Scientific Journal Impact Factor (SJIF): 4.364
International Journal of Modern Trends in Engineering and Research
IJMTER
ISSN (ONLINE) : 2349 - 9745
ISSN (PRINT) : 2393 - 8161

MULTI RESPONSE OPTIMIZATION OF PROCESS PARAMETERS FOR EDM OF COPPER AND HIGH SPEED STEEL

B Suneel Kumar*[1],P satish kumar[2] and Ch v s parameswra rao[3]
[1,2,3]PBR Visvodaya Institute of Technology and Science, Kavali, AP, India

Abstract- Electrical Discharge Machine (EDM) is the one nonconventional machining process which is used very widely. In EDM, it is necessary to optimize the process parameters like pulse on-time, pulse off- time, discharge current, voltage, for maximization of Material Removal Rate (MRR) for Copper and high speed steel (HSS). 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 analysed with responses surface methodology. Interaction effect of process parameters on the responses has been discussed. A multi responses optimization technique was use 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

**Corresponding author: B suneel Kumar[1]*

I. INTRODUCTION

Electrical Discharge Machine (EDM) is now become the most important accepted technologies in manufacturing industries since many complex 3D shapes can be machined using a simple 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 moldings, die castings, forging dies and etc. EDM technology is increasingly being used in tool; die and mould making industries, for machining of heat treated tool steels and advanced materials (super alloys, 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 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 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 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, 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

Volume 04, Issue 1, [January– 2017] ISSN (Online):2349–9745; ISSN (Print):2393-8161

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 diameter equal to five or greater. As the depth-todiameter ratio increases, it becomes extremely difficult to produce such holes, especially, in super alloys 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 [11] 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. [12] suggested that orthogonal array (OA) with grey relational analysis is useful for optimisation of multiple response characteristics which is more complex compared to optimization of single-performance characteristics. They obtained optimal EDM parameters setting of 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 effect of process parameters in machining of HSS and Copper. Response surface methodology was used to analyse the experimental results of surface roughness, MRR and tool wear rate. 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 μm 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 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. As shown in the 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 the Table 1 and 3 for copper and High speed steel respectively.

Figure 1. Experimental set up of EDM

Figure 2. (a)Copper work pieces (b) High speed steel work pieces

Table 1. Design of experiments and responses for copper

s.no	I	T_{on}	T_{off}	V	T	MRR	TWR	R_a
1	15	7	7	40	23.8333	5.3907	0.0314	1.800
2	15	8	8	60	73.64	1.7445	0.0110	1.330
3	15	9	9	70	69.5411	1.8475	$9.9221x10^{-3}$	6.200
4	15	10	10	80	126.7721	1.0134	$4.4962x10^{-3}$	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	3.1336	0.0129	2.389
9	25	7	7	80	24.1426	5.3217	0.0339	4.099
10	25	8	9	70	26.412	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	29.028	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

3.1 Analysis of responses for copper

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 confidence level of 95%. Then the responses which are having 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 significant effect on MRR, current has significant effect tool wear rate and voltage has significant effect on the surface roughness.

Table 2. ANOVA for copper

ANOVA for metal removal rate					
Source	SS	DF	M S	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

Volume 04, Issue 1, [January– 2017] **ISSN (Online):2349–9745; ISSN (Print):2393-8161**

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
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			

3.2 Interaction effect of process parameters on responses (Copper)

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 significant effect on the MRR at all voltages, T_{on} and T_{off}. Remain parameter not so significant. From the Figure 4, it was observed that the current and T_{off} are having significant effect on the TWR. At low T_{off} and low currents, the TWR was found to be very less. From the Figure 5, it can be observed that the current and T_{on} are found to be significant on the surface roughness. At highT_{on} and low currents, the surface roughness is observed as very less.

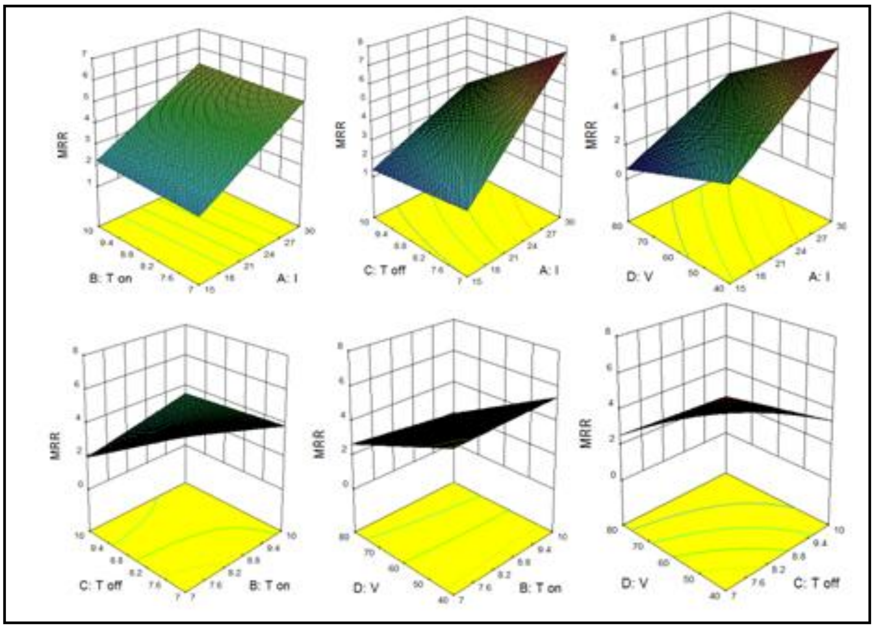

Figure 3 Interaction effects of parameters on the MRR

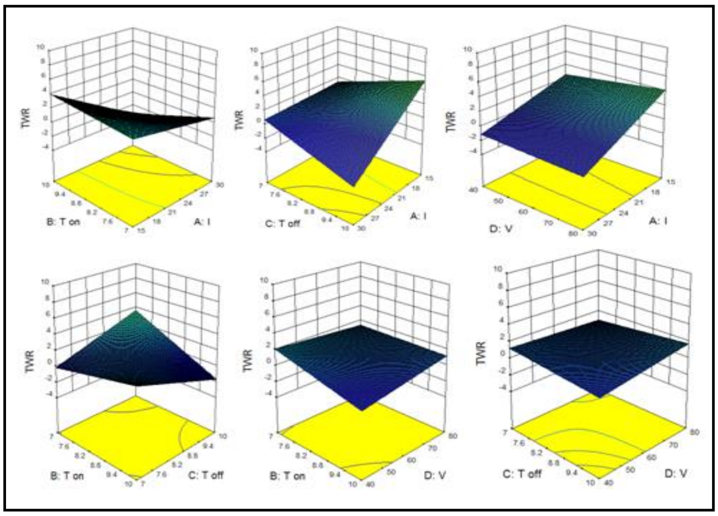

Figure 4 Interaction effects of parameters on the TWR

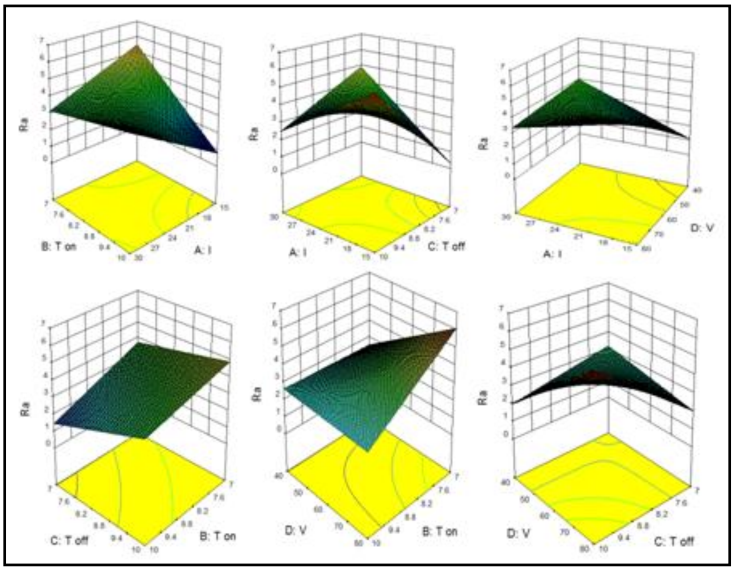

Figure 5 Interaction effects of parameters on the TWR

Table 3. Design of experiments and responses

S.No.	I	T_{on}	T_{off}	V	T	MRR	TWR	R_a
1	15	7	7	40	8.5147	30.1786	0.0093956	8.959
2	15	8	8	60	12.0915	21.2513	0.00082702	9.360
3	15	9	9	70	14.0653	18.269	0.001421	8.039
4	15	10	10	80	31.291	8.2119	0	4.899
5	20	7	8	70	19.3088	13.3079	0.00984	9.279
6	20	8	7	80	10.95567	23.4546	0.005476	7.160
7	20	9	10	40	5.9753	43.0036	0.001673	9.079
8	20	10	9	60	7.796	32.9606	0	1.440
9	25	7	7	80	13.3588	19.2352	0.01871	7.200
10	25	8	9	70	8.5615	30.0135	0.014101	7.720
11	25	9	7	60	4.158	61.799	0.009624	6.480
12	25	10	8	40	3.4922	73.5834	0	1.790

13	30	7	9	60	7.4155	34.6515	0.02994	3.979
14	30	8	9	40	2.6282	97.7743	0	6.320
15	30	9	8	80	7.9768	32.2135	0.2595	6.560
16	30	10	7	70	5.3843	47.7241	0.00185724	2.179

3.3 Analysis of responses for HSS

ANOVA was carried out for the high speed steel also 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 confidence level of 95%. Then the responses which are having p value less than the 0.05 are said to be significant.

From the Table 4, it was observed that the current and voltage have significant effect on MRR, voltage has significant effect tool wear rate and current and T_{on} have significant effect on the surface roughness.

Table 4. ANOVA for high speed steel

ANOVA for metal removal rate					
Source	SS	DF	M S	F- Value	**p-value**
Model	8046.753	10	804.675	10.642	0.0087
A-I	1232.334	1	1232.334	16.298	0.0099
B-T on	228.297	1	228.297	3.019	0.1427
C-T off	144.813	1	144.813	1.915	0.2249
D-V	1656.307	1	1656.307	21.906	0.0054
Residual	378.046	5	75.609		
Cor Total	8424.8	15			
ANOVA for tool wear rate					
Model	0.039	10	3.90E-03	0.89	0.4906
A-I	0.01	1	0.01	2.34	0.1866
B-T on	3.48E-03	1	3.48E-03	0.8	0.4129
C-T off	3.87E-03	1	3.87E-03	0.89	0.3900
D-V	0.012	1	0.012	2.75	0.0158
Residual	0.022	5	4.37E-03		
Cor Total	0.061	15			
ANOVA for surface roughness					
Model	62.64	4	15.66	3.80	0.0355
A-I	18.76	1	18.76	4.55	0.0563
B-T on	40.90	1	40.90	9.92	0.0093
C-T off	0.50	1	0.50	0.12	0.7351
D-V	0.13	1	0.13	0.032	0.8614
Residual	45.36	11	4.12		
Cor Total	108.01	15			

3.4 Interaction effect of process parameters on responses (HSS)

Figures 6, 7, and 8 show the interaction effect of process parameters on the responses such as MRR, TWR and surface roughness respectively. From the Figure 6, it was observed that the current and voltage have significant effect on the MRR. At low voltage and high current, the MRR is found to be less. From the Figure 7, it was observed that the current, voltage and T_{off} are having significant effect on the TWR. The TWR was found to be less at three combinations of parameters such as combination of low voltage and high current, combination of low T_{off} and low current and another combination of low voltage and low T_{off}. From the Figure 8, it can be observed that the current and T_{on} are found to be strong significant parameters on the surface roughness. The surface roughness was found to be less at four combinations of parameters such as combination of low T_{on} and low current, combination of low T_{off} and high current, combination of high T_{on} and low T_{off} and another combination of low voltage and low T_{on}.

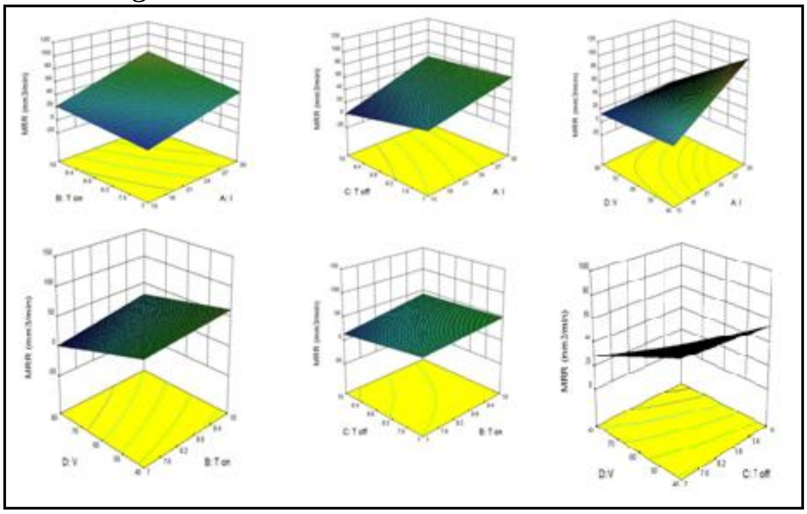

Figure 6 Interaction effects of parameters on the MRR

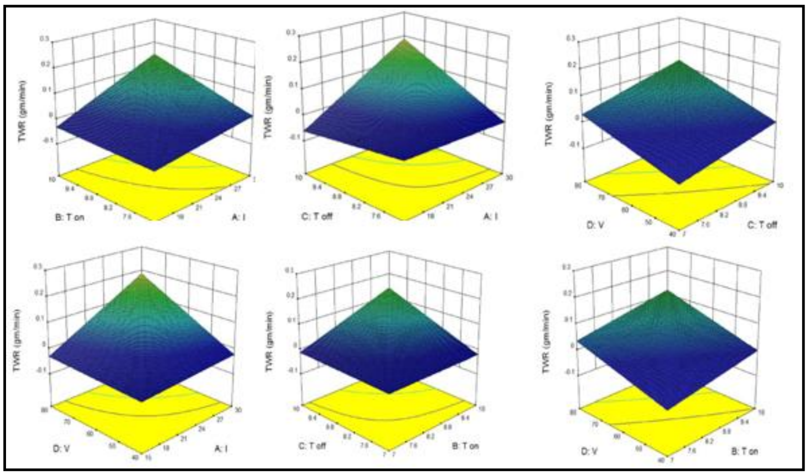

Figure 7 Interaction effects of parameters on the TWR

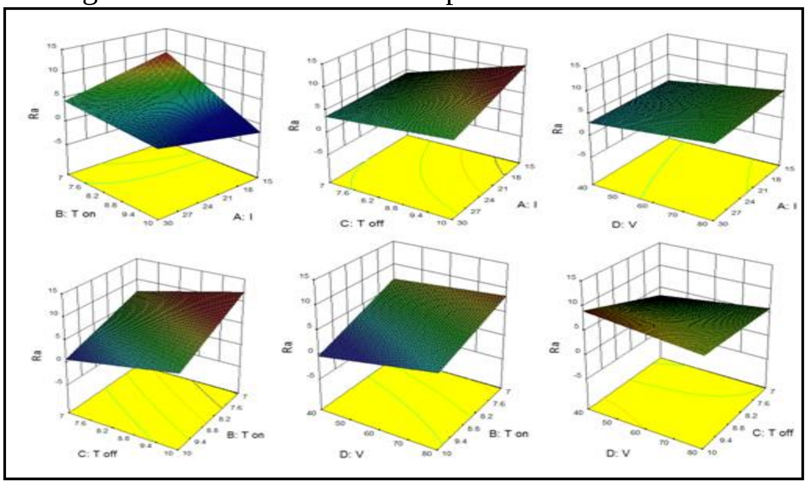

Figure 8 Interaction effects of parameters on the Ra

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. Figures 9 and 10 show the optimization of process parameters for the metals copper and high speed steel. Optimization of process parameters for the two metal was confirmed by desirability value. Composite desirability for the copper and HSS was found to be 0.8991 and 0.9839 respectively.

Table 5. Optimum process parameters

	Copper	HSS
Current	30	30
T_{on}	10	8.88
T_{off}	7.97	9.55
Voltage	74.74	40
Desirability	0.89991	0.9839

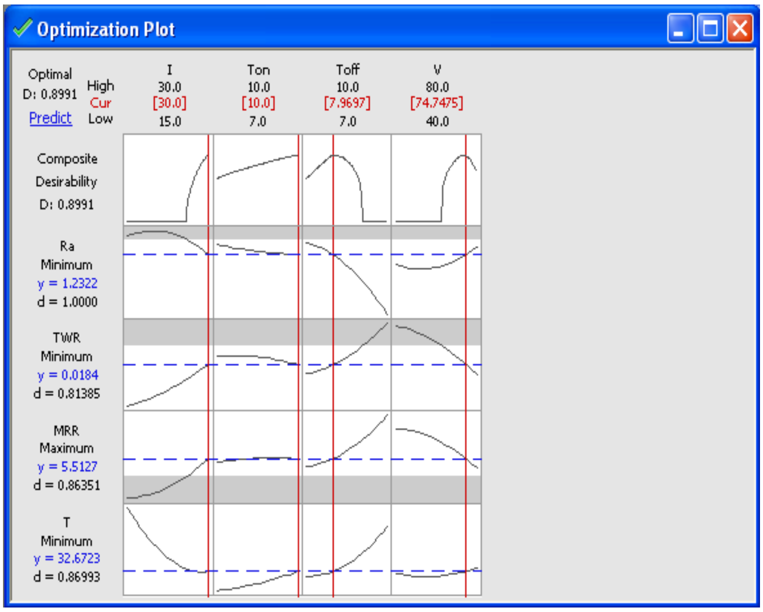

Figure 9. Multi response optimization parameters for Copper

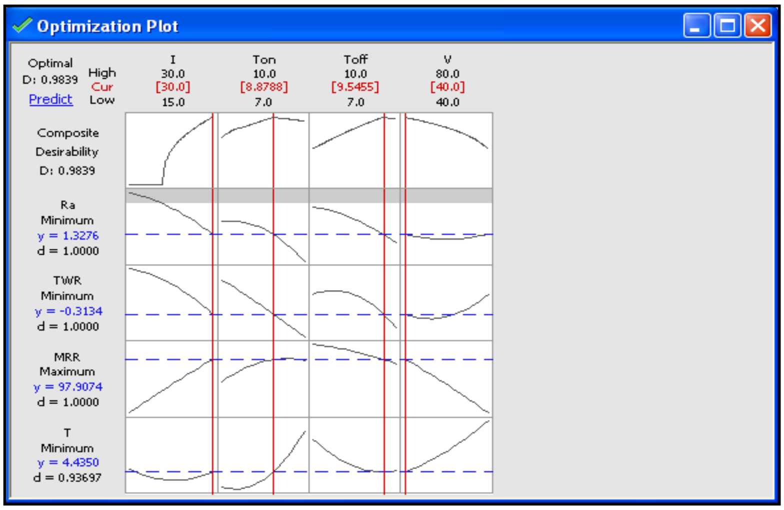

Figure 10. Multi response optimization parameters for HSS

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 for the two metals:

A. Copper

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

B. HSS

- Voltage has significant effect on MRR, voltage has significant effect tool wear rate and current and T_{on} have significant effect on the surface roughness.
- 30Amp of current, 8.88µs of Ton, 9.55 µs of Toff and 40 V of voltage were found to be optimum process parameter.

REFERENCES

[1] Krishna Mohana Rao G, Satyanarayana S, Praveen M (2008) 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
[2] Krishna Mohana Rao G, Rangajanardhaa G, Hanumantha Rao D, Sreenivasa Rao M (2009) Development of hybrid model and optimization of surface roughness in electric discharge machining using artificial neural networks and genetic algorithm. J Mater Process Technol 209:1512–1530
[3] Lin JL, Wang KS, Yan BH, Tarng YS (2000) Optimization of electrical discharge machining process based on the Taguchi method with fuzzy logics. J Mater Process Technol 102:48–55
[4] Sharman ARC, Hughes JI, Ridgway K (2004) Workpiece surface integrity and tool life issues when turning Inconel 718 nickel based superalloy. Mach Sci Technol 8(3):399–414
[5] Benes J (2000) Hole making trends run deep, fast and dry. Am Mach 144(5):97–104
[6] Chen JC, Liao YS (2003) Study on wear mechanisms in drilling of Inconel 718 super alloy. J Mater Process Technol 140:269–273
[7] Kao PS, Hocheng H (2003) Optimization of electrochemical polishing of stainless steel by grey relational analysis. J of Mater Processing Technol 140:255
[8] Singh PN, Raghukandan K, Pai BC (2004) Optimization by Grey relational analysis of EDM parameters on machining Al–10%SiCP composites. J of Mater Processing Technol 155–156:1658