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# Effect of Powder Metallurgical Compact Electrodes on MRR of H-13 Tool Steel during EDM

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## ABSTRACT

*EDMis immensely used in the modern era of industries to machine the materials that are hard to machine by conventional machining methods. Present paper deals with machining of H-13 tool steel with different types of electrodes in the EDM. A set of input parameters were chosen at different levels and their effect has been studied on material removal rate of the work piece. Experimentation showed that Polarity, Duty Cycle & Retract Distance are the most significant factors under the chosen conditions of machining*

***Keywords***

***EDM, Material Removal Rate (MRR), Surface Roughness (SR), Powder Metallurgical Compact different Electrodes***

## INTRODUCTION

Electrical Discharge Machining is one of the most preferred non- traditional machining processes used to machine hard to machine, complicated designs of electrically conductive materials. It is a thermal process that involves melting and vaporization of the pair of work piece and electrode. Studieshasshownthat combined pulse generation and a relaxation circuit enhances the tool electrode transfer [1].EDM with pulsing relaxation generator using a powder compact electrode and reverse polarity setting can modify the surface properties of a machined surface [2]. A new method named electrical discharge alloying is used for modification of surface of aluminium [3]. PM electrodes affect the micro- and macro variables in EDM and the properties of PM electrodes can be controlled over a wide range by adjusting the compacting and sintering conditions [4]. In some cases compounds of ZrB2 and TiSi with Cu at a variety of compositions, for EDM electrodes with either solid-state sintering or molten state sintering are also used [5].Rapid Prototyped-sintered EDM electrodes show good performance in finishing the surface and best results can be obtained by addition of 15% TiC, i.e. the lowest tool wear rate, highest material removal rate and best surface finish [6]. Besides erosion of work material during machining, the essential nature of the process consequences in removal of some tool material also. This can be reduced to some extent under precise machining conditions by using either composite electrodes or by dispersing metallic powders in the dielectric or both [7]. Experimentation shows that on machining AISID2 tool steel in kerosene; it is observed that copper tungsten Powder metallurgical electrode gives improved multi-objective performance than ordinary Cu electrode [8].

**Effect of Powder Metallurgical Compact Electrodes on MRR of H-13 Tool Steel during EDM**,
**Experimentation:**In the present study, the machine used for experimentation is Smart ZNC EDM with servo head, Electronica Machine Tools, India (Pune). The work piece material selected was H-13 tool steel. A rectangular piece of size 75 mm × 45 mm × 05 mm was chosen for the study.Selected input

machining parameters with their designation,levels and assigned values at these levels are listed in Table 1.All other parameters were kept constant during the experimental investigation. Electrodes used in the study were conventional copper, copper Tungsten and powder metallurgy electrodes.

**Table 1:Input machining parameters with their designation, Levels and assigned values**

| **Factor Designation** | **Machining Parameter (units)** | **Levels and corresponding values of Machining parameter** | | |
|---|---|---|---|---|
| | | **Level-1** | **Level-2** | **Level-3** |
| A | Polarity | Positive | Negative | -------- |
| B | Electrode Type | Conventional Copper | Copper Tungsten (CuW) | Copper Silicon Carbide Powder metallurgy Electrode (CuSiC) |
| C | Peak Current (Amp) | 6 | 10 | 14 |
| D | Duty Cycle | 0.7 | 0.8 | 0.9 |
| E | Gap Voltage (Volts) | 40 | 50 | 60 |
| F | Retract Distance (mm) | 1 | 2 | 3 |

The experimental combinations of the machining parameters using the $L_{36}$ orthogonal array are presented in Table 2.

**Table 2: Design Matrix of $L_{36}$ ($3^5$ x $2^1$) orthogonal array**

| **Exp No.** | **INPUT PARAMETERS** | | | | | |
|---|---|---|---|---|---|---|
| | **A:Polarity** | **B:Electrode type** | **C:Peak Current (Ampere)** | **E:Duty Cycle** | **F:Gap Voltage (Volt)** | **D:Retract Distance: (µm)** |
| 1 | Positive | Copper | 6 | 0.7 | 40 | 1 |
| 2 | Positive | CuW | 10 | 0.8 | 50 | 2 |
| 3 | Positive | CuSiC | 14 | 0.9 | 60 | 3 |
| 4 | Positive | Copper | 6 | 0.7 | 40 | 2 |
| 5 | Positive | CuW | 10 | 0.8 | 50 | 3 |
| 6 | Positive | CuSiC | 14 | 0.9 | 60 | 1 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 7 | Positive | Copper | 6 | 0.8 | 60 | 1 |
| 8 | Positive | CuW | 10 | 0.9 | 40 | 2 |
| 9 | Positive | CuSiC | 14 | 0.7 | 50 | 3 |
| 10 | Positive | Copper | 6 | 0.9 | 50 | 1 |
| 11 | Positive | CuW | 10 | 0.7 | 60 | 2 |
| 12 | Positive | CuSiC | 14 | 0.8 | 40 | 3 |
| 13 | Positive | Copper | 10 | 0.9 | 40 | 3 |
| 14 | Positive | CuW | 14 | 0.7 | 50 | 1 |
| 15 | Positive | CuSiC | 6 | 0.8 | 60 | 2 |
| 16 | Positive | Copper | 10 | 0.9 | 50 | 1 |
| 17 | Positive | CuW | 14 | 0.7 | 60 | 2 |
| 18 | Positive | CuSiC | 6 | 0.8 | 40 | 3 |
| 19 | Negative | Copper | 10 | 0.7 | 60 | 3 |
| 20 | Negative | CuW | 14 | 0.8 | 40 | 1 |
| 21 | Negative | CuSiC | 6 | 0.9 | 50 | 2 |
| 22 | Negative | Copper | 10 | 0.8 | 60 | 3 |
| 23 | Negative | CuW | 14 | 0.9 | 40 | 1 |
| 24 | Negative | CuSiC | 6 | 0.7 | 50 | 2 |
| 25 | Negative | Copper | 14 | 0.8 | 40 | 2 |
| 26 | Negative | CuW | 6 | 0.9 | 50 | 3 |
| 27 | Negative | CuSiC | 10 | 0.7 | 60 | 1 |
| 28 | Negative | Copper | 14 | 0.8 | 50 | 2 |
| 29 | Negative | CuW | 6 | 0.9 | 60 | 3 |
| 30 | Negative | CuSiC | 10 | 0.7 | 40 | 1 |
| 31 | Negative | Copper | 14 | 0.9 | 60 | 2 |
| 32 | Negative | CuW | 6 | 0.7 | 40 | 3 |
| 33 | Negative | CuSiC | 10 | 0.8 | 50 | 1 |
| 34 | Negative | Copper | 14 | 0.7 | 50 | 3 |
| 35 | Negative | CuW | 6 | 0.8 | 60 | 1 |
| 36 | Negative | CuSiC | 10 | 0.9 | 40 | 2 |

The experimental results for MRR are tabulated in Table 3 and the average values of signal-to-noise (S/N) ratios for MRR at different levels are plotted in figure 1, keeping the objective as “higher-the-better”. To study the significance of the selected parameters in effecting the MRR, analysis of variance (ANOVA) was performed and is given in Table 4.

The results shown in Table 3 of MRR were analyzed using the Minitab 17 software. For MRR the requirement is to maximize it so the criteria related using the software is larger is better. The ANOVA table for MRR clearly indicates that the polarity, electrode type, current, duty cycle, gap voltage and retract distance are influencing factors for MRR.

**Table 3: Experimental results for MRR**

| Cut No. | Work Piece Weight (gms) | | Work Piece Weight Loss (gms) | Time Of Cut (min) | MRR (gms/min) |
|---|---|---|---|---|---|
| | Initial | Final | | | |
| 1 | 162.6 | 162.442 | 0.158 | 2.3 | 0.0686957 |
| 2 | 144.792 | 144.589 | 0.203 | 4.25 | 0.0477647 |
| 3 | 124.739 | 124.525 | 0.214 | 1.15 | 0.186087 |
| 4 | 162.442 | 162.232 | 0.21 | 2.766667 | 0.0759036 |
| 5 | 144.589 | 144.394 | 0.195 | 3.5 | 0.0557143 |
| 6 | 124.384 | 124.224 | 0.16 | 1.2 | 0.1333333 |
| 7 | 162.232 | 162.134 | 0.098 | 2.3 | 0.0426087 |
| 8 | 144.394 | 144.185 | 0.209 | 2.45 | 0.0853061 |
| 9 | 124.05 | 123.848 | 0.202 | 1.583333 | 0.127579 |
| 10 | 162.134 | 161.895 | 0.239 | 2.283333 | 0.1046715 |
| 11 | 144.185 | 143.938 | 0.247 | 3.25 | 0.076 |
| 12 | 123.711 | 123.621 | 0.09 | 916667 | 9.818E-08 |
| 13 | 161.895 | 161.704 | 0.191 | 2.066667 | 0.0924193 |
| 14 | 143.938 | 143.708 | 0.23 | 1.74 | 0.1321839 |
| 15 | 123.436 | 123.379 | 0.057 | 8.016667 | 0.0071102 |
| 16 | 161.704 | 161.464 | 0.24 | 1.283333 | 0.187013 |
| 17 | 143.708 | 143.469 | 0.239 | 1.43 | 0.1671329 |
| 18 | 123.184 | 123.106 | 0.078 | 9.066667 | 0.0086029 |
| 19 | 161.464 | 161.409 | 0.055 | 65 | 0.0008462 |
| 20 | 142.775 | 142.655 | 0.12 | 65.7 | 0.0018265 |
| 21 | 122.974 | 122.862 | 0.112 | 4.333333 | 0.0258462 |
| 22 | 161.409 | 161.298 | 0.111 | 128 | 0.0008672 |
| 23 | 142.928 | 142.775 | 0.153 | 88.75 | 0.0017239 |
| 24 | 122.725 | 122.619 | 0.106 | 4.933333 | 0.0214865 |
| 25 | 161.298 | 161.255 | 0.043 | 43 | 0.001 |
| 26 | 142.655 | 142.583 | 0.072 | 159.71 | 0.0004508 |
| 27 | 122.497 | 122.333 | 0.164 | 2.033333 | 0.0806558 |
| 28 | 161.255 | 161.246 | 0.009 | 9 | 0.001 |
| 29 | 143.583 | 142.544 | 1.039 | 151.68 | 0.0068499 |

| | | | | | |
|---|---|---|---|---|---|
| 30 | 122.204 | 122.054 | 0.15 | 1.9 | 0.0789474 |
| 31 | 161.246 | 161.073 | 0.173 | 60 | 0.0028833 |
| 32 | 142.544 | 142.48 | 0.064 | 150.25 | 0.000426 |
| 33 | 121.927 | 121.796 | 0.131 | 1.35 | 0.097037 |
| 34 | 161.073 | 161.035 | 0.038 | 47 | 0.0008085 |
| 35 | 142.48 | 142.432 | 0.048 | 153.5 | 0.0003127 |
| 36 | 121.664 | 121.524 | 0.14 | 1.833333 | 0.0763637 |

**Table 4: Analysis of Variance for means of SN ratio for MRR (Larger is Better)**

| Source | DF | Seq. SS | Adj. SS | Adj. MS | F | P |
|---|---|---|---|---|---|---|
| **Polarity** | 1 | 3098.9 | 3098.9 | 3098.94 | 7.82 | 0.010 |
| **Electrode Type** | 2 | 191.4 | 191.4 | 95.69 | 0.24 | 0.787 |
| **Peak Current** | 2 | 2208.2 | 2208.2 | 1104.12 | 2.79 | 0.082 |
| **Duty Cycle** | 2 | 3387.7 | 3387.7 | 1693.84 | 4.28 | 0.026 |
| **Voltage** | 2 | 1043.0 | 1043.0 | 521.52 | 1.32 | 0.287 |
| **Retract Distance** | 2 | 3155.3 | 3155.3 | 1577.64 | 3.98 | 0.032 |
| **Residual Error** | 24 | 9506.5 | 9506.5 | 396.10 | | |
| **Total** | 35 | 22591.1 | | | | |

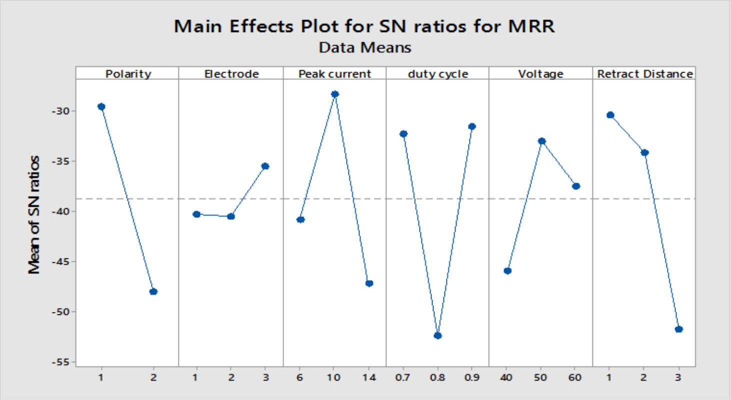

**Figure 1: Main effects plot for means SN ratio (MRR).**

During the process of electrical discharge machining, the influence of various input machining parameter has considerable effect on MRR, as shown in main effects plot for SN ratio of MRR in Figure 1. It is clear from fig that MRR is maximum at the 1st level of polarity, 3rd level of electrode type, 2nd level of peak current, 3rd level of duty cycle, 2nd level of Gap Voltage and 1st level of retract distance. Main effect plots for SN ratios suggest these levels of the parameters are best levels for maximum MRR.

## Conclusion

From the study it can be concluded that the 1st level of polarity, 3rd level of electrode type, 2nd level of peak current, 3rd level of duty cycle, 2nd level of Gap Voltage and 1st level of retract distance are optimum parameters but Polarity, Duty Cycle & Retract Distance are found to be the most significant factors in maximizing MRR. The confirmatory experiments have been conducted according to best settings and there is 2.19 % improvement in MRR.

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