

# **Optimization of Process Parameters for Machining of High Carbon High Chromium (HC-HCR) Steel with EDM**

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**ABSTRACT:** Electrical Discharge Machine (EDM) is the one nonconventional machining process which is used very widely in tooling sector. In EDM, it is necessary to optimize the process parameters like a pulse on time, pulse off- time, discharge current, voltage, for maximization of Material Removal Rate (MRR) for High Carbon High Chromium (HC-HCr) steel which is a tool material. As per Taguchi L16, sixteen experiments have been conducted at different levels of current, Ton, Toff and Voltage on the tool steel HC-HCr. Experimental results of surface roughness, tool wear rate, and metal removal rate were analyzed with responses surface methodology. Interaction effect of process parameters on the responses has been discussed. Multi responses optimization technique was used to optimize process parameters for minimum surface roughness and tool wear rate and maximum metal removal rate.

**KEYWORDS:** EDM, ANOVA, Multi-response optimization, MRR, and machinability.

## **I. INTRODUCTION**

Electrical Discharge Machine (EDM) now becomes the most important accepted technologies in manufacturing industries since many complex 3D shapes can be machined using a simply shaped tool electrode. EDM is an important 'non-tradition manufacturing method', developed in the late 1940s and has been accepted worldwide as a standard processing manufacture of forming tools to produce plastics mouldings, die castings, forging dies and etc. EDM technology is increasingly being used in the tool; die and mould making industries, for machining of heat-treated tool steels and advanced materials (superalloys, ceramics, and metal matrix composites) requiring high precision, complex shapes, and high surface finish. Traditional machining technique is often based on the material removal using tool material harder than the work material and is unable to machine them economically. An EDM is based on the eroding effect of an electric spark on both the electrodes used. EDM actually is a process of utilizing the removal phenomenon of electrical discharge in the dielectric. Therefore, the electrode plays an important role, which affects the material removal rate and the tool wear rate.

A considerable amount of work has been reported by the researchers on the measurement of EDM performance on the basis of MRR, TWR, RWR, and SR for various types of steels. Rao et al. [1] studied the influence of process parameters on EDM of MDN 250 steel. They have considered discharge current, pulse on time, and duty factor as performance measures whereas process parameters are MRR and SR. However, in their study, parametric optimization was not done. TWR and RWR ratios were not considered. Furthermore, they extended their studies and developed a

# International Journal of Innovative Research in Science, Engineering and Technology

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hybrid model for SR is to predict the behavior of the MDN 250 steel [2]. In EDM, for optimum machining performance measures, it is an important task to select the proper combination of machining parameters [3].

Inconel 718 is a high strength, temperature resistant (HSTR) nickel-based super alloy. It is extensively used in aerospace applications, such as gas turbines, rocket motors, and spacecraft as well as in nuclear reactors, pumps, and tooling. Inconel 718 is difficult to machine, because of its poor thermal properties, high toughness, high hardness, high work hardening rate, the presence of highly abrasive carbide particles and strong tendency to weld to the tool to form build-up edge [4]. Hole making has long been recognized as one of the most important machining processes. Approximately 50 to 70% of production time is spent in making holes [5]. The term 'deep hole' refers to a depth to a diameter equal to five or greater. As the depth-to-diameter ratio increases, it becomes extremely difficult to produce such holes, especially, in superalloys like Inconel 718. The earlier studies on machinability of Inconel 718 were mainly on turning and milling operations. Only very little published information is available on drilling studies of Inconel [6].

Kao and Hocheng [7] obtained grey relational grade using grey relational analysis while electrochemical polishing of the stainless steel. Optimal machining parameters were determined by the grey relational grade as the performance index. They observed that the performance characteristics such as surface roughness and passivation strength are improved. Singh et al. [8, 9] suggested that orthogonal array (OA) with the grey relational analysis is useful for optimization of multiple response characteristics which is more complex compared to optimization of single-performance characteristics. They obtained optimal EDM parameters setting off metal removal rate, tool wear rate, taper, radial overcut and surface roughness while EDM of Al-10%SiCP as-cast metal matrix composites

In the present work, experiments have been conducted on EDM machine to identify the effect of process parameters in machining of High Carbon High Chromium steel. Response surface methodology was used to analyse the experimental results of surface roughness, MRR, and tool wear rate. A multi-response optimization technique is also used to optimize the process parameters.

## II. MATERIALS AND EXPERIMENTATION

In the experiments to obtain fine surface finish, die-sinking and milling micro-EDM was conducted using 500  $\mu\text{m}$  W electrodes on the surface under different machining conditions. In the EDM, positive electrode polarity resulted in extensive electrode wear compared with material removal rate from the workpiece. On the contrary, negative electrode polarity gives much better surface finish with comparatively higher material removal rate, lower electrode wear and controlled performance. Hence, the experiments were carried out with the electrode as the negative polarity. In the process, the spark always occurs at the closest point between the electrode and the workpiece. Thus if the surface of the electrode facing the workpiece is rough then the machining depth may not be equal to the anticipated depth.

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Figure 1. Experimental set up of EDM  
(Courtesy: PBR VITS, Kavali-A.P)

As shown in Figure 1, Experiments were carried out at different levels of current, Ton, Toff and voltages. Workpieces used in this work are shown in the Figure 2. Experimental results of surface roughness, tool wear and MRR are given in Table 1 and 3 for High Carbon High Chromium steel.



Figure 2. High Carbon High Chromium steel workpieces

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Table 1. Design of experiments and responses for High Carbon High Chromium steel

S.NO	I	Ton	Toff	V	T	MRR	TWR	R <sub>a</sub>
1	15	7	7	40	23.8333	5.3907	0.0314	1.800
2	15	8	8	60	73.6400	1.7445	0.0110	1.330
3	15	9	9	70	69.5411	1.8475	9.9221x10 <sup>-3</sup>	6.200
4	15	10	10	80	126.7721	1.0134	4.4962x10 <sup>-3</sup>	5.760
5	20	7	8	70	63.2053	2.0327	0.0204	4.960
6	20	8	7	80	61.1606	2.1007	0.0135	2.640
7	20	9	10	40	45.4691	2.8256	0.0164	2.119
8	20	10	9	60	41.0000	3.1336	0.0129	2.389
9	25	7	7	80	24.1426	5.3217	0.0339	4.099
10	25	8	9	70	26.4120	4.8644	0.0295	4.839
11	25	9	7	60	26.4483	4.8577	0.0268	3.340
12	25	10	8	40	19.5603	6.5684	0.0338	3.899
13	30	7	9	60	29.0280	4.4260	0.0268	2.279
14	30	8	9	40	18.6031	6.9063	0.0413	2.820
15	30	9	8	80	40.2013	3.1959	0.0129	3.100
16	30	10	7	70	20.5981	6.2374	0.0217	3.760

### III. RESULTS AND DISCUSSIONS

**Analysis of responses for High Carbon High Chromium steel:** ANOVA was carried out to identify significant parameter on the surface roughness, tool wear rate, and material removal rate. The ANOVA for the surface roughness was carried out at a confidence level of 95%. Then the responses which are having a p-value less than the 0.05 are said to be significant. From the Table 2, it was observed that the current and voltage have a significant effect on MRR, the current has significant effect tool wear rate and voltage has a significant effect on the surface roughness.

Table 2. ANOVA for High Carbon High Chromium steel

ANOVA for Metal Removal Rate					
Source	SS	DF	MS	F-Value	P-Value
Model	42.31	4	10.58	9.84	0.0012
A-I	19.47	1	19.47	18.11	0.0014
B-T on	0.086	1	0.086	0.080	0.7828
C-T off	5.84	1	5.84	5.43	0.0398
D-V	15.00	1	15.00	13.95	0.0033
Residual	11.83	11	1.08		
Cor Total	54.14	15			
ANOVA for tool wear rate					
Model	44.38	4	11.10	2.01	0.0124

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A-I	18.10	1	18.10	3.28	0.0374
B-T on	2.93	1	2.93	0.53	0.4817
C-T off	7.93	1	7.93	1.44	0.2559
D-V	9.08	1	9.08	1.65	0.2260
Residual	60.69	11	5.52		
Cor Total	105.07	15			
ANOVA for surface roughness					
Model	10.65	4	2.66	1.48	0.0248
A-I	0.14	1	0.14	0.076	0.7873
B-T on	0.72	1	0.72	0.40	0.5414
C-T off	1.57	1	1.57	0.87	0.3705
D-V	8.15	1	8.15	4.52	0.0470
Residual	19.84	11	1.80		
Cor Total	30.50	15			

**Interaction effect of process parameters on responses (High Carbon High Chromium steel):** Figures 3, 4, and 5 show the interaction effect of process parameters on the responses such as MRR, TWR and surface roughness respectively. From the Figure 3, it was observed that the current has a significant effect on the MRR at all voltages, Ton and T off. Remain parameter not so significant.

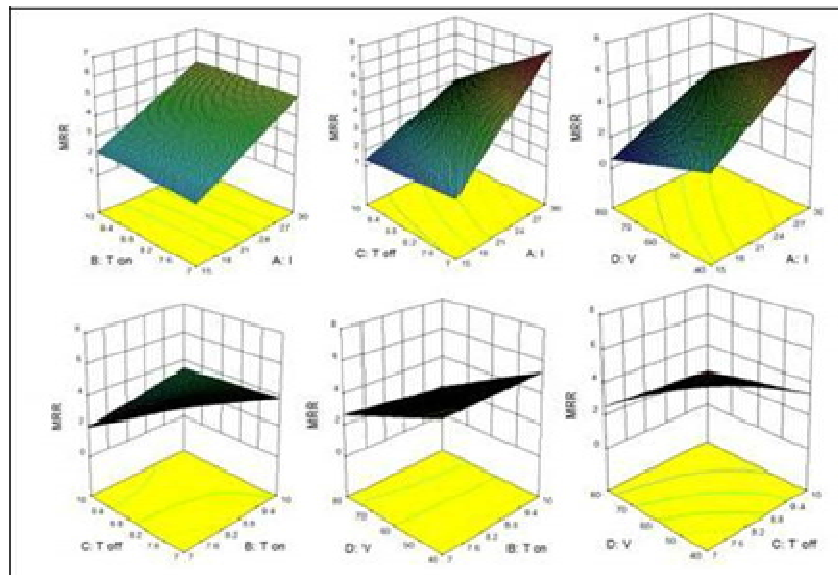


Figure 3 Interaction effects of parameters on the MRR

From the Figure 4, it was observed that the current and Toff are having a significant effect on the TWR. At low Toff and low currents, the TWR was found to be very less.

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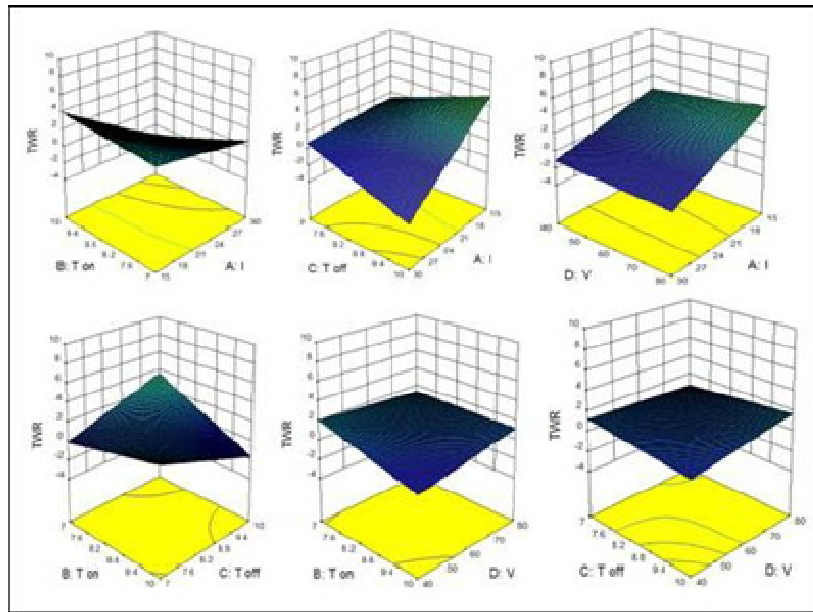


Figure 4 Interaction effects of parameters on the TWR

From the Figure 5, it can be observed that the current and Ton are found to be significant on the surface roughness. At high Ton and low currents, the surface roughness is observed as very less.

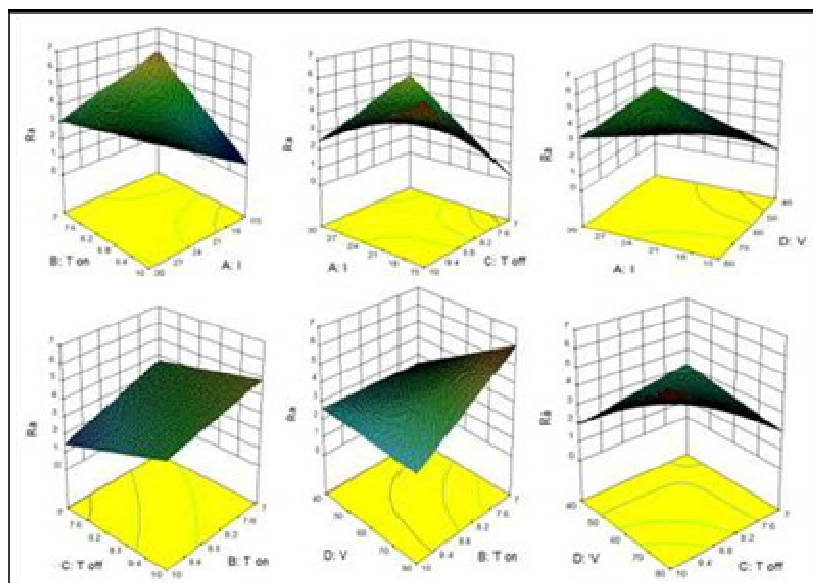


Figure 5 Interaction effects of parameters on surface roughness

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Table 3. Design of experiments and responses

S.No.	I	Ton	Toff	V	T	MRR	TWR	R <sub>a</sub>
1	15	7	7	40	8.5147	30.1786	0.00939560	8.959
2	15	8	8	60	12.0915	21.2513	0.00082702	9.360
3	15	9	9	70	14.0653	18.2690	0.00142100	8.039
4	15	10	10	80	31.2910	8.2119	0.00000000	4.899
5	20	7	8	70	19.3088	13.3079	0.00984000	9.279
6	20	8	7	80	10.9557	23.4546	0.00547600	7.160
7	20	9	10	40	5.9753	43.0036	0.00167300	9.079
8	20	10	9	60	7.7960	32.9606	0.00000000	1.440
9	25	7	7	80	13.3588	19.2352	0.01871000	7.200
10	25	8	9	70	8.5615	30.0135	0.01410100	7.720
11	25	9	7	60	4.1580	61.7990	0.00962400	6.480
12	25	10	8	40	3.4922	73.5834	0.00000000	1.790
13	30	7	9	60	7.4155	34.6515	0.02994000	3.979
14	30	8	9	40	2.6282	97.7743	0.00000000	6.320
15	30	9	8	80	7.9768	32.2135	0.25950000	6.560
16	30	10	7	70	5.3843	47.7241	0.00185724	2.179

Development of Mathematical Correlations: The Mathematical Correlations were developed for MRR, TWR and Ra (surface roughness) keeping the current, T-on and T-off as variables using RSM software

$$\text{MRR} = +8.814615 + 0.20032 * I + 0.068219 * \text{Ton} - 0.62729 * \text{Toff} - 0.066464 * V \dots\dots\dots (1)$$

$$\text{TWR} = -7.37782 - 0.19314 * I + 0.39830 * \text{Ton} + 0.73072 * \text{Toff} + 0.051703 * V \dots\dots\dots (2)$$

$$\text{Ra} = -3.58599 - 0.016854 * I + 0.19712 * \text{Ton} + 0.32553 * \text{Toff} + 0.0448999 * V \dots\dots\dots (3)$$

### IV. MULTI RESPONSE OPTIMIZATION

In the present work, multi-responses optimization was used to optimize process parameters for minimum surface roughness, tool wear rate, and maximum metal removal rate.

Table 5 Optimum process parameters

Parameter	High Carbon High Chromium steel	HSS
Current	30	30
Ton	10	8.88
Toff	7.97	9.55
Voltage	74.74	40
Desirability	0.89991	0.9839



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Fig.6 shows the optimization of process parameters for the High Carbon High Chromium steel. Optimization of process parameters for the material under present research was confirmed by desirability value. Composite desirability for the High Carbon High Chromium steel was found to be 0.8991.

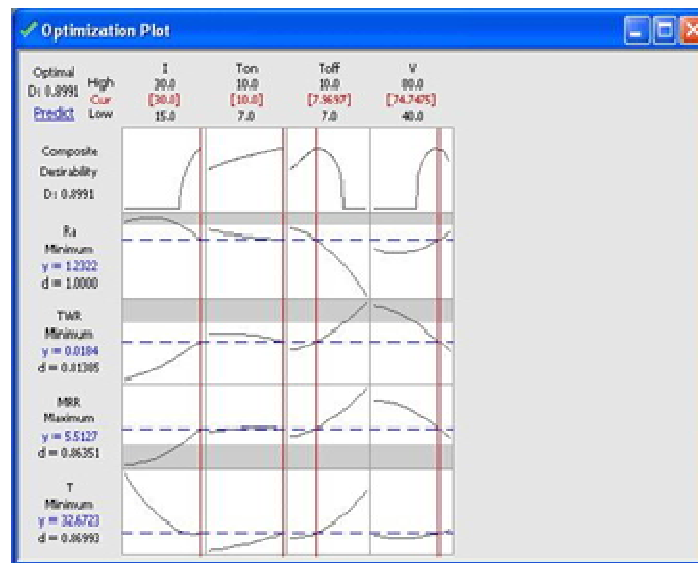


Fig. 6 Multi-response optimization parameters for High Carbon High Chromium steel

## V. CONCLUSIONS

In the present work, as per Taguchi L16, sixteen experiments have been conducted at different levels of current, Ton, Toff and Voltage on the two metals. Experimental results of surface roughness, tool wear rate, and metal removal rate were analyzed with responses surface methodology. The following conclusions may be drawn from the work.

- Current and voltage have a significant effect on MRR, the current has significant effect tool wear rate and voltage has a significant effect on the surface roughness.
- 30Amp of current, 10 $\mu$ s of Ton, 7.97 $\mu$ s of Toff and 74.74 V of voltage were found to be optimum process parameters.

## REFERENCES

- [1] Krishna Mohana Rao G, Satyanarayana S, Praveen M "Influence of machining parameters on electric discharge machining of Maraging steels—an experimental investigation", Proceedings of the World Congress on Engineering. Vol. II, London, UK.2008.
  - [2] Krishna Mohana Rao G, Rangajanardhaa G, Hanumantha Rao D, Sreenivasa Rao M, "Development of hybrid model and optimization of surface roughness in electric discharge machining using artificial neural networks and genetic algorithm" J Mater Process Technology 209:1512–1530.2009.
  - [3] Lin JL, Wang KS, Yan BH, Tarn YS, "Optimization of electrical discharge machining process based on the Taguchi method with fuzzy logics", J Mater Process Technol 102:48–55. 2000.
  - [4] Sharman ARC, Hughes JI, Ridgway K, "Workpiece surface integrity and tool life issues when turning Inconel 718 nickel based superalloy" Mach Sci Technol 8(3):399–414. 2004.
  - [5] Benes J "Hole making trends run deep, fast and dry". Am Mach 144(5):97–104.2000.
  - [6] Chen JC, Liao YS, "Study on wear mechanisms in the drilling of Inconel 718 super alloy", J Mater Process Technology 140:269–273. 2003
  - [7] Kao PS, Hocheng H, "Optimization of electrochemical polishing of stainless steel by grey relational analysis". J of Mater Processing Technology 140:255.2003.
  - [8] Singh PN, Raghukandan K, Pai BC, "Optimization by Grey relational analysis of EDM parameters on machining Al–10%SiCP composites". J of Mater Processing Technology 155–156:1658. 2004.
- JiayangWu,MingZhou,XiaoyiXu,JianweiYang,XiangweiZeng: "Fast and stable electrical discharge machining (EDM)", MechanicalSystemsandSignalProcessing72-73(2016)420–431.