Experimental study on the affecting factors of compensating blocks for repairing EDM abrasive electrode

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Abstract. Aiming at the problem of electrode wear during EDM, a method of instantaneous repairing EDM abrasive electrode with compensation block was proposed, taking relative mass wear as research index. The results show that diamond abrasive electrode is processed by intermittent spray cooling at 1mm / min feed rate, and the adhesion layer appears on the surface of abrasive electrode. The experimental results show that the relative wear of the electrode with compensation block is lower than that of the electrode without compensation block by comparing the relative wear value of the electrode with different speed, voltage and duty cycle for the 304 stainless steel processed by EDM abrasive electrode 0.7 times. The method of adding compensation block shows that the electrode grinding head can be compensated online to some extent.

1. Introduction

In recent years, as the needs of production and the rapid development of science and technology, the machining accuracy requirements of the work-pieces are also getting higher and higher, especially with the appearance of new materials that are difficult to process. Furthermore, traditional processing methods cannot meet the acquirement of the manufacture of precision, ultra-precision, complicated structures and special shape parts. Thus the special processing method, matches the advantages, gradually becomes the trend of the development of modern processing [1,2]. Among them, Electrical Discharge Machining (EDM) technology, which is one of the most popular processing methods at present and it is in parallel with milling, turning and grinding, has become one of the irreplaceably important processing methods in the modern manufacturing industry because of its unique non-contact electric erosion machining principle and good and stable processing performance. Subsequently, scholars in pursuit of higher EDM machining accuracy and efficiency, put forward the traditional machining methods to EDM process, forming EDM machining, such as EDM grinding [3,4], Ultrasonic EDM [5], Electro-chemical machining [6], EDM milling [7], as well as EDM surface enhancing [8], and so on.

Among them, EDM grinding is developed based on EDM and composite mechanical grinding method. It is a compound processing method, based on impulsive discharge removal material between electrode and work-piece in medium with a certain resistance that the electrode with abrasive grain layer is used as the tool electrode and the grinding machine is used as the main equipment. The
rotating electrode in the process of machining is beneficial for the discharge channel to timely eliminate ionization to improve processing efficiency and decentralizes erosion products and discharge points to improve the processing stability.

However, due to the high temperature and high pressure generated during EDM, not only the surface material of the work-piece can be removed, but also the electrode will suffer some wear, which will seriously affect the machining accuracy and shape accuracy [9,10]. Therefore, it is necessary to compensate the electrode wear to reach a certain degree of processing accuracy.

In this paper, in order to research the problem of electrode wear during the time of machining stainless steel by EDM grinding with electroplated diamond grinding electrode, a method of on-line compensation electrode based on aluminum-based compensation block was proposed.

2. Experimental methods and principles

2.1. Experimental principle

The experiment principle diagram is shown in figure 1. Diamond grinding electrode, connected to a pole of the power supply is used as EDM grinding tool electrode to achieve grinding and discharge function. The work piece is fed in normal discharge under the control of the servo controller and returned while abnormal discharge or short circuit. The compensation block is controlled by the motion control loop to achieve feed motion. In the EDM grinding process, the atomized cooling liquid moistens the electrodes and the surface of the compensation block to make the ground debris adhere to the electrode surface. As shown in the compensation area, the debris is adhered to the gap between the abrasive particles of the tool electrode, and with the electrode for rotational movement, the electrode forms metal adhesion layer. When the debris is brought to the processing area, the electrode surface of the debris can compensate for the electrode wear due to spark discharge on the electrode substrate. As the rotation progresses, some of the debris that is not electrically eroded by the spark will fall in the area to be compensated, and then in the compensation area for grinding, the original wear of metal adhesion layer has electrode surface debris compensation again. In order to return after the compensation, wear and then compensate for the processing state.

![Figure 1. The schematic of experiment processing.](image-url)
2.2. Experimental equipment and materials

The experiment is carried out on a self-designed test platform, as shown in figure 2. The test uses 6061 Aluminum as a grinding compensation block, which is fixed on the fixture. The fixture, mounted above the screw rail, will have radial movement relative to the abrasive electrode in the machining process through the command of controller. As the figure 3 shows, abrasive electrode whose grinding head is made by 46 mesh galvanized diamond, is mounted on the spindle for rotational movement. As shown in figure 4, the intermittent spraying method using tap water as medium is employed for cooling. Not only can this method cool the heat generated during the grinding process but also make the grinding aluminum scrap effectively adhere to the electrode.

\[ v_w = \frac{V}{t} (\text{mm}^3/\text{min}) \]
\[ v_{Em} = \frac{m}{t \, (g/min)} \]  
\[ \theta_m = \frac{v_{Em}}{v_w} \times 100\% \]

Where, \( V \) Indicates the volume of the machining work-piece, which can be measured by machining a through hole; \( m \) indicates the quality of electrode wear during processing, which can be measured with an electronic analytical balance.

3. Results and discussion

3.1. Effect of spindle speed on relative wear of electrode

Table 1 demonstrates the experimental processing parameters and the experimental results are shown in table 2.

| Compensation block | Rotating speed/rpm | Relative wear \( \theta_m \) | Mean | Standard deviation |
|--------------------|--------------------|-----------------|------|-------------------|
|                    | 720                | 0.159 0.173 0.174 0.184 | 0.172 | 0.0103           |
| N                  | 1440               | 0.151 0.161 0.152 0.145 | 0.152 | 0.0069           |
|                    | 2160               | 0.149 0.156 0.155 0.163 | 0.156 | 0.0057           |
|                    | 720                | 0.148 0.152 0.1438 0.132 | 0.143 | 0.0085           |
| Y                  | 1440               | 0.094 0.102 0.097 0.094 | 0.097 | 0.0038           |
|                    | 2160               | 0.106 0.113 0.111 0.115 | 0.111 | 0.0042           |

Figure 5 depicts the relative wear of grinding head electrode with the changes of voltage. It can be seen from the figure that with the increase of rotating speed, the relative wear of the electrode decreases first and then increases no matter whether EDM grinding employs compensating block or not. Along with the increase of the rotation speed, the changes of relative wear value of the electrode without compensation block changes are not particularly obvious. While the electrode with the compensation block has the lowest electrode relative wear value when the rotation speed is 1440 rpm. At this speed, the relative wear value is reduced about 0.6 times when compared with EDM grinding without compensating block. This is mainly because the low speed electrode will beat at a certain degree, making the grinding force from time to time poly increase and the processing unstable. At the same time, the diamond in the electrode is also impacted to varying degrees, resulting in diamond particles off. In addition, when the rotation speed is large, the grinding force increases due to the overall grinding force, so that the relative wear of the electrode will increase slowly. On the one hand,
the compensation block limits a side of the electrode reducing comparatively jump, so the relative wear at low speed is also reduced. On the other hand, after the electrode has been filled with the compensating pieces, the electrode substrate originally electrocuted is covered and protected by the crumb layer, thus the relative wear of electrodes is reduced.

![Figure 5. The effect of rotational speed on relative wear of electrodes.](image)

### 3.2. Effect of voltage on relative wear of electrodes

The rotating speed was set as 1440 rmp, the voltage was set to 75 v and 90 v respectively and the other parameters were the same as those in table 3. The experimental results were shown in table 3.

| Compensation block | Voltage/V | Relative wear θm | Mean E | Standard deviation |
|--------------------|-----------|------------------|--------|-------------------|
|                    |           | θm1  | θm2  | θm3  | θm4  |        |        |
| N                  | 75        | 0.150| 0.149| 0.152| 0.157| 0.152| 0.0034 |
|                    | 90        | 0.169| 0.162| 0.166| 0.166| 0.166| 0.0028 |
| Y                  | 75        | 0.094| 0.101| 0.097| 0.097| 0.097| 0.0027 |
|                    | 90        | 0.096| 0.104| 0.099| 0.098| 0.099| 0.0036 |

Figure 6 describes the wear of the electrode relative wear with voltage changes. As the figure illustrates that with the addition of voltage, the relative wear of electrodes increases both in the absence of compensation blocks and with compensation block for EDM grinding. In addition, the wear electrode with the compensation block shows the lowest relative wear of the electrode at the voltage of 75 V, which is about 0.5 times lower than the relative wear of the uncompensated block at this voltage. In addition, the value of electrode wear after adding compensation block is slower than that without compensation block. It is mainly because during the process of EDM grinding with the voltage increases, the ability to remove the material and the electrode wear are improved, resulting in the electrode relative wear increases. Furthermore, after the compensation block is added, the debris layer ground adhered to the electrode surface partially acts as a part of the electrode surface that is removed, so that the relative wear of the electrode increases more slowly. What’s more, it can be seen that the
relative wear values of the electrodes of 75 V and 90 V are the same.

Figure 6. The effect of voltage on relative wear of electrodes.

3.3. The effect of duty cycle in relative wear of electrodes

The voltage was set as 75 V, the rotating speed was set as 1440 rpm, and the duty cycle was set to 20%, 35% and 50% respectively. The data results were shown in table 4.

| Compensation block | Duty cycle /% | Relative wear θ_m | Mean E | Standard deviation |
|--------------------|---------------|-------------------|--------|-------------------|
|                    |               | θ_m1   | θ_m2   | θ_m3   | θ_m4   |        |        |
| N                  | 20            | 0.199  | 0.210  | 0.203  | 0.197  | 0.202  | 0.0056 |
|                    | 35            | 0.165  | 0.161  | 0.167  | 0.176  | 0.167  | 0.0061 |
|                    | 50            | 0.161  | 0.153  | 0.156  | 0.154  | 0.156  | 0.0036 |
| Y                  | 20            | 0.102  | 0.128  | 0.107  | 0.114  | 0.113  | 0.0113 |
|                    | 35            | 0.099  | 0.092  | 0.093  | 0.103  | 0.097  | 0.0052 |
|                    | 50            | 0.100  | 0.086  | 0.092  | 0.090  | 0.092  | 0.0062 |

Figure 7 describes the relationship of the wear of the electrode relative wear and duty cycle. It can be seen from the figure, whether to add compensation block for EDM grinding or not, the relative wear of the cut electrode would tend to decrease with the increase of duty cycle. The wear electrode with compensation block shows a relative wear value of the lowest electrode at a duty cycle of 50%, which is about 0.7 times lower than the relative wear value of the uncompensated block under this duty cycle.

It can be seen that the curve of the relative wear about electrode without employing the compensation block to conduct EDM grinding decline more significantly than that of using the compensation block. In the case of small duty cycle, the effect of relative wear of EDM on the electrode may be greater than that of diamond particle grinding. Therefore, with the decrease of pulse interval, the electrical corrosion between the discharge gaps is increased and more electric erosion products are spattered to the electrode to compensate for the electrode so that the relative wear is reduced.
However, when employing the compensation block for EDM grinding at small duty cycle, the effect of diamond grain grinding on the relative wear of the electrode may be larger than that of EDM, which leads to the larger relative wear value of the electrode. While as the duty cycle increases, the processing energy per unit time increases, which will make the work-piece materials adhere to the electrode surface after electric erosion. Therefore, the relative wear of electrode changes little as the pulse interval decreases.

![Figure 7. The effect of duty cycle on relative wear of electrode.](image)

4. Conclusion
With the increase of rotational speed, the relative wear of the electrode first decreases and then increases, that is because it is very difficult to form an adhesive layer, whether it is low speed or high speed. The relative wear of the electrode changes slightly with the increase of the voltage, but it shows an increasing trend, as the compensation block is added; the debris layer adhered to the surface of the grinding electrode acts as a part of the removal of the electrode surface, so that the relative wear rate of the electrode increases slowly. As the increase of the duty cycle, the relative wear rate of the electrode shares a downward trend, which because with the duty cycle increases, the energy processed per unit of time increases, causing the removed material to be adhered to the surface of the electrode.

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