

Experimental Investigation and Optimization of Process Parameters of Electrical Discharge Machining with H13 Steel

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ABSTRACT: H13 steel is well known for its high strength to weight ratio along with high corrosive resistance makes it inevitable application in the field of automobile and aeronautical industries. Electrical Discharge Machining (EDM) is used to machine the 'hard-to-cut' materials which are not machined by traditional methods. In this method an attempt is made to optimize the output parameters such as surface roughness (Ra), material removal rate (MRR), and tool wear rate (TWR) by varying the input parameters such as peak current (I_p), pulse on (T_{on}) time and pulse off (T_{off}) time. Response Surface Methodology (RSM) is applied to design the number of experiments and the experimental results are to be analyzed using analysis of variance (ANOVA) to find out significant contribution of machining parameters over responses and the optimal combinations of the parameters are determined.

KEYWORDS: H13 steel, Ra, MRR, TWR, I_p , T_{on} , T_{off} , Response Surface Methodology, Analysis of variance

I. INTRODUCTION

Electrical discharge machining (EDM), sometimes colloquially also referred to as spark machining, spark eroding, burning, die sinking, wire burning or wire erosion, is a manufacturing process whereby a desired shape is obtained using electrical discharges (sparks). Material is removed from the workpiece by a series of rapidly recurring current discharges between two electrodes, separated by a dielectric liquid and subject to an electric voltage. One of the electrodes is called the tool-electrode, or simply the "tool" or "electrode", while the other is called the workpiece-electrode, or "workpiece". When the distance between the two electrodes is reduced, the intensity of the electric field in the volume between the electrodes becomes greater than the strength of the dielectric (at least in some point(s)), which breaks, allowing current to flow between the two electrodes. This phenomenon is the same as the breakdown of a capacitor (condenser). As a result, material is removed from both electrodes. Once the current stops (or is stopped, depending on the type of generator), new liquid dielectric is usually conveyed into the inter-electrode volume, enabling the solid particles (debris) to be carried away and the insulating properties of the dielectric to be restored. Adding new liquid dielectric in the inter-electrode volume is commonly referred to as "flushing". Also, after a current flow, the difference of potential between the electrodes is restored to what it was before the breakdown, so that a new liquid dielectric breakdown can occur.

II. EXPERIMENTAL WORK

The experimental work is discussed which consists of the design of experiments using Response Surface Methodology (RSM) with 20 experiments for the three input parameters input current, pulse on time, pulse off time and experiments are carried out for the response parameters Material Removal Rate, Electrode Wear Rate and Surface Roughness.

International Journal of Innovative Research in Science, Engineering and Technology

An ISO 3297: 2007 Certified Organization,

Volume 5, Special Issue 7, April 2016

National Conference on Trends in Automotive Parts Systems and Applications (TAPSA-2016)

On 18th & 19th March

Organized by

Sri Krishna College of Engineering & Technology, Kuniamuthur, Coimbatore-641008, Tamilnadu, India

In this work H13 hot work tool steel is used for the experimentation. H13 hot work tool steel has high tensile strength, wear-resistance and toughness with good thermal conductivity and insensitiveness to hot cracking. H13 type grade offers a good resistance to softening, up to 600°C, combined with good stability in hardening and high toughness, making it suitable not only for hot die applications but also plastic moulds. It has many applications for making hot punches and dies for blanking, bending, swaging and forging, hot extrusion dies for aluminium, cores, ejector pins, inserts and nozzles for aluminium, tin and lead die casting. In this work H13 tool steel plate of 100mm x 100mm x 8mm is used for experimentation.

Table 1: H13 tool steel composition

Element	C	Mn	S	Si	Cr	V	Mo	P	Fe
%	0.316	0.338	0.0134	0.8025	4.956	1.09	1.285	0.0125	Remaining

In this experimental study, it was decided to study the effects of current, pulse on time and pulse off time on process performance keeping voltage as constant. Based on earlier studies, trial conditions, the range of input parameters was decided as in Table 2. In selecting an appropriate orthogonal array, the pre-requisites are (i) selection of process parameters and interactions to be evaluated and (ii) selection of number of levels for the selected parameters.

Table 2: Controllable parameters and their levels

PARAMETERS(UNIT)	NOTATION	LEVELS		
		-1	0	+1
Current (A)	I	4	7	10
Pulse on-time(µs)	T _{ON}	29	36	43
Pulse off-time (µs)	T _{OFF}	7	8	9

Gap voltage: 60 V (constant).

Evaluation of response parameters

The MRR is expressed as the ratio of the difference of weight of the workpiece before and after machining to the machining time.

$$MRR = (W_{jb} - W_{ja}) / t$$

whereas W_{jb} = Weight of the job before machining.

W_{ja} = Weight of the job after machining.

t = Machining time

TWR is expressed as the ratio of the difference of weight of the tool before and after machining to the machining time.

$$TWR = (W_{tb} - W_{ta}) / t$$

whereas W_{tb} = Weight of the tool before machining.

W_{ta} = Weight of the tool after machining.

t = Machining time

Surface Roughness is the measure of the texture of the surface. It is measured in µm. If the value is high then the surface is rough and if low then the surface is smooth. It is denoted by Ra. The values are measured using Portable style type profilometer, TESA rugosurf 10.

III. RESULTS AND DISCUSSION

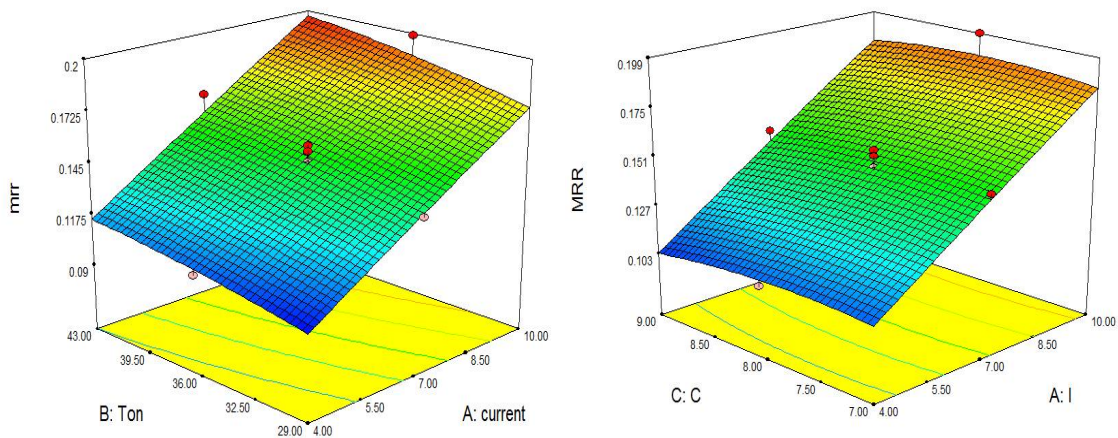
Table 3 shows the response values for MRR, TWR and surface roughness along with the input factors.

Table 3: L20 orthogonal array with multi-response values

Run order	Current(A)	T _{ON} (μ s)	T _{OFF} (μ s)	MRR(g/min)	TWR(g/min)	Ra(μ m)
1	10	29	9	0.17334	0.00155	4.63
2	7	36	9	0.14987	0.00091	4.57
3	4	36	8	0.10572	0.00062	4.19
4	10	43	9	0.18595	0.00059	5.25
5	10	29	7	0.16727	0.00151	5.01
6	7	36	8	0.14604	0.00088	4.76
7	7	36	8	0.15481	0.00092	4.51
8	7	36	8	0.14273	0.00088	4.69
9	7	36	8	0.13977	0.00084	4.44
10	7	43	8	0.16672	0.00051	5.12
11	7	29	8	0.13589	0.00121	4.25
12	4	43	9	0.10639	0.00063	4.52
13	10	36	8	0.19894	0.00118	5.17
14	7	36	8	0.15184	0.00091	4.86
15	4	43	7	0.11586	0.00068	4.99
16	4	29	9	0.09713	0.00057	3.49
17	7	36	8	0.14437	0.00089	4.64
18	10	43	7	0.19375	0.00059	5.43
19	7	36	7	0.14962	0.00091	4.95
20	4	29	7	0.09828	0.00089	3.87

Influences of Parameters on MRR

The combined effects of the input parameters on Material Removal Rate (MRR) are represented in graphs, which clearly shows that increase of current increases the Material Removal Rate and also in the same manner, increase of pulse on time increases the material removal rate and the increase of pulse off time first increases Material Removal Rate slightly and then decreases slightly with increase of pulse off time.



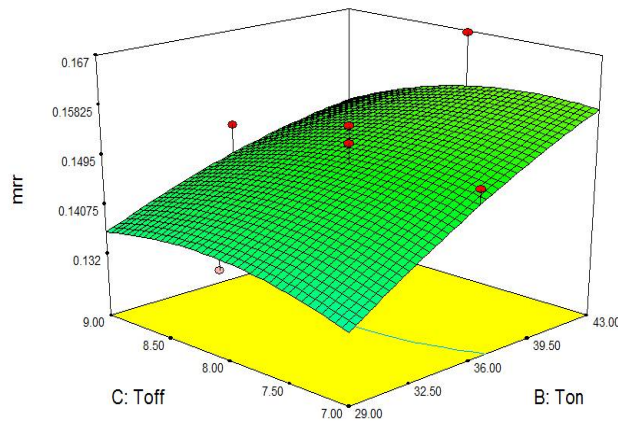


Figure 1: Effect of input parameters on MRR

Influences of Parameters on Tool Wear Rate

The effects of the each input parameter on Tool Wear Rate (TWR) are discussed, where the combined effects of the input parameters on Tool Wear Rate are represented in graphs, which clearly shows that increase in current increases the Tool Wear Rate and increase in pulse on time decreases Tool Wear Rate and pulse off time not showing a greater influence over TWR. Combined effect of input parameters on TWR is represented in graphs.

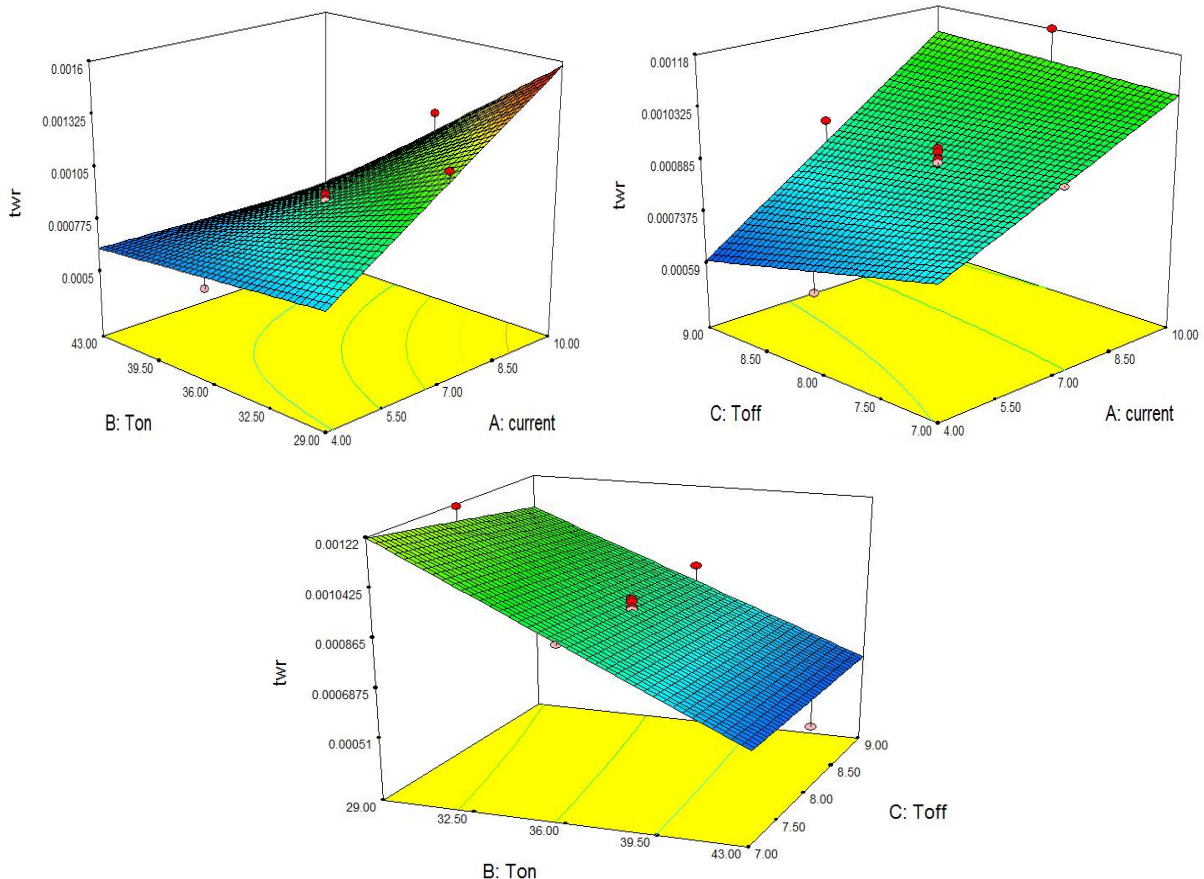


Figure 2: Effect of input parameters on TWR

Influence of Parameters on Surface Roughness

The effects of the each input parameter on Surface Roughness (Ra) are discussed, where the combined effects of the input parameters on Surface Roughness are represented in graphs, which clearly shows that increase in current increases the Surface Roughness and also in the same manner increase in pulse on time increases the Surface Roughness and increase in pulse off time decreases the Surface Roughness. Combined effect of input parameters on Surface Roughness is represented in graphs.

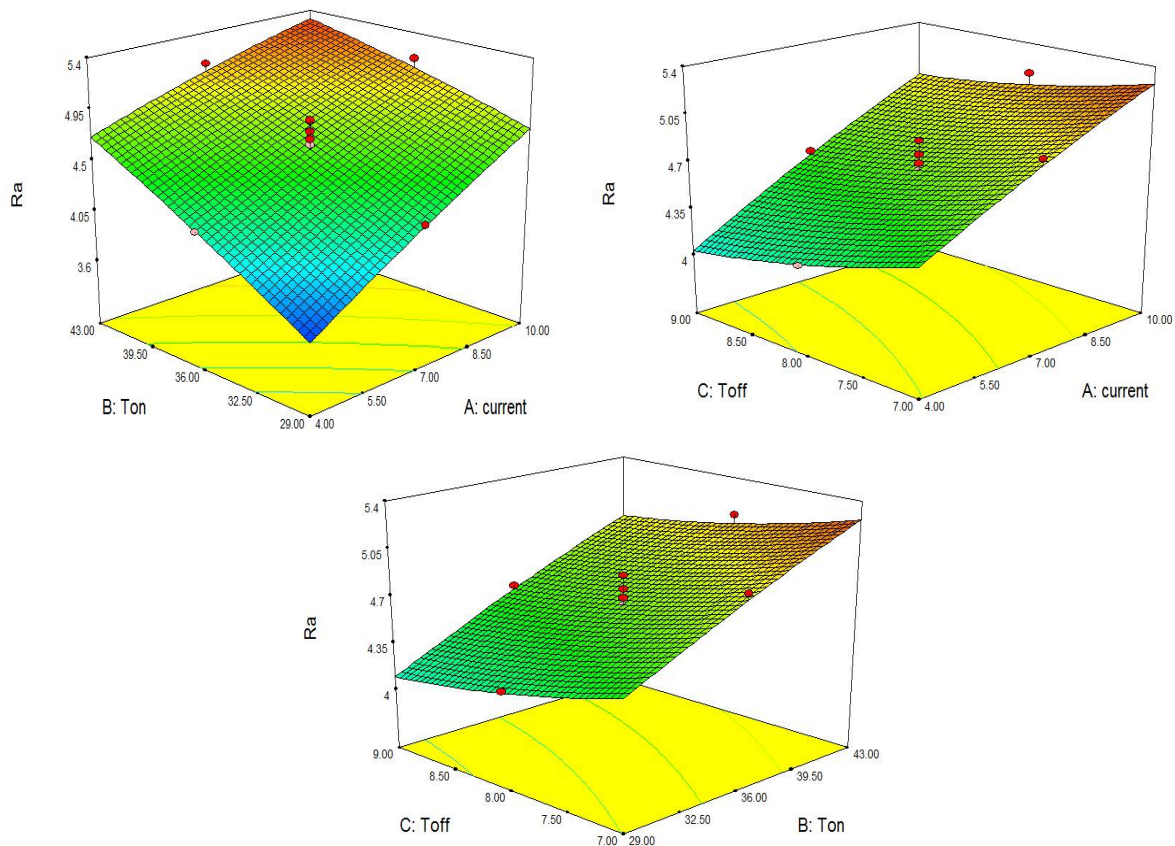


Figure 3: Effect of input parameters on Surface Roughness.

IV. CONCLUSION

The following conclusions are made based on the results and discussion for the H13 steel material with copper electrode:

- From the combined effects of the parameters, it is studied that MRR increases with increase in current and pulse on time and pulse off time didn't show significant contribution.
- The TWR increases with increase in current and decreases with increase in pulse on time whereas pulse off time didn't show significant contribution.
- Surface roughness increases with increase in current and pulse on time and decreases with pulse off time.

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International Journal of Innovative Research in Science, Engineering and Technology

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