Process parameter optimization on EN8 steel in Electric Discharge Machining (EDM) using Response Surface Methodology (RSM) Technique

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ABSTRACT

Electric discharge machining (EDM) is widely used in the manufacturing sector due to its exceptional machining attributes and high fastidiousness, which could not be accomplished via other conventional machining. The research work aims at analyzing the optimal machining parameter and to reduce the machining time by varying in an increase material removal rate (MRR) and productivity and low tool wear rate (TWR). The parameters of Peak current, Pulse on time, Di-Electric Pressure and Tool diameter are varied. The usage of variance analysis (ANOVA) optimized parameters are determined by way of doing diverse dry runs the usage of Response Surface Methodology (RSM) approach and the mistake percent can be mounted and parameter contribution for MRR and TWR have been also observed.

Keywords: EDM, MRR, TWR, RSM, ANOVA

1. Introduction

The major role played by the quality in the growth of manufacturing industries in this world is rapid. To do this, many companies continue to use several standards and techniques to maintain their standard of goods when it comes to surface finishing also for manufacturing sector, the secret to the consistency of the manufactured goods. Long-established machining processes can’t acquire this type of surface end that may be synthetic via unconventional machining. EDM is one such type of non-conventional machining wherein the steel is processed by means of discharging intense electric powered sparks among the working material (anode) and the electrode (cathode). Right here, an inner-electrode distance (IEG) of 0.005 to 0.005 separates the electrode and the material [1]. The temperature goes up to 12000 ° C with this explosion of spark. This in turn erodes the metal via vaporization. The tool and work piece are submerged in a dielectric fluid tank where the overall process takes place. The coolant is a dielectric fluid which always carries the fragment generated during machining and the chips. In order to determine the optimal responses, the MRR and TWR may be numerous by varying the machining key in features such as peak current, pulse on time, di-electric pressure and tool diameter. In this article, the Response Surface Methodology (RSM) technique has been used in the direction of optimizes the parameter to maximise the MRR and to minimize the TWR. It is also simple to implement the response surface model; when responses are nonlinear, there is a very large estimation value error in this technique. Many
other approaches, such as the Artificial Neural Network (ANN) [2, 4, 6]. At the same time as enhancing the technique parameters it allows an EDM operator to get the most beneficial machining outputs for a required motive. Different methodologies have additionally been used for EDM machining optimization, together with Taguchi [3, 8]. In order to optimize the EDM parameter toward solve problems found in modern solving techniques, the advancement of the hybrid artificial neural network (HANN) and Grey Relation Analysis was suggested [5]. In collaboration with dynamic fuzzy, this approach uses evolutionary method (ES) to calculate the maximum suitable multi-goal optimization surroundings for the EDM operation. Whilst machining with Inconel 718 alloy, Lin et al. to reap numerous recital traits of excessive MRR, brief operating hole and short electrode put on, the grey-Taguchi approach has been used. [7]. Investigations have been performed to optimize excessive MRR and minimize TWR on the influence of the concert key referred to as grey relational grade [9]. If you want to reduce the output variables such as SR and to optimize the Material Removal Rate, it chose Ip, Ton, Toff because the layout factor to analyse the EDM method overall performance on AISI H3 tool steel as a workpiece [10]. Using the RSM method, they deliberate the overall performance of Electric Discharge Machining with the identical production parameters using Ip, Ton, electrode turning round and flush pressure at the same time as involvement parameters on WC / WC-CO and authenticated the results by conducting it experimentally [11]. The focus of this paper is to determine, using Response Surface Methodology, the best machining parameter for EN8 steel and discover the satisfactory optimal outputs by means of the equivalent input parameter on behalf of maximum Material Removal Rate and minimum Tool Wear Rate.

2. Experimental Setup

On this works, the experiment on EN8 material on V5030 GRACE Die sinking EDM through brass as a tool were performed. The system is PC-Managed, consists of a controlled motor with a servo mechanism as well as dielectric supply device magnetic work surface. The pulse on time settings on board, the device has 10 current settings varying from 3 to 34 amps. The work piece is 60 mm x 80 mm EN8 steel with a thickness of 10 mm, with the a hardness of 202BHN and HRC = 55, a density of 7480 kg / m³, a thermal conductivity of 45 w / mk. Electric Discharge Machining oil have been utilized as a di-electric intermediate for lubrication and cooling purposes. The processing was achieved with instant polarity. The experiments are evaluated by RSM methodology with respect to levels and factors. The maximum MRR and a minimal TWR was determined using the formula after the completion of all the experiments using the data obtained from Box Behnken Design from the Design Expert software.

\[
MRR = \frac{1000 \times \text{Weight Loss (g)}}{\text{Density (g/cc)} \times \text{Machining time (min)}}
\]  

(1)

\[
TWR = \frac{1000 \times \text{Weight Loss (g)}}{\text{Density (g/cc)} \times \text{Machining time (min)}}
\]

(2)

3. Levels for Machining

Table1.summarizes the levels and also the techniques parameter through which the machining operations be carried out. The EDM machine is represented in Fig1.
4. Results and Discussion

The observations on the die sinking EDM are carried out, the input parameters to be identified from a random assortment of possible values. The values of input parameters that would be of interest in the finishing phase of the rough cut are identified. The RSM, a performance characteristics parameter design tool, was used to calculate optimal machining parameters for maximum MRR and minimum TWR in EDM.

Table 2. Experimental Results.

| Sl.No | Peak Current (Amps) | Pulse on Time (microsec) | Di-Electric Pressure (Kg/Sq.cm) | Tool Diameter (mm) | MRR (mm³/min) | TWR (mm³/min) |
|-------|---------------------|--------------------------|-------------------------------|-------------------|----------------|---------------|
| 1     | 9                   | 100                      | 1.2                           | 12                | 35             | 11.841        |
| 2     | 34                  | 100                      | 1.2                           | 12                | 75.453         | 20.540        |
| 3     | 9                   | 1000                     | 1.2                           | 12                | 70.333         | 13.459        |
| 4     | 34                  | 1000                     | 1.2                           | 12                | 76.068         | 9.910         |
| 5     | 21                  | 500                      | 0.8                           | 10                | 99.795         | 14.538        |
| 6     | 21                  | 500                      | 1.6                           | 10                | 95.957         | 11.346        |
| 7     | 21                  | 500                      | 0.8                           | 15                | 34.295         | 9.057         |
| 8     | 21                  | 500                      | 1.2                           | 10                | 55.94          | 11.505        |
| 9     | 9                   | 500                      | 1.2                           | 10                | 55.94          | 11.505        |
| 10    | 34                  | 500                      | 1.2                           | 10                | 55.94          | 11.505        |
Figure 2a. Interaction (MRR) of Peak Current Vs Pulse on Time

Figure 2b. Interaction (TWR) of Pulse on Time Vs Di-Electric Pressure

Figure 2a examines the interaction of process parameters on MRR. Due to extensive machining, MRR increase with the boom in peak current. Additionally Material Removal Rate will increase if pulse on time will increase.

The consequence of techniques parameter on Tool Wear Rate is investigated in Figure 2b. TWR decrease with the boom in pulse on time Vs increases Di-Electric Pressure.

4.1 Analysis of Variance (ANOVA)

Main objective of Analysis of variance is to assess the design parameter which have a major influence on the quality capabilities and to determine the percentage of contribution to the performance measures of the process.
(ANOVA) is being used in the paper in an analysis to find the influence of different parameters. The mean square error is derived from the F-ratio analysis against the residual error. This assists in determining in the essential the parameters of the test. The proportions contribution is definite because the part of the outputs variable (Material Removal Rate and Tool Wear Rate) that each variable contributes. Table 3a and 3b show that the Peak Current, Tool Diameter, and pulse on time influence the MRR by 61.725%, 24.867%, and 12.407%, Pulse on Time, Peak Current and Tool Diameter influence the Tool Wear Rate by 55.94%, 30.369%, 11.336% respectively.

**Table 3a Analysis of Variance (ANOVA) designed for MRR**

| Factors            | DOF | Sum of Squares | Mean Square | F Value | Percentage (%) |
|--------------------|-----|----------------|-------------|---------|----------------|
| Peak Current       | 1   | 4466.24        | 4466.24     | 100.96  | 61.725         |
| Pulse on Time      | 1   | 897.76         | 897.76      | 20.29   | 12.407         |
| Di-Electric Pressure| 1  | 7.38           | 7.38        | 0.17    | 0.101          |
| Tool Diameter      | 1   | 1799.34        | 1799.34     | 40.67   | 24.867         |
| Error              | 4   | 64.87          | 16.22       | 0.47    | 0.01           |
| **Total**          |     | 7235.59        |             |         |                |

**Table 3b Analysis of Variance (ANOVA) designed for TWR**

| Factors            | DOF | Sum of Squares | Mean Square | F Value | Percentage (%) |
|--------------------|-----|----------------|-------------|---------|----------------|
| Peak Current       | 1   | 99.87          | 99.87       | 59.25   | 30.369         |
| Pulse on Time      | 1   | 183.96         | 183.96      | 109.13  | 55.94          |
| Di-Electric Pressure| 1  | 1.34           | 1.34        | 0.79    | 0.407          |
| Tool Diameter      | 1   | 37.28          | 37.28       | 22.12   | 11.336         |
| Error              | 4   | 6.4            | 6.4         | 0.37    | 0.01           |
| **Total**          |     | 328.85         |             |         |                |

**4.2 Mathematical Model**

\[
\text{MRR} = -423.34901 + 10.65474 \times \text{Peak Current} + 0.059025 \times \text{Pulse on Time} + 183.61895 \times \text{Di-Electric Pressure} + 38.45841 \times \text{Tool Diameter} + 9.4683E-004 \times \text{Peak Current} \times \text{Pulse on Time} - 1.83393 \times \text{Peak Current} \times \text{Di-Electric Pressure} + 0.30231 \times \text{Peak Current} \times \text{Tool Diameter} + 3.10635 E-005 \times \text{Pulse on Time} \times \text{Di-Electric Pressure} - 3.7133E-003 \times \text{Pulse on Time} \times \text{Tool Diameter} - 2.41251 \times \text{Di-Electric Pressure} \times \text{Tool Diameter} - 0.25883 \times \text{Peak Current}^2 - 5.08065E-005 \times \text{Pulse on Time}^2 - 46.67566 \times \text{Di-Electric Pressure}^2 - 1.41068 \times \text{Tool Diameter}^2 . \tag{3}
\]

\[
\text{TWR} = -5.89574 - 0.32421 \times \text{Peak Current} + 1.75284E-003 \times \text{Pulse on Time} + 13.07629 \times \text{Di-Electric Pressure} + 1.37214 \times \text{Tool Diameter} - 1.71872E-004 \times \text{Peak Current} \times \text{Pulse on Time} + 0.024404 \times \text{Peak Current} \times \text{Di-Electric Pressure} + 0.055111 \times \text{Peak Current} \times \text{Tool Diameter} + 1.21980E-003 \times \text{Pulse on Time} \times \text{Di-Electric Pressure} - 2.06303E-003 \times \text{Pulse on Time} \times \text{Tool Diameter} - 0.94134 \times \text{Di-Electric Pressure} \times \text{Tool Diameter} - 1.41686E-003 \times \text{Peak Current}^2 + 1.57593E-005 \times \text{Pulse on Time}^2 - 1.40433 \times \text{Di-Electric Pressure}^2 + 0.016743 \times \text{Tool Diameter}^2 . \tag{4}
\]
5. CONCLUSION

- The EDM process has illustrated its acceptability for machining EN8 steel with a Maximum MRR in addition to Minimal TWR of 71.366 mm³/min and 10.982 mm³/min.
- A list of 29 parametric combinations will help as technical requirements for the values of parameters.
- Results from ANOVA suggest that peak current in MRR (61.725%) and pulse on time in TWR (55.94%) play an important role.
- Using the Mathematical Model for MRR and TWR, Design Expert Software V 7.0 is used. It can be used to find dynamic performance for the possible combinations of inputs.

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