

# Experimental Investigation on Electric Discharge Machining of H13 by Using Taguchi Approach

A.Saravan Bhavan<sup>1</sup>

Associate Professor, Department of Mechanical Engineering, Mallareddy Engineering College (Autonomous), Secunderabad, India<sup>1</sup>

**ABSTRACT:** In die casting process H13 is the primary choice for manufacturing of moulds. It has high hardness and high heat resisting capability. Electrical discharge machining (EDM) process is mostly using for machining hard materials like titanium, tungsten carbide, Inconel and performs special tasks which were not possible with conventional machining process. It can produce complex shapes with high dimensional accuracy. The present study explores the effect of process parameters of EDM on material removal rate (MRR), tool wear rate (TWR), surface roughness (SR). Interestingly, this experiment improves the material removal rate, reduces the tool wear rate and surface roughness. In this L9 Orthogonal Array is selected for the design of experiments

**KEYWORDS:** Material removal rate, Tool wear rate, surface Roughness.

## I. INTRODUCTION

AISI H13 tool steel is a versatile chromium-molybdenum hot work steel that is widely used in hot work and cold work tooling application. With respect to application and properties of AISI H13 tool steel, electrical discharge machining is well known method for its machining. Electrical discharge machining (EDM) is known to be applicable to conductive material regardless of their physical and mechanical properties.

In the EDM process the material is removed by successive electrical discharges occurring between an electrode and a work piece immersed in a dielectric fluid. Every discharge ionizes a very restricted area between, the closest opposing peaks of roughness of the electrodes and generates a localized plasma channel, within a vapour bubble bridge, in which the temperature can be as high as 8000- 10000 °C . The plasma pressure has been estimated to be up to several hundreds of bars. This hot plasma may lead to melting and evaporate of both electrodes [3]. At the end of the pulse, when the current is stopped, the pressure suddenly falls, causing the superheated molten liquid on the surface of both electrodes to explode into the liquid dielectric, leaving a crater on the electrode of surfaces and creating small and or hollow debris. Several researchers have reported that ultrasonic assisted EDM of steel improves discharge characteristics [5]-[7].

Gao and Liu [5] reported that the workpiece vibration induced by ultrasonic action has a significant effect on the performance of the micro-EDM process and efficiency of the ultrasonically aided micro-EDM is up to eight times greater than Micro- EDM. Murti [6] showed that ultrasonic assisted EDM of steel significantly reduced inactive pulses. Zhixin et al. [7] reported that for machining of advanced ceramics, the combination of ultrasonic machining and EDM may provide a higher MRR. Lin and Yan [8] have pointed out that EDM of titanium alloy by using ultrasonic tool vibrations give higher MRR and eliminate the recast layer.

## II. MATERIAL REQUIRED

The materials used in this experiment was H13. The work materials samples were rectangular shape with dimensions of (50mm×40mm×20mm). The chemical composition of H13 and properties of copper electrode is shown in the table 1,2



Element	C	Cr	Mn	Mb	P	Si	S	Vn
% Composition	0.32-0.45	4.75-5.5	0.2-0.5	1.1-1.75	0.03 max	0.8-1.2	0.03 max	0.8-1.2

Table 1: Chemical composition of H13

Material	Copper
Melting Point	1085
Boiling Point	2562
Density	8.95 g/cm <sup>3</sup>
Poison's ratio	0.34
Specific heat	0.39 KJ/KgK
Thermal conductivity	401 W/mk
Vickers Hardness	369 MPa
Young's Modulus	110-128 GPa

Table 2: Properties of Copper electrode

### III. MACHINE SPECIFICATIONS OF EDM

S. No.	Parameter	Range
1	Pulse on time (T on)( $\mu$ s)	0 -1800
2	Pulse off time (T off)( $\mu$ s)	0 – 12
3	Peak current (A)	Up to 30
4	Voltage(V)	0 -300
5	Flushing Pressure (kg/sq.cm)	0 -3

Table 3: Range of EDM parameters

### IV. DESIGN OF EXPERIMENTS BY TAGUCHI L-9 ORTHOGONAL ARRAY

Experiments are designed using L-9 array with Pulse on time, Pulse off time and Peak current each at three levels and process parameters chosen for the experiment are pulse on time, pulse off time and peak current Metal removal rate, surface roughness and tool wear rate are calculated for each experiment. The EDM parameters and number of levels of the parameters are selected as follows.

Parameter	Symbol	Level 1	Level 2	Level 3
Current (Amps)	A	12	15	21
Time - ON ( $\mu$ s)	B	150	200	300
Time - OFF ( $\mu$ s)	C	4	5	6

Table 4: Experimental Factors and Their Levels



Expt.No	Current	Time - ON (μs)	Time - OFF (μs)
1	12	150	4
2	12	200	5
3	12	300	6
4	15	150	5
5	15	200	6
6	15	300	4
7	21	150	6
8	21	200	4
9	21	300	5

Table 5: Experiments parameter using Taguchi L-9 Design Matrix

### V. EXPERIMENT FINDINGS

Experimental machining operation on H13 by using copper as electrode on EDM, to obtain optimal combination, using Taguchi method.

- Material Removal Rate (MRR) is calculated using the formula  

$$MRR \text{ (mm}^3\text{/min)} = \Delta W / \rho_w \times t$$
 Where  $\Delta W$  the weight difference of work piece before and after machining (g),  $\rho_w$  is the density of work material ( $\text{g/mm}^3$ ) and t is the machining time in minutes
- Surface Roughness Measure by the Instrument Surftest SJ-310 Series of machined cut surface
- Tool Wear Rate (TWR) is calculated using the formula  

$$TWR \text{ (mm}^3\text{/min)} = \Delta T / \rho_t \times t$$
 Where  $\Delta T$  the weight difference of work electrode before and after machining (g),  $\rho_t$  is the density of electrode material ( $\text{g/mm}^3$ ) and t is the machining time in minutes
- Signal-to-noise ratio(S/N Ratio): A signal-to-noise ratio is a measure of robustness, which can be used to identify the control factor settings that minimize the effect of noise on the response.
  - Larger is better:  $S/N = -10 \cdot \log (\Sigma (1/Y^2)/n)$  for MRR
  - Smaller is better:  $S/N = -10 \cdot \log (\Sigma (Y^2)/n)$  for Surface Roughness
  - Smaller is better:  $S/N = -10 \cdot \log (\Sigma (Y^2)/n)$  for TWR
- Conformation test is required when the combination is not matching for that we use a formula.

$$Y_{opt} = m + (M_{Aopt} - m) + (M_{Bopt} - m) + (M_{Copt} - m) + (M_{Dopt} - m) \quad \text{----Eq.1}$$

### VI. RESULTS & DISCUSSIONS

The experiment work is done according to Taguchi L-9 Orthogonal array; Process Parameters are specified and optimize the working conditions. The novelty of work can be found in EDM machining of H13 with outcomes TWR, MRR and SR are Table 6



Expt. No	TWR	SNRA1	MRR	SNRA2	SR(μm)	SNRA3
1	0.467	6.6088	30.1075	29.5735	7.890	-17.9415
2	0.338	9.4173	36.5591	31.2599	9.325	-19.3930
3	0.224	12.9822	47.3118	33.4994	8.062	-18.1289
4	1.030	-0.2579	38.7097	31.7564	5.921	-15.4479
5	0.642	3.8528	43.0108	32.6715	9.741	-19.7721
6	0.364	8.7729	60.2151	35.5941	11.763	-21.4104
7	2.652	-8.4720	49.4624	33.8855	7.661	-17.6857
8	1.410	-2.9865	58.0650	35.2783	7.295	-17.2605
9	0.926	0.6646	64.3350	36.1689	9.614	-19.6581

Table 6: Experiment results of H13 using EDM

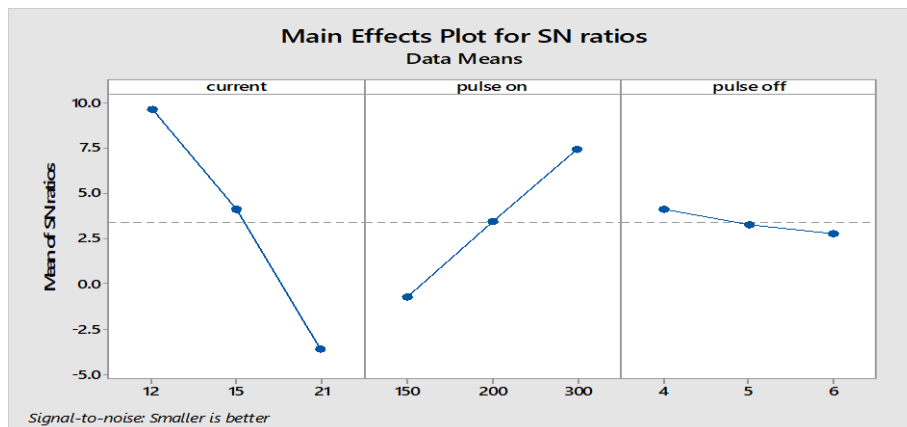


Fig1: Signal to Noise Ratios for Tool Wear Rate i.e Smaller is the Better

From the above Fig, the optimum combinations for Tool Wear Rate is A1-B3-C1 (Current-12Amps, T-On-300μs, T-OFF-4μs. The Design of experiments did not match with L9 orthogonal array for TWR of H13 of EDM-. So confirmation Test is required for the combination A1-B3-C1

**Confirmation Test for TWR**

- From the equation 1 the Tool Wear Rate is calculated for the optimum combination A1-B3-C1 is **0.329 mm<sup>3</sup>/min**

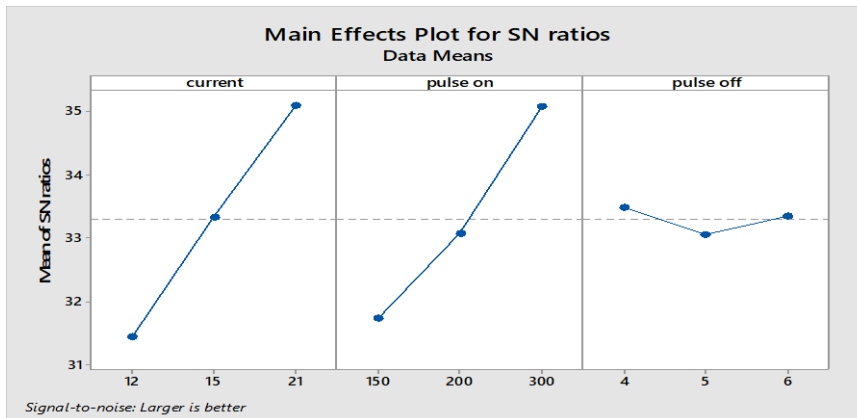


Fig 2: Signal to Noise Ratio Graph of Material Removal Rate for H13 material

From the above Fig the optimum combinations for Material Removal Rate is A3-B3-C1 (Current-21Amps, T-On-300µs, T-OFF-4µs. The Design of experiments did not match with L9 orthogonal array for MRR of H13 of EDM-. So confirmation Test is required for the combination A3-B3-C1

**Confirmation Test for MRR**

- From the equation 1 the Material Removal Rate is calculated for the optimum combination A3-B3-C1 is **64.5322 mm<sup>3</sup>/min**

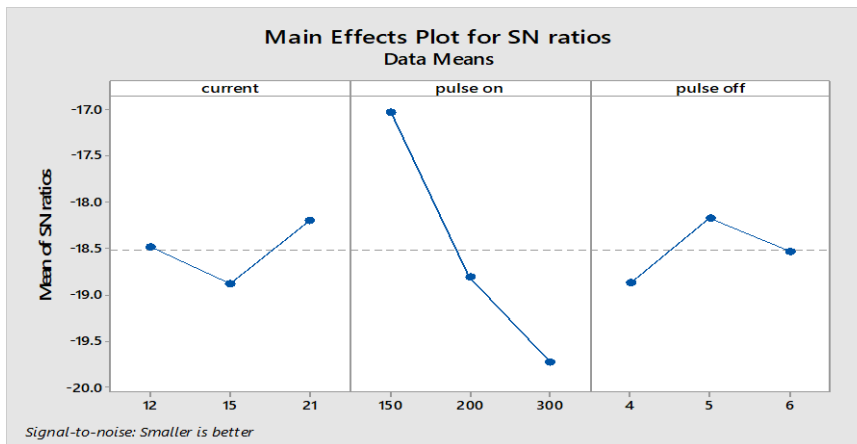


Fig:3 Signal to Noise Ratios for Surface Roughness i.e. Smaller is the Better

From the above Table.8 and Fig.3 the optimum combinations for Surface Roughness is A3-B1-C2 (Current-21 Amps, T-On-150µs, T-OFF-5µs. The Design of experiments did not match with L9 orthogonal array for Surface Roughness of H13 of EDM-. So confirmation Test is required for the combination A3-B1-C2

**Confirmation Test for Surface Roughness**

- From the equation 1 the Surface Roughness is calculated for the optimum combination A3-B1-C2 is **4.988µm**

**VII. CONCLUSIONS**

The present work deals with optimization of the process parameters on EDM machining for H13 Tool Wear Rate (TWR), Material Removable Rate (MRR) and Surface Roughness (SR) as responses. The following conclusions were drafted

- The optimum combination for TWR is A1-B3-C1 is **0.329 mm<sup>3</sup>/min**
- The optimum combination for MRR is A3-B3-C1 is **64.5322 mm<sup>3</sup>/min**
- The optimum combination for SR is A3-B1-C2 is **2.714µm**

- Conformation test has been done for TWR, MRR & SR as Taguchi combination is not according to the design of experiments.

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