variance

Source	DF	Sum of Squares	Mean Squares	F-value	P
Regression	3	10.1957	3.39855	7.56	0.001
I	1	9.5776	9.57761	21.30	0.000
T on	1	0.6161	0.61605	1.37	0.254
T off	1	0.0020	0.00201	0.00	0.947
Error	23	10.3411	0.44961		
Total	26	20.5367			

Regression Equation

SR = 0.89 + 0.1459 current + 0.185 pulse on time + 0.011 pulse off time (8)

4. Experimentation result for C45 steel is shown below table17.

Table.17. Experimentation for C45 steel:

S .NO	I (a)	T on µs	T off µs	TOOL MATERIAL	MRR (Mg/min)	SR µm
1	10	6	4	COPPER	0.0204	3.6
2	10	6	5	BRASS	0.0588	2.64
3	10	6	6	GRAPHITE	0.05	4.08
4	10	7	4	BRASS	0.05	2.51
5	10	7	5	GRAPHITE	0.02272	3.35
6	10	7	6	COPPER	0.08333	2.74

7	10	8	4	GRAPHITE	0.03225	3.37
8	10	8	5	COPPER	0.06521	3.29
9	10	8	6	BRASS	0.01034	2.59
10	15	6	4	COPPER	0.24285	3.44
11	15	6	5	BRASS	0.02272	2.46
12	15	6	6	GRAPHITE	0.100	3.18
13	15	7	4	BRASS	0.01785	2.41
14	15	7	5	GRAPHITE	0.07142	4.68
15	15	7	6	COPPER	0.3333	4.35
16	15	8	4	GRAPHITE	0.100	3.92
17	15	8	5	COPPER	0.125	3.9
18	15	8	6	BRASS	0.05263	2.71
19	20	6	4	COPPER	0.300	3.68
20	20	6	5	BRASS	0.02777	2.25
21	20	6	6	GRAPHITE	0.1111	3.43
22	20	7	4	BRASS	0.05882	2.3
23	20	7	5	GRAPHITE	0.1111	3.35
24	20	7	6	COPPER	0.400	4.03
25	20	8	4	GRAPHITE	0.08333	3.24
26	20	8	5	COPPER	0.1428	3.71
27	20	8	6	BRASS	0.04545	2.70

Regression Analysis: MRR versus current, pulse on time, pulse off time steel is shown in the below table18.

Table.18.Analysis of Variance

Source	DF	Sum of Squares	Mean Squares	F-value	P
Regression	3	0.052372	0.01745	1.87	0.162
I	1	0.043744	0.04374	4.70	0.041
T on	1	0.004250	0.00425	0.46	0.506
T off	1	0.004377	0.00437	0.47	0.500
Error	23	0.214190	0.00931		
Total	26	0.266561			

Regression Equation

MRR = -0.017 +0.00986 current – 0.0154 pulse on time +0.0156 pulse off time (9)

Regression Analysis: SR versus current, pulse on time, pulse off time is shown in below table19.

Table.19.Analysis of Variance

Source	DF	Sum of Squares	Mean Squares	F-Value	P-Value
Regression	3	0.1397	0.04657	0.09	0.962
I	1	0.0150	0.01502	0.03	0.863
Ton	1	0.0249	0.02494	0.05	0.824
T off	1	0.0998	0.09976	0.20	0.657
Error	23	11.3531	0.49361		
Total	26	11.4929			

Regression Equation

SR = 2.54 + 0.0058 current + 0.037 pulse on time + 0.074 pulse off time (10)

III. RESULT AND ANALYSIS

This multi-objective optimization problem (MOP) is solved to obtain solutions by the multi objective Genetic algorithm employed by MATLAB 15b Software. Multi objective Genetic algorithm (MOGA) is worked for the optimized problem with of some selective conditions such as number of generations: 1000; lower boundary (I, Ton, T off) = (10, 6, 4); higher boundary (I, Ton, T off) = (20, 8, 6); Mutation criteria: Adaptive feasible; cross over function: Intermediate with ratio 1 and Tournament selection with size 2. So the MOGA obtained results are compared with of Teacher Learner based optimization technique (TLBO) for confirmation of the results

By using of Genetic algorithm and Tlbo optimization technique, the optimum machining conditions obtained for HE20 steel material is

Table.20 GA optim value for HE20 steel

Out put result	Current (amp)	T on (µs)	T off (µs)	Mrr (mg/min)	Surface roughness(µm)
MOGA	10	6	4	0.003	3.503
TLBO	10.9218	6.8431	4.0733	0.024	3.794

By using of Genetic algorithm and Tlbo optimization technique, the optimum machining conditions obtained for AISI P20 steel material is

Table.21 GA optim value for AISI P20 steel

Out put result	Current (amp)	T on (µs)	T off (µs)	Mrr (mg/min)	Surface roughness(µm)
MOGA	20	6	4	0.098	3.382
TLBO	19.0187	6.3366	4.3718	0.168	3.478

By using of Genetic algorithm and Tlbo optimization technique, the optimum machining conditions obtained for C45 steel material is

Table.22 GA optim value for C45 steel

Out put result	Current (amp)	T on (µs)	T off (µs)	Mrr (mg/min)	Surface roughness(µm)
MOGA	10	6	4	0.052	3.116
TLBO	13.3578	6.4353	5.5634	0.102	3.267

By using of Genetic algorithm and Tlbo optimization technique, the optimum machining conditions obtained for EN47 steel material is

Table.23 GA optim value for EN47 steel

Out put result	Current (amp)	T on (µs)	T off (µs)	Mrr (mg/min)	Surface roughness(µm)
MOGA	19.535	6.003	4.004	0.234	3.18
TLBO	18.1637	6.5051	5.9455	0.223	4.02

IV. CONCLUSION

The four steels, EN47, C45, AISI P20, and HE20 are machined on electric discharge machining process using copper, brass and graphite tools. Based on the L27 orthogonal array, pulse on time, pulse off time, tool material and current are taken as input parameters. ANOVA analysis is conduct and multiple regression equations are developed. By using multi objective Genetic algorithm, optimum values are obtained. The following conclusions can be drawn from this work.

- The optimal machining condition for EN47 steel with Genetic Algorithm is at on 19.535(A) I, 6.003(µs) T on, 4.004(µs) T off, with 0.234 (mg/min) MRR, 3.18(µm) SR are obtained using Copper as a tool.
- The desired outputs for HE20 steel: 10(A) I, 6(µs) T on, 4(µs) T off, with 0.003 (mg/min) MRR, 3.503(µm) SR are obtained brass using as a tool.
- The desired outputs for AISI P20 steel: 20(A) I, 6(µs) T on, 4 (µs) T off, with 0.098 (mg/min) MRR, 3.3828(µm) SR are obtained graphite using as a tool.
- The desired outputs for C45 steel: 10(A) I, 6(µs) T on, 4(µs) T off, with 0.052 (mg/min) MRR, 3.116(µm) SR are obtained graphite using as a tool.

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