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# Analysis of MRR and SR of Die Steel H-11

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***Abstract— This study has been done on Die Steel H-11 with the Electro discharge machining. Input parameters are current, pulse on time, pulse off time and flushing pressure. Hexagonal copper electrode is used as a tool. The work has been analyzed by using Taguchi's method for the material removal rate (MRR) and surface roughness (SR). Pulse on time is most effective for MRR and current is most effective for SR.***

***Index Terms— H-11, EDM, MRR, SR, Taguchi Design***

## I. INTRODUCTION

Electrical discharge machining (EDM) is used for the study of Die steel h-11 which is a non conventional machine and removes the material by sparking process. Mehra et al. [1] compare the surface roughness on ductile cast iron by using the solid and hollow electrode and found that surface roughness increase with hollow electrode. Chen at al. [2] found that surface roughness is mostly affected with the pulse current and duty cycle during the machining of A6061-T6 and CuZn40(C-2800B). Raghuraman at el. [3] Study the machining of mild steel IS 2026 by using Taguchi method and Grey relational analysis on EDM. Subrahmanyam et al. [4] study the material removal rate and surface roughness with Grey and Taguchi method on hot die steel H-13 by taking eight parameters and found that Grey-Taguchi method is most suitable for optimizing the parameter because it make the complex mathematical computation into easy form. Sanghani et al. [5] found that Taguchi technique is most common in optimizing the parameter rather than others. Bergalay et al. [6] results show that current and pulse on time effect the material removal rate when machining is done on high carbon high chromium steel. Singh et al. [7] study the material removal rate of die steel with wire EDM and found that with increase of pulse on time and discharge current, the material removal rate increase.

## II. EXPERIMENT METHODOLOGY

Mixed level $L_{18}$ Taguchi design is used to optimize the parameters of H-11 die steel. One parameter flushing pressure has taken two levels and other three parameters have taken three levels. The input levels are given below in Table 1.

**Table 1: Levels of Input Parameters**

| PARAMETERS | LEVEL | | |
|---|---|---|---|
| | **1** | **2** | **3** |
| Pulse ON Time ($T_{on}$) | 2 | 5 | 8 |
| Pulse OFF time ($T_{off}$) | 2 | 5 | 8 |
| Current ( I) | 4 | 8 | 12 |
| Flushing Pressure (p) | 5 | 10 | |

Experiments are conducted on the electric discharge machining as shown in Fig 1.


**Fig. 1: EDM Setup**

## III. OBSERVATIONS

Material removal rate was calculated from weight difference of work piece and machining time.

$$MRR = \frac{W_1 - W_2}{T}$$

Here Table 2 shows the observations of MRR which are calculated by the formula.

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**Table 2: Observation of MRR**

| P (kg/cm$^2$) | I (A) | $T_{on}$ (µs) | $T_{off}$ (µs) | MRR (g/min) |
|---|---|---|---|---|
| 5 | 4 | 2 | 2 | 0.021231 |
| 5 | 4 | 5 | 5 | 0.029308 |
| 5 | 4 | 8 | 8 | 0.011454 |
| 5 | 8 | 2 | 2 | 0.030723 |
| 5 | 8 | 5 | 5 | 0.03851 |
| 5 | 8 | 8 | 8 | 0.022341 |
| 5 | 12 | 2 | 5 | 0.081471 |
| 5 | 12 | 5 | 8 | 0.103687 |
| 5 | 12 | 8 | 2 | 0.017186 |
| 10 | 4 | 2 | 8 | 0.001576 |
| 10 | 4 | 5 | 2 | 0.086875 |
| 10 | 4 | 8 | 5 | 0.02044 |
| 10 | 8 | 2 | 5 | 0.025049 |
| 10 | 8 | 5 | 8 | 0.029808 |
| 10 | 8 | 8 | 2 | 0.031765 |
| 10 | 12 | 2 | 8 | 0.007256 |
| 10 | 12 | 5 | 2 | 0.026467 |
| 10 | 12 | 8 | 5 | 0.043385 |

In this study, surface roughness is measured with the help of Mitutoyo surftest SJ-400. Table 3 shows the observations of SR.

**Table 3: Observation of SR**

| P (kg/cm$^2$) | I (A) | $T_{on}$ (µs) | $T_{off}$ (µs) | SR1 (µm) | SR2 (µm) | SR3 (µm) |
|---|---|---|---|---|---|---|
| 5 | 4 | 2 | 2 | 2.44 | 2.46 | 2.47 |
| 5 | 4 | 5 | 5 | 1.88 | 1.86 | 1.84 |
| 5 | 4 | 8 | 8 | 2.19 | 2.20 | 2.21 |
| 5 | 8 | 2 | 2 | 2.35 | 2.35 | 2.36 |
| 5 | 8 | 5 | 5 | 3.67 | 3.66 | 3.65 |
| 5 | 8 | 8 | 8 | 3.01 | 3.03 | 3.02 |
| 5 | 12 | 2 | 5 | 4.34 | 4.33 | 4.34 |
| 5 | 12 | 5 | 8 | 2.88 | 2.90 | 2.91 |
| 5 | 12 | 8 | 2 | 4.42 | 4.42 | 4.43 |
| 10 | 4 | 2 | 8 | 1.30 | 1.31 | 1.31 |
| 10 | 4 | 5 | 2 | 2.23 | 2.25 | 2.26 |
| 10 | 4 | 8 | 5 | 2.35 | 2.36 | 2.35 |
| 10 | 8 | 2 | 5 | 1.80 | 1.81 | 1.80 |
| 10 | 8 | 5 | 8 | 2.86 | 2.87 | 2.87 |
| 10 | 8 | 8 | 2 | 2.75 | 2.75 | 2.74 |
| 10 | 12 | 2 | 8 | 2.95 | 2.96 | 2.97 |
| 10 | 12 | 5 | 2 | 2.77 | 2.77 | 2.76 |
| 10 | 12 | 8 | 5 | 3.97 | 3.98 | 3.98 |

## IV. RESULTS AND DISCUSSION

### *A. MRR Analysis*

Fig 2 shows the mean values and S/N ratio of the MRR.

| ➞ | C1 | C2 | C3 | C4 | C5 | C6 | C7 |
|---|---|---|---|---|---|---|---|
| | P | I | T on | T off | MRR | SNRA1 | MEAN1 |
| 1 | 5 | 4 | 2 | 2 | 0.021231 | -33.4608 | 0.021231 |
| 2 | 5 | 4 | 5 | 5 | 0.029308 | -30.6602 | 0.029308 |
| 3 | 5 | 4 | 8 | 8 | 0.011454 | -38.8206 | 0.011454 |
| 4 | 5 | 8 | 2 | 2 | 0.030723 | -30.2508 | 0.030723 |
| 5 | 5 | 8 | 5 | 5 | 0.038510 | -28.2885 | 0.038510 |
| 6 | 5 | 8 | 8 | 8 | 0.022341 | -33.0178 | 0.022341 |
| 7 | 5 | 12 | 2 | 5 | 0.081471 | -21.7800 | 0.081471 |
| 8 | 5 | 12 | 5 | 8 | 0.103687 | -19.6855 | 0.103687 |
| 9 | 5 | 12 | 8 | 2 | 0.017186 | -35.2963 | 0.017186 |
| 10 | 10 | 4 | 2 | 8 | 0.001576 | -56.0478 | 0.001576 |
| 11 | 10 | 4 | 5 | 2 | 0.086875 | -21.2221 | 0.086875 |
| 12 | 10 | 4 | 8 | 5 | 0.020440 | -33.7905 | 0.020440 |
| 13 | 10 | 8 | 2 | 5 | 0.025049 | -32.0241 | 0.025049 |
| 14 | 10 | 8 | 5 | 8 | 0.029808 | -30.5134 | 0.029808 |
| 15 | 10 | 8 | 8 | 2 | 0.031765 | -29.9611 | 0.031765 |
| 16 | 10 | 12 | 2 | 8 | 0.007256 | -42.7858 | 0.007256 |
| 17 | 10 | 12 | 5 | 2 | 0.026467 | -31.5458 | 0.026467 |
| 18 | 10 | 12 | 8 | 5 | 0.043385 | -27.2533 | 0.043385 |

**Fig. 2: Mean Value and S/N Ratio for MRR**

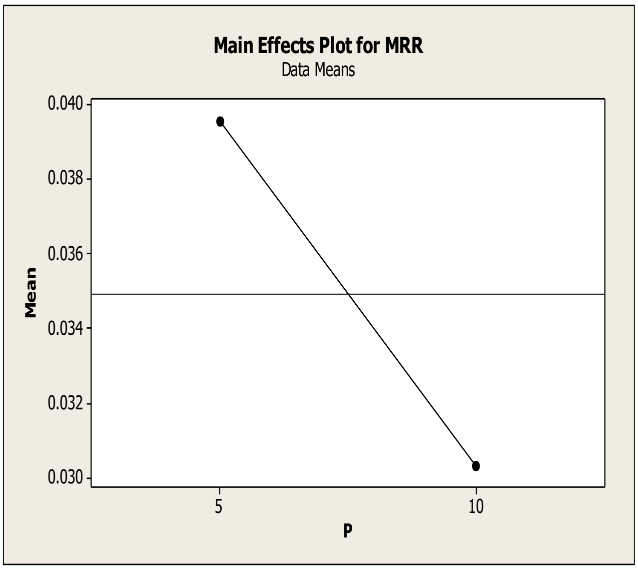


**Fig. 3: Main Effects Plot for MRR v/s Flushing Pressure**

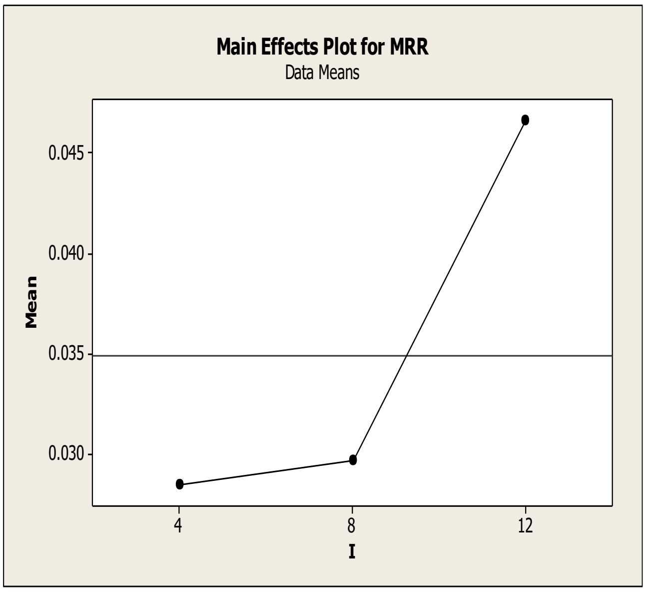


**Fig. 4: Main Effects Plot for MRR v/s Current**



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In this study, I found when flushing pressure increase from 5 kg/cm$^2$ to 10 kg/cm$^2$, the MRR is decreased as shown in fig 3. When increased the current from 4A to 12A, the MRR is increased as shown in fig 4.

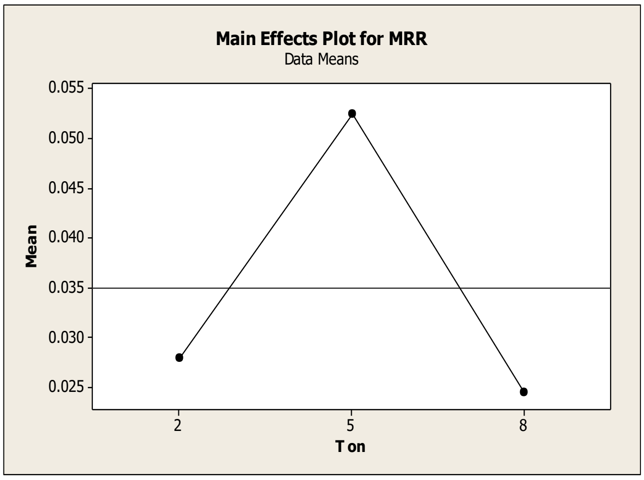


**Fig. 5: Main Effects Plot for MRR v/s Pulse on Time**

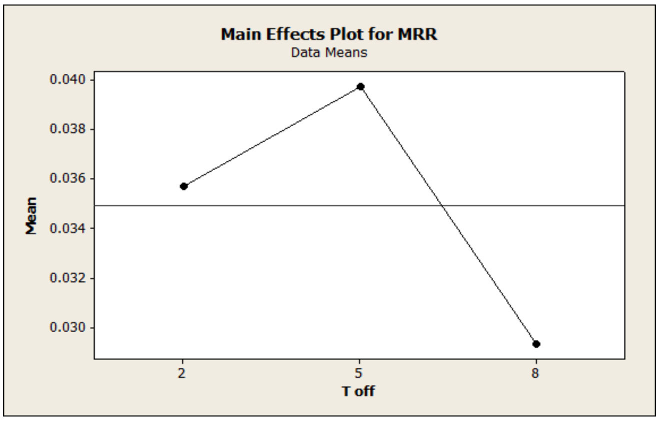


**Fig. 6: Main Effects Plot for MRR v/s Pulse off Time**

But when increase the pulse on time from 2 µs to 5 µs, the MRR is increased and then further it is decreased when pulse on time increase from 5 µs to 8 µs as shown in fig 5. When increase the pulse off time from 2 µs to 5 µs, the MRR is increased and then further it is decreased when pulse off time increase from 5 µs to 8 µs as shown in fig 6.

### *B. SR Analysis*

Fig 7 shows the mean values and S/N ratio of the SR.

| ↓ | C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 | C9 |
|---|---|---|---|---|---|---|---|---|---|
| | P | I | Ton | Toff | SR 1 | SR 2 | SR 3 | SNRA1 | MEAN1 |
| 1 | 5 | 4 | 2 | 2 | 2.44 | 2.46 | 2.47 | -7.8070 | 2.45667 |
| 2 | 5 | 4 | 5 | 5 | 1.88 | 1.86 | 1.84 | -5.3906 | 1.86000 |
| 3 | 5 | 4 | 8 | 8 | 2.19 | 2.20 | 2.21 | -6.8485 | 2.20000 |
| 4 | 5 | 8 | 2 | 2 | 2.35 | 2.35 | 2.36 | -7.4337 | 2.35333 |
| 5 | 5 | 8 | 5 | 5 | 3.67 | 3.66 | 3.65 | -11.2696 | 3.66000 |
| 6 | 5 | 8 | 8 | 8 | 3.01 | 3.03 | 3.02 | -9.6002 | 3.02000 |
| 7 | 5 | 12 | 2 | 5 | 4.34 | 4.33 | 4.34 | -12.7431 | 4.33667 |
| 8 | 5 | 12 | 5 | 8 | 2.88 | 2.90 | 2.91 | -9.2381 | 2.89667 |
| 9 | 5 | 12 | 8 | 2 | 4.42 | 4.42 | 4.43 | -12.9150 | 4.42333 |
| 10 | 10 | 4 | 2 | 8 | 1.30 | 1.31 | 1.31 | -2.3234 | 1.30667 |
| 11 | 10 | 4 | 5 | 2 | 2.23 | 2.25 | 2.26 | -7.0309 | 2.24667 |
| 12 | 10 | 4 | 8 | 5 | 2.35 | 2.36 | 2.35 | -7.4337 | 2.35333 |
| 13 | 10 | 8 | 2 | 5 | 1.80 | 1.81 | 1.80 | -5.1215 | 1.80333 |
| 14 | 10 | 8 | 5 | 8 | 2.86 | 2.87 | 2.87 | -9.1476 | 2.86667 |
| 15 | 10 | 8 | 8 | 2 | 2.75 | 2.75 | 2.74 | -8.7761 | 2.74667 |
| 16 | 10 | 12 | 2 | 8 | 2.95 | 2.96 | 2.97 | -9.4259 | 2.96000 |
| 17 | 10 | 12 | 5 | 2 | 2.77 | 2.77 | 2.76 | -8.8391 | 2.76667 |
| 18 | 10 | 12 | 8 | 5 | 3.97 | 3.98 | 3.98 | -11.9904 | 3.97667 |

**Fig. 7: Mean Value and S/N Ratio for SR**

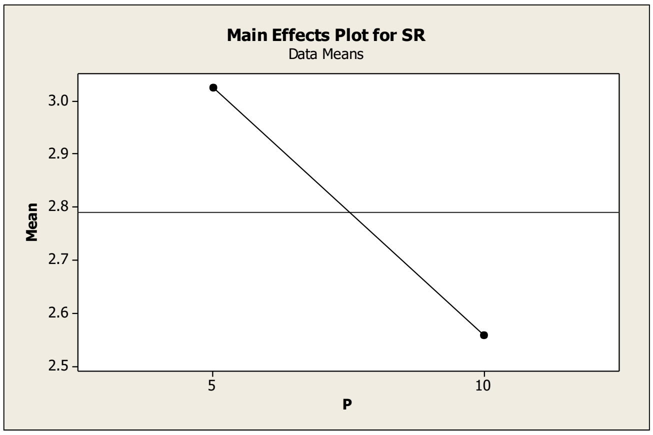


**Fig. 8: Main Effects Plot for SR v/s Flushing Pressure**

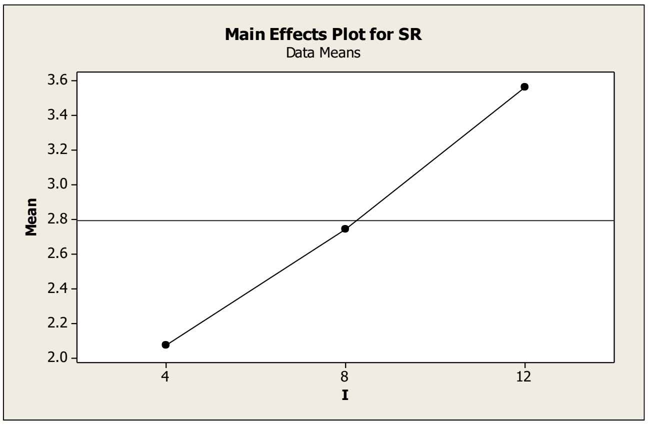


**Fig. 9: Main Effects Plot for SR v/s Current**



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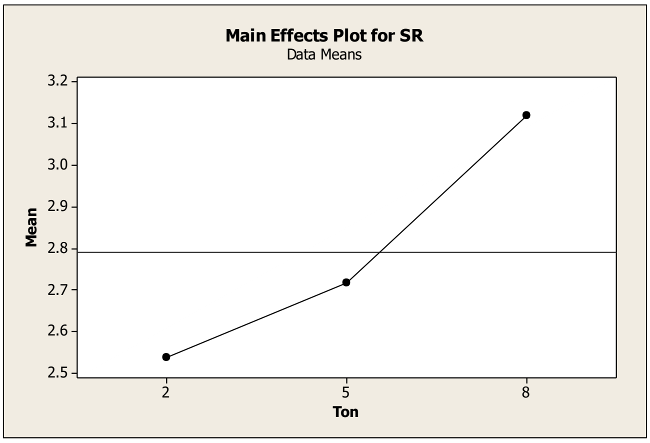


**Fig. 10: Main Effects Plot for SR v/s Pulse on Time**

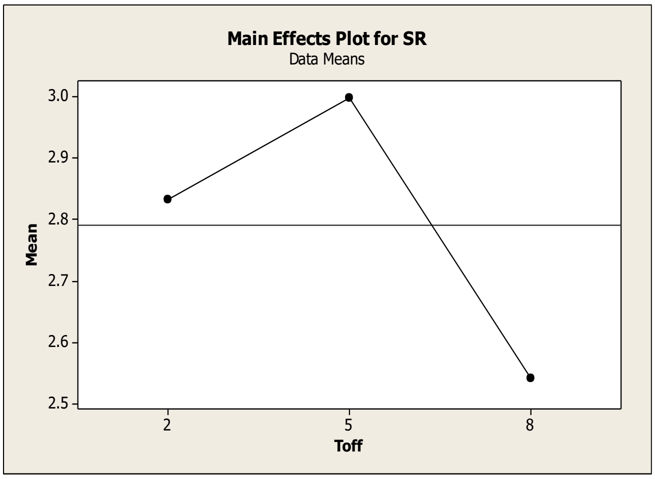


**Fig. 11: Main Effects Plot for SR v/s Pulse off Time**

The SR is decreased when increase the flushing pressure from 5 kg/cm$^2$ to 10 kg/cm$^2$ as shown in fig 8. The SR is increased with the increase the current from 4A to 12A as shown in fig 9. With increase the pulse on time from 2 µs to 8 µs, the SR is increased as shown in fig 10. When pulse off time increase from 2 µs to 5 µs, the SR is increased and then further it is decreased when pulse off time is increased from 5 µs to 8 µs as shown in fig 11.

## V. CONCLUSION

From this study, the following conclusions can be drawn.

(a) There is decrease in mean of MRR and SR by increase the flushing pressure.

(b) Current is the effective parameter for SR and MRR.

(c) With increase of Pulse on time, the MRR first increase then decrease. But the SR increases with the increase of pulse on time.

(d) When increased the pulse off time, the MRR and SR first increased and then decreased.

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