Research on some factors which influence the aperture of precision micro hole in electronic discharge machining

Min Wang¹, Gangjian Ma¹, *, Jianyong Liu², ³, ⁴

¹Advanced Manufacturing technology of the Key Laboratory of Beijing Municipality, College of Mechanical Engineering and Applied Electronics Technology, Beijing University of Technology, Beijing 100124, China
²Beijing Municipal Key Lab of EDM Technology, Beijing 100191, China
³Beijing Institute of Electro-Machining, Beijing 100191, China
⁴BeiJing Natural Science Foundation & Beijing Academy of Science And Technology, Beijing 100195, China

*Corresponding author e-mail: 1062188911@qq.com

Abstract. The factors which influence the size of the hole during the process of machining precision micro hole are studied in this paper. Through the way that using the same diameter of electrode wire to process large number of micro hole on different materials and different thickness, the processing time, electrode wire loss and pore size was written down. The law of the factors which influence the size of the micro hole is found by analysing the data. It can help to select the appropriate electrical processing parameters to ensure the quality of the aperture during actual operation process. And these are usually ensured by repeated testing and multiple measurements. This research get great help for improving processing efficiency. The study is of great guiding significance to the actual production.

1. Introduction

With the development of science and technology, people pay more and more attention to the precision micro-hole’s processing technology in the production. Many countries have invested a lot of manpower and resources to carry out the research [1]. Especially in recent years the technology has been widely used in aerospace, computer technology, instrumentation, precision machinery, automotive, light industry and other industries in some cutting-edge products. At the same time ,as the reason that precision micro-spark hole processing technology has the advantages: non-contact processing, no macro-cutting force, killing with kindness, precision micro square, realistic and other characteristics, to further determine its broad prospects of development [2,3]. Such as Japan, Switzerland, the United States and other countries have mature products [4]. However the domestic research in this area is mainly to solve the problem of practical application.

The accuracy of the hole is the key to judge whether the processing task is up to or not [5]. It is one of the important criteria to assess the level of precision of precision micro EDM. However, there are many complicated factors such as the length of the processing time, the size of the discharge gap, the loss of the electrode wire and so on. These factors results that the stability of the aperture can not be stabilized during the machining process. In this paper, the test plan that to design different thickness of
test pieces, a variety of materials, several groups test program is designed. Record the data of processing time, electrode wire loss, hole’s size. And through the data processing to explore the law among these factors.

2. Analysis on the Test Methods of Micro Hole’s Size and Real-time Loss of Electrode Wire

In precision micro-hole processing, the accuracy of micro whole’s size depends on the discharge state during EDM. While the discharge state is influenced by the pulse width, pulse, working fluid state and many other factors. Therefore, the study that the relationship among aperture and its influencing factors needs large numbers of process tests and test data. In view of this, this paper will use the method of test sample’s thickness accumulation: gradually increase the thickness of the work piece to be processed to process larger number of micro holes under the state of liquid and the given parameter. To monitor the electrode wire loss, record the processing time, measure the size of the micro holes.

The method of measuring the size of the micro hole is shown in Figure 1. The sizes which in two vertical directions of the precision micro holes are recorded by the x and y sets of data. Where $x_1, x_2, ... x_n$ denote the dimensions in the direction of the aperture $x$; $y_1, y_2, ... y_n$ denote the dimensions in the direction of the aperture $y$.

![Figure 1. Schematic diagram of the scheme to measure the aperture](image)

The loss of electrode wire is shown in Figure 2, Where $l_1, l_2, ... l_n$ denote the test sample’s thickness, $\Phi_1, \Phi_2, ... \Phi_n$ denote the test sample’s diameter of the micro holes, $\delta_1, \delta_2, ... \delta_n$ denote the loss of electrode wire. According to the test results, the relationship among electrode wire loss, processing time and pore diameter was analyzed.

![Figure 2 Schematic diagram of electrode wire’s loss](image)

3. Test scheme

EDM processing is a special processing ranks [6], influenced by the electrode wire’s size, the work piece’s material and other factors.

In the case of insufficient number of samples, even under the same processing environment and the same processing parameters to process micro-hole, may also cause instability of micro-aperture, the data of electrode wire loss and the data of processing time. In this paper, TC4 titanium alloy, TC11 titanium alloy and GH4169 spirally with the same thickness of 0.5mm, 0.8mm, 1.0mm, 1.2mm, 1.7mm, 2mm and 3mm were prepared and 40 pieces were processed on each work piece. In the process of processing, the samples with the same material were processed with the same parameters. The processing methods and materials are shown in Table 1.
### Table 1 Processing methods and materials

| Electrode wire diameter (mm) | Electrode wire material | Cutting fluid       | Processing methods       |
|-----------------------------|-------------------------|---------------------|--------------------------|
| 0.19                        | Tungsten                | Deionized water     | Rinse processing         |

Through the statistical analysis of the data, the relationship among the depth of the pores of different depth, electrode wire loss and the working hours were determined. The processing equipment is the precision micro EDM equipment witch developed independently by Beijing Institute of Electro-Machining, as shown in Figure 3. The machined micro pores were measured by using a high power electronic measuring instrument, as shown in Fig 4.

![Figure 3 Precision micro-EDM equipment](image1)

![Figure 4 High-power electronic measuring instrument aperture](image2)

### 4. Test data analysis

Since the size of the micro hole is closely related to the discharge state, so the precision micro holes are not absolutely circulars, the front and back sides of the machined holes are also slightly different. The micro holes’ size data of TC4 titanium alloy is shown in Table 2.

#### Table 2 Aperture data of Titanium alloy TC4

| Sample thickness/mm | Front aperture/μm | Negative aperture/μm | Hole diameter/μm |
|---------------------|-------------------|-----------------------|------------------|
| 0                   | 0                 | 0                     | 0                |
| 0.5                 | 224.06375         | 210.05                | 217.0569         |
| 0.8                 | 228.96            | 212.913               | 220.9365         |
| 1                   | 231.855           | 220.22625             | 226.0406         |
| 1.5                 | 237.60375         | 218.2375              | 227.9206         |
| 2                   | 235.2             | 223.18                | 229.19           |
| 3                   | 244.77625         | 216.3638              | 230.57           |

If the whole’s number is j and its thickness is i, its Processing time is $t_{ij}$, its Electrode loss is $l_{ij}$; So the Average processing time:

$$\bar{t} = \frac{\sum_{j=1}^{n} t_{ij}}{n}$$  \hspace{1cm} (1)

The Average electrode wire loss:

$$\bar{l} = \frac{\sum_{j=1}^{n} l_{ij}}{n}$$  \hspace{1cm} (2)
For the pore diameter of the fine micropores just as shown in Figure 1:
The diameter of the j-th hole:

$$\phi_j = \frac{x_j + y_j}{2}$$  \hspace{1cm} (3)

The average pore diameter:

$$\bar{\phi} = \frac{\sum_{j=1}^{n} \phi_j}{n}$$  \hspace{1cm} (4)

According to the above calculation and test data can be obtained in Table 3 - Table 5, Figure 5, 6 shows the processing time and the corresponding relationship between the wire loss.

**Table 3** TC4 titanium alloy processing time and electrode wire loss, the corresponding relationship between the apertures

| Sample thickness/mm | Processing time/s | Electrode wire loss/μm | Hole diameter/μm |
|--------------------|-------------------|------------------------|------------------|
| 0                  | 0                 | 0                      | 0                |
| 0.5                | 81.4              | 248.175                | 217.0596         |
| 0.8                | 108.525           | 276.725                | 220.9365         |
| 1                  | 114.2             | 289.4                  | 226.0406         |
| 1.5                | 151.5             | 343.4                  | 227.9206         |
| 2                  | 205.325           | 422.075                | 229.19           |
| 3                  | 280.225           | 973.425                | 230.57           |

**Table 4** TC11 titanium alloy processing time and electrode wire loss, the corresponding relationship between the apertures

| Sample thickness/mm | Processing time/s | Electrode wire loss/μm | Hole diameter/μm |
|--------------------|-------------------|------------------------|------------------|
| 0                  | 0                 | 0                      | 0                |
| 0.5                | 86.925            | 256.25                 | 220.637          |
| 0.8                | 100.85            | 277.825                | 228.5285         |
| 1                  | 110.275           | 300.425                | 225.8435         |
| 1.5                | 142.475           | 370.125                | 229.258          |
| 2                  | 192.75            | 465.55                 | 234.8965         |
| 3                  | 268.05            | 951.6                  | 235.5525         |
Table 5  GH4169 Superalloy processing time and electrode wire loss, the corresponding relationship between the apertures

| Sample thickness/mm | Processing time/s | Electrode wire loss/µm | Hole diameter/µm |
|---------------------|-------------------|------------------------|------------------|
| 0                   | 0                 | 0                      | 0                |
| 0.5                 | 70.97561          | 582.8293               | 250.235          |
| 0.7                 | 85.356            | 850.521                | 251.3745         |
| 1                   | 106.5854          | 1096.951               | 254.4525         |
| 1.2                 | 132.7561          | 1481.878               | 259.097          |
| 1.7                 | 208.6829          | 2341.415               | 269.3            |
| 2                   | 238.4146          | 2706.268               | 263.613          |
| 3                   | 306.9268          | 4506.64                | 296.325          |

Figure 5  TC4 and TC11 titanium alloy processing time and electrode wire loss, the corresponding relationship between the apertures
Figure 6 GH4169 Superalloy processing time and electrode wire loss, the corresponding relationship between the apertures

5. Conclusion
From the above analysis, it is obviously to know that the relationship between the processing time in the machining, the real-time loss of the electrode wire and the size of the micro hole can be matched by the different cubic equations of one unknown. The relationship between the working time and the electrode wire loss, the relationship between the wire filament processing time and the working whole diameter and the relationship between the electrode wire loss and the whole diameter were founded to provide a theoretical basis for the identification of abnormalities in the process of machining. And lay the foundation for the identification of abnormal processing in small whole machining.

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