INVESTIGATION OF EDM HOLE DRILLING

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Abstract—This paper presents an investigation of holes drilling using electrical discharge machining (EDM) on SKD 11, difficult to machine conventionally. EDM is a thermal machining process that utilizes spark discharges to erode a conductive material. In the present study, attempt is made to find the optimal machining conditions with metal removal rate (MRR) and electrode wear rate (EWR) as objective. It was observed that with increase in discharge energy MRR and EWR increases. Response surface methodologies D optimality test was used to determine the optimal machining parameters, among which the discharge current and the pulse on time are found to be the most significant. The obtained optimal machining conditions are current of 6 A, voltage of 28.68 V and a pulse-on time of 25.84 µs. It was observed that MRR mainly depend on discharge energy while longer pulses increases EWR.

Keywords—EDM Drilling, Material removal rate, Electrode wear rate, RSM

I. INTRODUCTION

Electrical discharge machining (EDM) is one of the most extensively used non-conventional material removal processes. Its unique feature, that is, the use of thermal energy to machine electrically conductive parts regardless of hardness has been its distinctive advantage in the manufacture of moulds, dies, automotive, as well as aerospace and surgical components. The growing popularity of micro-EDM can be attributed to advantages including low set-up cost, high-aspect-ratio parts, enhanced precision, and significant design freedom [1]. Another characteristic of EDM is the lack of direct contact between the electrode and the workpiece, thus eliminating mechanical stress, chatter and vibration during machining [2].

T. Masuzawa et al. [3] fabricated micro pins, micro nozzles and micro pipes using EDM. D. M. Allen et al. [4] used micro-EDM technology to manufacture ink jet nozzles. B. H. Yan et al. [5] described the characteristics of micro-hole of carbide produced by micro-EDM using copper tool electrode and investigated the effects various machining parameters on the quality of micro-holes. M. P. Jahan et al. [6] investigated the influence of major operating parameters on the performance of micro-EDM with an electrode of WC in producing quality micro-holes in both transistor- and RC-type generators. S. Son et al. [7] investigated the influence of EDM parameters especially pulse duration, on micro-EDM characteristics such as material removal rate and machining accuracy. Y.Y. Tsai and T. Masuzawa [8] observed that the TWR in brass electrode is higher than the tungsten electrode material, due to the higher melting and boiling point of tungsten material which possess high thermal capability with excellent wear resistance. Natarajan N. et al. [9] done optimization using grey relational analysis with input parameters as current, voltage, pulse on time and pulse off time while the response are material removal rate (MRR), electrode wear rate (EWR), diametral overcut (DOC) and taper (T).

EDM is an efficient machining process for the fabrication of a micro hole with various advantages. Although most micro EDM machine today have process control, but selecting and maintaining optimal setting is still an extremely difficult job which must be addressed. The goal of the present study is to determine the optimal machining parameters for formation of holes with minimum electrode wear rate and maximum metal removal rate. The response surface methodology was employed to reveal the effect of the machining parameters on the characteristics of the EDM.
process. D optimality test was used to find the optimal machining parameters satisfying the multiple characteristics of the EDM process.

II. EXPERIMENTAL SET-UP

Experiments of hole drilling have been conducted using Die sinking Rapid Drill EDM. The EDM machine is shown in Fig. 1. Rotary brass hollow tubular electrode of diameter $\phi$ 1 mm is fed downward into the work piece under servo control. The EDM oil is circulated as a dielectric fluid and it is injected through the tubular electrode. Positive polarity machining by means of a negative electrical source connected to the electrode and a positive electrical source connected to the work material, was utilized. This type of machining allowed higher machining rate along with lesser electrode wear.

Fig 1: EDM drilling Machine

2.1. Experimental procedure

The experiments were designed using response Surface Methodology. Total 20 runs were conducted designed with central composite design. The experiments has been conducted with three controllable factors namely Pulse on time, Current and Voltage. On the basis of preliminary experiments conducted by using one variable at a time approach the range of input parameters was selected. Machining parameters and their level chosen for this study are shown in Table 1. Experiments were carried out in single block. Weighing machine with least count 0.1 mg was used to measure the electrode and work piece weight.

| Parameters       | Units | Levels |
|------------------|-------|--------|
|                  |       | -1     | 0     | 1       |
| Pulse on time    | µsec  | 17     | 33    | 50      |
| Current          | Amp   | 2      | 4     | 6       |
| Voltage          | V     | 20     | 30    | 40      |

III. RESULT AND DISCUSSION

The analysis was made using the popular software specifically used for design of experiment applications known as MINITAB 16. In present study, it is desirable to maximize MRR and to
minimize EWR. The MRR and EWR for each run was calculated by weight difference of specimen and electrode before and after the machining of each hole respectively.

\[
\text{MRR} = \frac{W_1 - W_2}{T_m} \text{ gm/min} \quad \ldots \ldots \ldots (1)
\]

\[
\text{EWR} = \frac{W_t1 - W_t2}{T_m} \text{ gm/min} \quad \ldots \ldots \ldots (2)
\]

Where \(W_1\) and \(W_t1\) are initial weight of work piece and electrode respectively; \(W_2\) and \(W_t2\) are final weight of work piece and electrode respectively and \(T_m\) is the machining time.

3.1. Analysis of material removal rate

The MRR is calculated as the work piece removal weight over the machining time, which is expressed as grams per minute. Fig 2 shows that the MRR is directly proportional to the current and pulse-on time. MRR decreases with increase in voltage initially but after critical value it starts increasing.

3.2. Analysis of electrode wear rate

EWR is calculated as the ratio of tool wear weight to the machining time, which is expressed as grams per minute. Fig 3 shows that the EWR is directly proportional to the current and pulse-on time. But the EWR is lower at initial stage of voltage and then it starts increasing.

![Main Effect Plot for MRR](image1)

*Figure 2. Main Effect Plot for MRR*

![Main Effect Plot for EWR](image2)

*Figure 3. Main Effect Plot for EWR*

IV. RSM’S D-OPTIMAL METHOD

Response Optimizer helps to identify the factor settings that optimize a single response or a set of responses. For multiple responses, the requirements for all the responses in the set must be satisfied. Response optimization is often useful in product development when you need to determine operating conditions that will result in a product with desirable properties.
Table 2. Response Optimization for MRR and EWR

| Parameters | Goal     | Lower   | Target  | Upper   | Weight | Import |
|------------|----------|---------|---------|---------|--------|--------|
| MRR        | Maximum  | 0.0005  | 0.0425  | 0.0425  | 1      | 1      |
| EWR        | Minimum  | 0.0005  | 0.0005  | 0.4385  | 1      | 1      |

From the plot it is observed that the composite desirability is obtained as 0.62430 reflecting the setting of input variables marked by red color will provide optimum responses value

- **Global Solution**
  - Pulse on = 25.8487 µsec
  - Current = 6 Amp
  - Voltage = 28.6869 V

- **Predicted Responses**
  - MRR = 0.025537 gram/min, desirability = 0.596123
  - EWR = 0.152129 gram/min, desirability = 0.653816

V. CONCLUSION

The hole drilling experiments were successfully performed on SKD 11 using copper electrode. The material removal rate and electrode wear rate are evaluated. It is observed that increase in discharge energy drastically reduces the machining time to machine a hole on the workpiece at the same time EWR is high. The optimal parameters for performance are Current (I) = 6 A, Pulse-on time (Ton) = 25.84 µsec and Voltage (V) = 28.68 V. It was observed that current is most significant among all parameters followed by pulse on time.

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