Optimization of Electrical and Non Electrical Factors in EDM for Machining Die Steel using Copper Electrode by Adopting Taguchi Technique

Ajeet Bergaley, Narendra Sharma

Abstract: ***EDM machining is used for very hard and complex cutting of conducting materials with higher surface finish and close dimensions. EDM process parameters are affected by both electrical and non electrical parameters. In these paper cutting of hard material high carbon high chromium (HCHcr) D3 steel is done on electro discharge machine with copper as cutting tool electrode. This paper presents a work on the performance parameter optimization for material removal rate (MRR) and electrode wear rate (EWR). There are electrical and non electrical factors which influences MRR and EWR such as voltage ,current pulse on time , pulse off time , dielectric fluid material , flushing pressure, tool rotation etc. In theses paper both the electrical factors and non electrical factors has been focused which governs MRR, EWR and there optimization. Paper is based on Design of experiment and optimization of EDM process parameters .The technique used is Taguchi technique which is a statistical decision making tool helps in minimizing the number of experiments and the error associated with it. The research showed that the peak current has significant effect on material removal rate.***

Key feature: ***Electro discharge machine, high carbon high chromium material, material removal rate, Taguchi technique, Anova test.***

I. INTRODUCTION

Electrical discharge machining [EDM] is a thermo electric, non-conventional machining process, used for manufacturing geometrically complex or hard and electrically conductive material parts that are extremely difficult-to-cut by other conventional machining processes. It is precise machining independent of hardness of cutting material. The EDM process is mainly used for making dies, moulds, and parts of aerospace, heat exchangers, automotive industry and surgical components. In EDM [13] controlled erosion of metal takes place by rapid heating and cooling of work piece metal. In EDM the electric spark is setup between the work piece and the cutting tool separated by dielectric fluid flowing through very small gap, the arc so produces heat energy is utilized to melt and vaporize the work piece metal. Continually the dielectric fluid with pressure flow side way over the metal through gap between electrode tool and the work piece material. The dielectric fluid takes away the debris of solidified melted metal. Several studies showed that the process parameters severely effects the performance parameters like surface roughness, material removal rate and electrode wear.

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T.C Bhagat et al [1] in his study found that increasing current intensity increases the surface roughness drastically. P. Janmanee et al [2] in his research found that increasing discharge current led to greater material removal rate and greater wear ratio but poor surface. R.chaudhry [3,9] found that at the higher values of current arcing takes place and the debris particle size increases as a result MRR decreases after a limit of current, tool and machining surface gets drastically damages. M.L Jaiswani [4] studied the addition of fine graphite powder enhances the spark gap and makes sparking stable, excess of concentration of particle result in short circuiting. H. Narumiya [5] studied addition of aluminium and graphite particle size less than 15 μm in concentration of 2 – 15 g/l improves surface finish of the work piece. V.S Murti et al [6] research showed that the ultrasonic vibration improves the MRR and surface finish at the cost of tool wear. H.S Payal et al [8] studied different electrode material effect on performance of EDM and found in her study that brass gives better surface finish as compared to copper and lower MRR than copper. In these paper work on HcHcr steel (D3) has been presented. Present work aims to investigate the effect of electrical and non electrical parameters on the material removal rate and electrode wear rate while machining of (HCHcr) D3 steel and to optimize them for higher MRR and lower EWR. Taguchi technique has been opted to optimize theses parameters and a confirmation test anova being performed to find the significance level of the controlling parameters.

II. EXPERIMENTAL DETAILS

2.1 Experimental Materials

In the research, the work piece material selected for machine is high carbon high chromium steel. It is cold rolled and has a Vickers hardness of 238 HV has density 7.80 g/cc. The chemical composition of work piece material HCHcr steel is as Fe 87.12%, C 1.596%, Si 0.565 %, Mn 0.422 %, Cr 10.14 % by weight. Cutting tool used for EDM machining is 99 percent pure copper. The powder mixed in dielectric is copper with particle size 10 micron, spherical shape 99.99 percent pure metallic basis.

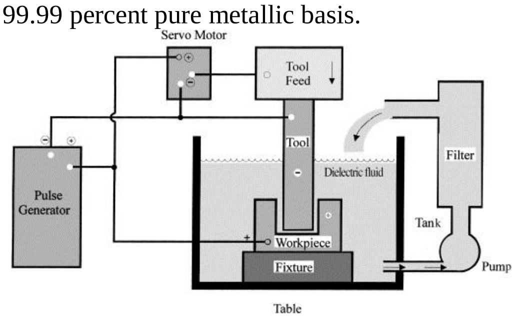

Figure 1: showing experimental set up [10]

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2.2 Experimental Method

A schematic diagram of experiment set up for EDM (spark erosion) is shown in figure. The experiment is conducted on spark erosion machine model G30 tool craft .The working EDM is of maximum discharge current capacity of 50 Amperage. A series of experiments have been conducted by varying parameters current, pulse on time, pulse off time, copper powder mixed concentration in dielectric to analyse the effects on MRR as per the Taguchi orthogonal L_9 array. The process parameters taken are peak current, pulse on time, pulse off time and copper powder mixed concentration in dielectric with each has 3 levels. A copper electrode of diameter 1.2 mm is used as cutting tool and the work piece of HcHcr steel is machined for 15 minutes each time and observation is taken. Observations are taken in the form of mass of material removed per sec (gram/sec)for both work piece and copper electrode. Mass lost is measured with accuracy 0.1 milligram. The data collected in MRR and EWR form is optimized and analysed by Taguchi technique and there after confirmation test Anova is performed.

Table 1: showing experimental conditions

Working condition	Description
Work piece	D3 steel
Electrode	Circular Copper electrode
Polarity	Positive
Peak Current	2,5,10 A
Pulse on time	50,100,200 μ sec
Pulse of time	10,20,50 μ sec
Dielectric fluid	Kerosene
Dielectric flushing	Side flushing with pressure
Jump of tool	4 sec
Copper concentration in dielectric	0,25,50 gram

Figure 2 : showing work piece before and after machining

III. DESIGN OF EXPERIMENT AND DATA ANALYSIS

3.1 Design of Experiment

Taguchi [11,12] is an optimization technique in design of experiment which is combination of mathematical model (curve fit) and statistical analysis. Taguchi is best method to solve optimization problem if the input or controlling parameters are much large in number (<50). It is decision making tool. It is best method to analyze interaction among the control variables during experiment. This method helps us to save time and money by reducing the number of experiments. Here in the experiment it has been assumed that there is no interactions between the controlling variable or factors (current, pulse on time, pulse of time) and each has its own effect on the response variable (MRR, EWR). Noise is always present there which makes the response variable deviate from the mean value. Noise may be present due to hardness of carbon component while machining and dielectric fluid strength variation at elevated temperature. In the experiment four controlling variable and three level of each is been used and they forms L_9 orthogonal array. The results are converted to S/N ratio for further calculation and analysis. Performance characteristics now depend on S/N ratio. For better performance higher material removal rate and lower the tool wear is been the objective. Hence, here MRR lie in the higher the better category of S/N ratio and EWR lie in lower the S/N ratio.

For EWR S/N = -10 log ($\frac{1}{n}\sum y_i^{2}$)

For MRR S/N = -10 log ($\frac{1}{n}\sum \frac{1}{yi^2}$)

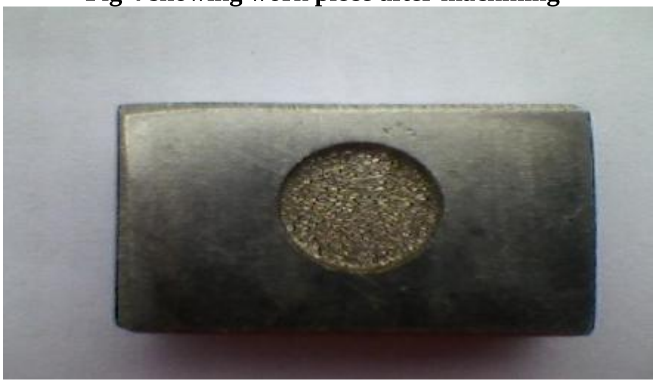
Further the model is tested by anova at 5% confidence level.

Table 2: Orthogonal Factor and their levels used in the Experiment

Control parameters	Levels			Response signal
	First	Second	Third	
Current (A)	2	5	10	Material removal rate (MRR) And Tool wear rate or Electrode wear rate (EWR)
Pulse on (μ sec)	50	100	200	
Pulse off (μ sec)	10	20	50	
Copper Powder concentration in dielectric (gram)	50	25	0	

Fig 3 showing work piece before machining

Fig 4 showing work piece after machining



3.2 Data analysis

Table 3: L_9 array and observation for MRR and S/ N ratio

Experiment No.	Parameters				MRR measured (grams/sec)	S/N ratio for MRR	Electrode wear rate (gram/sec)	S/N Ratio for EWR
	Current (Amp)	Pulse on time (μ sec)	Pulse off time (μ sec)	Copper powder (gram)				
1	2	50	10	50	0.0464	-26.669	0.00194	54.24
2	2	100	20	25	0.03613	-28.843	0.00075	62.49
3	2	200	50	0	0.03362	-29.468	0.00052	65.68
4	5	50	20	0	0.15537	-16.173	0.02242	32.99
5	5	100	50	50	0.14946	-16.510	0.01410	37.02
6	5	200	10	25	0.14931	-16.518	0.00774	42.23
7	10	50	50	25	0.48908	-6.212	0.08872	21.04
8	10	100	10	0	0.41816	-7.573	0.02658	31.51
9	10	200	20	50	0.42114	-7.511	0.00232	52.69

Table 4: Response mean table for MRR

Controlling variables	Level			Del	Rank
	First	Second	Third		
Current (A)	-28.32	-16.40	-7.09	21.23	1
Pulse on time(μ sec)	-16.35	-17.64	-17.83	1.48	2
Pulse off time (μ sec)	-16.92	-16.78	-17.340	0.615	4
Copper powder concentration (gram)	-16.89	-17.19	-17.738	0.848	3

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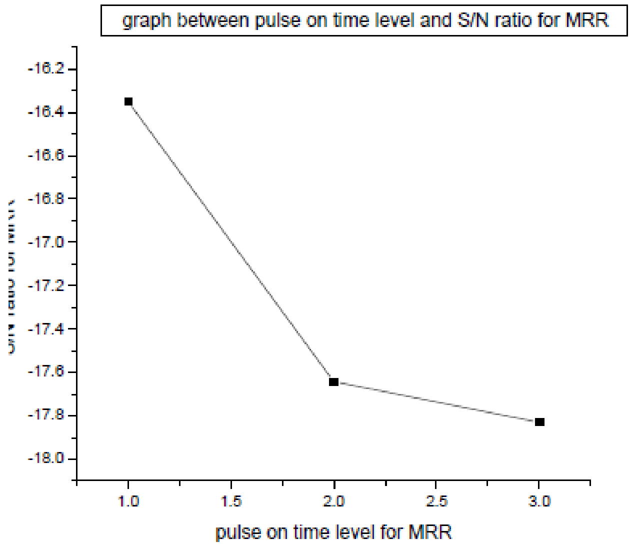
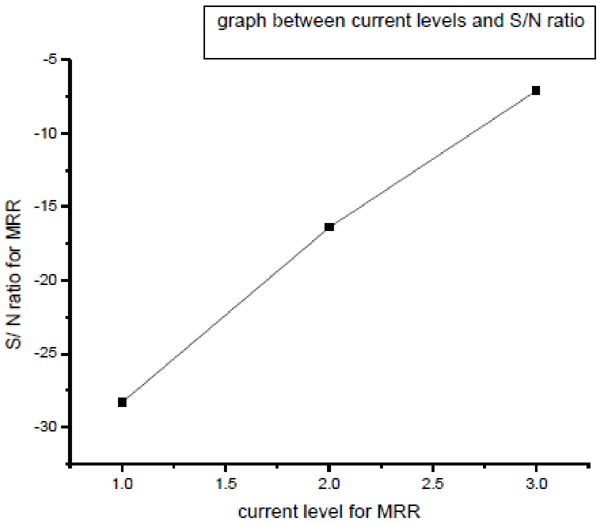
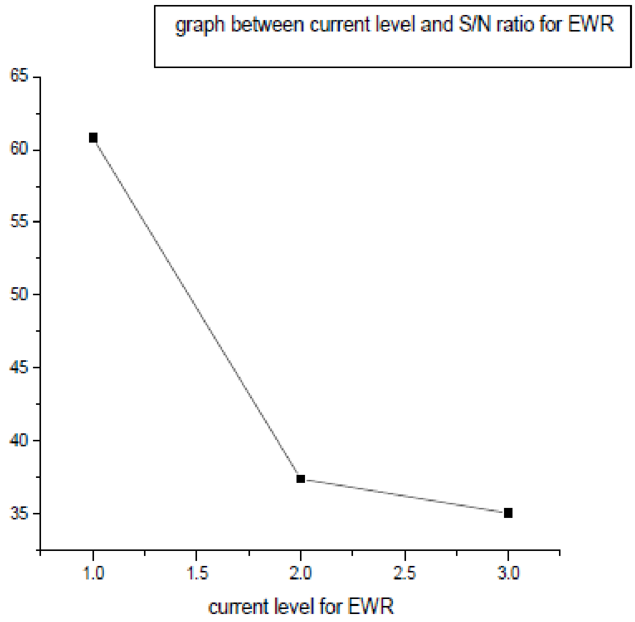
Table 5: Response mean table for EWR

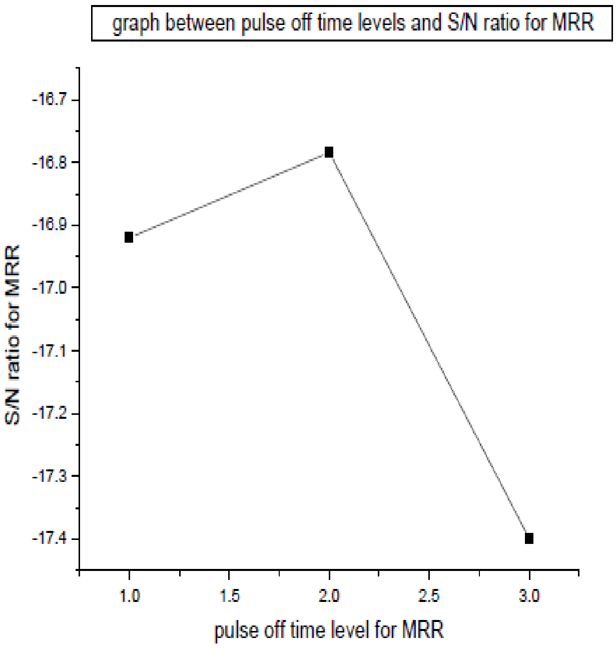
Controlling variables	Level			Del	Rank
	First	Second	Third		
Current (A)	60.80	37.41	35.08	25.72	1
Pulse on time(μ sec)	36.09	43.67	53.53	17.44	2
Pulse off time (μ sec)	42.66	49.06	41.24	7.8	4
Copper powder concentration (gram)	47.98	41.92	33.39	14.5	3

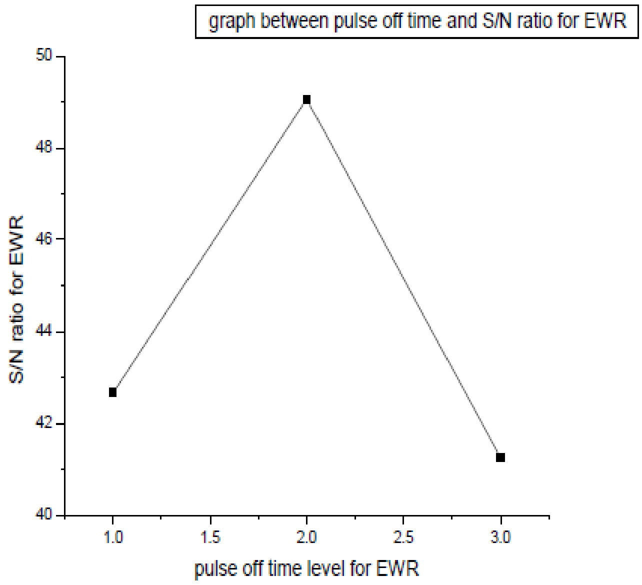
The table 4 shows the rank order in which the controlling factors affect the material removal rate. Difference in maximum and minimum mean S/N value of each signal is calculated as Del and gives the measure of rank. Higher the del value more is the impact of controlling factor on the MRR and EWR. From the table 4 it has been concluded that the controlling factor current is majorly responding to the output signal MRR, followed by pulse off time and pulse on time. Further these variations of mean signal can be plotted on graph and analyses through conformation F test to give the significant level of each controlling factor.

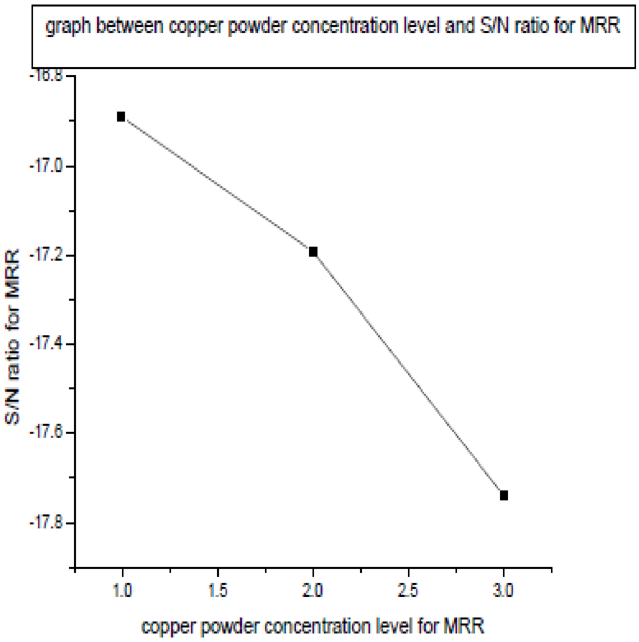


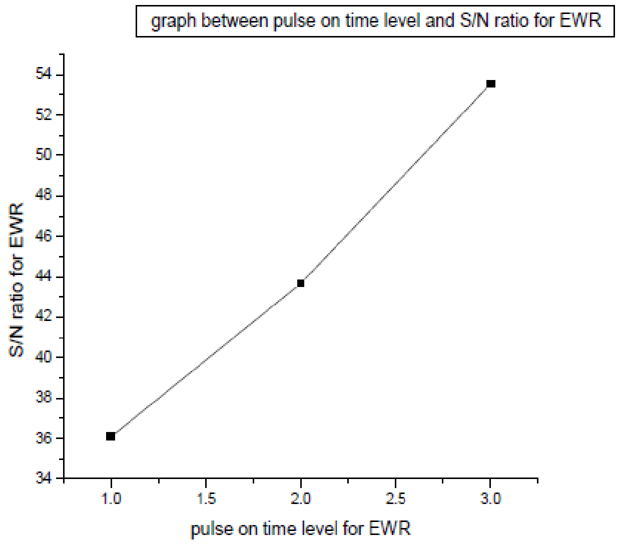


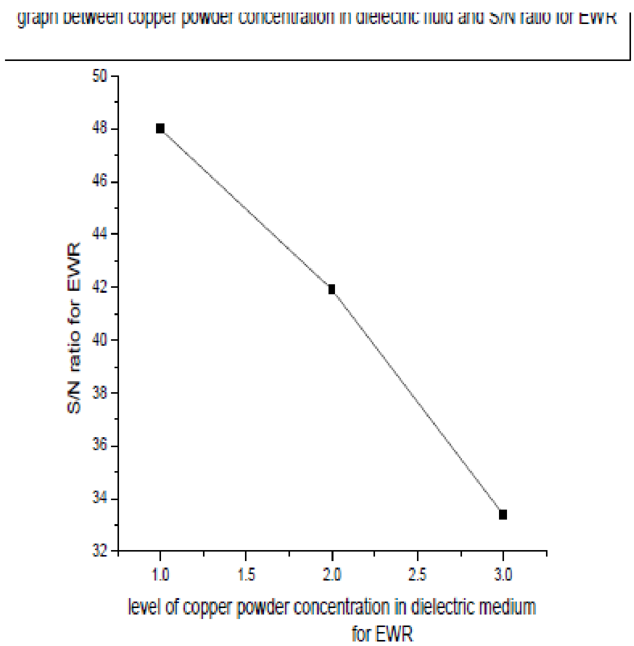












IV. ANOVA TEST

Table 6: Anova (F test) for MRR

Sources of variation	Sum of squares Between Group	Degree of freedom	Mean Square between group	Sum of squares With in group	Degree of freedom	Mean Square with in group	F ratio	F ratio critical at 5% confidence	Significance Level $F_{critical} > F_{cal}$	Percentage contribution
current	0.261	2	0.1305	0.0033	6	0.0006	217.5	5.14	Significant	98.86
Pulse on time	0.00168	2	0.0008	0.26254	6	0.0438	0.0183	5.14	Sub significant	0.635
Pulse Off time	0.00077	2	0.0004	0.26345	6	0.0439	0.0091	5.14	Sub significant	0.29
Copper Powder	0.00089	2	0.0004	0.26334	6	0.0439	0.0091	5.14	Sub significant	0.337
Total sum of squares = 0.2642165589690001										

Table 7: Anova(F test) for EWR

Sources of variation	Sum of squares Between Group	Degree of freedom	Mean Square between group	Sum of squares With in group	Degree of freedom	Mean Square with in group	F ratio	F ratio critical at 5% confidence	Significance Level $F_{critical} > F_{cal}$	Percentage contribution
current	0.002264	2	0.0011	0.00408	6	0.0007	1.57	5.14	Sub significant	35.67
Pulse on time	0.001868	2	0.0009	0.00447	6	0.0007	1.28	5.14	Sub significant	29.43
Pulse Off time	0.001210	2	0.0006	0.00513	6	0.0009	0.66	5.14	Sub significant	19.07
Copper Powder	0.001076	2	0.0005	0.00526	6	0.0009	0.55	5.14	Sub significant	16.95
Total sum of squares = 0.006345487699999976										

ANOVA is a particular form of statistical hypothesis testing heavily used in the analysis of experimental data ANOVA is useful in comparing (testing) three or more means (groups or variables) for statistical significance. Anova helps in comparing the variations between group and within group. Anova is a statistical tool used to analyse how do the controlling parameters affect the response variable (MRR, EWR) within each level group and between levels group. F ratio is ratio of variance between group and variance within group. From the table 6 it is confirmed that current strongly is responsible for variation between the group levels. Hence current is significant for MRR. Rest all the controlling factors are sub significant as there F value calculated is less than the F critical value at 5 % confidence.

V. RESULTS AND CONCLUSIONS

Material removal rate

- Material removal rate is mainly affected by current followed by pulse on time and concentration of copper powder in dielectric fluid. MRR is least affected by pulse off time.
- Peak current is majorly contributes for MRR. MRR increases with increasing current across the spark gap.
- MRR increases with increasing copper concentration in dielectric concentration.

Optimal setting for MRR in the experiment level is as

- Current - 10 Amp
- Pulse on time – 50 μ sec
- Pulse off time – 20 μ sec
- Copper concentration in dielectric fluid – 50 grams

Tool wear rate

- Tool wear rate is mainly affected by current and it decreases with increasing current. Tool wear rate is least affected by pulse off time.

- Tool wear rate increases with increasing copper powder concentration in dielectric medium.
- Tool wear rate increases with increasing pulse on time.

Optimal setting for EWR in the experiment level is as

- Current - 10 Amp
- Pulse on time – 50 μ sec
- Pulse off time – 50 μ sec
- Copper concentration in dielectric fluid – 0 grams

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