Diamond Forming Tool Innovative Design Based on Segments Thickness Dimension Compensation

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Abstract. Based on machining experiments the diamond forming tool wear degrees of irregular area were studied, the tool wear rate mathematical model was deduced by regression analysis and the improvement project of tool was innovatively designed. Through the diamond forming tool segments thickness dimension compensation, the tool wear of irregular area can be uniformly achieved, the performance of diamond forming tool has been increased highly and the diamond forming tool life is greatly extended.

1. Introduction
The granite special-shaped products have exquisite artistic shapes, excellent physical properties and other special characteristics, they are widely used in architectural decoration, living appliances, precision machinery, scientific instruments, craft products and so on. The manufacturing processes of granite special-shaped products are mainly the special surface processing. To simplify shaping movement, reduce equipment costs, increase productivity, the forming processing methods are generally used. Currently, the diamond Segments forming cutting tools are widely used to produce granite special-shaped products as a cost-effective processing methods in stone enterprises.

It is the diamond particles that play the cutting role in manufacturing granite products, it is the grinding process by the diamond particles controlled by diamond segments [1]. Because the granite is very hard stone, so the diamond tool is seriously grinded, a large number of diamond particles are consumed, which is due to the high processing cost for manufacturing granite products. The current research focus are abrasive processes and forms of diamond particles in diamond tool. Some researchers have established a diamond grinding single particle model [2]. The state of diamond particle was divided into first appearance, fully exposed, removed, local collapse, micro-crushing, macro-crushing and particle detachment [3]. Other scholars have studied the wear processes of diamond circular saw [4-6].

The key technology of manufacturing granite special-shaped products is the forming processing, namely, how to use the shortest possible time to remove the machining granite allowance, rough machining the required irregular surface. Take the processing of quarter arc granite surface as an example shown in Figure 1, the cross-section $EDF$ is the removed region. Because the diameter of each section in arc region of diamond tool is different, so the diamond particles in each arc section are different to machining allowance, processing parameters and cutting loads, the wear degree of each part of the tool is also different. If the local region of diamond tool was excessive abraded, even if
other parts of the tool are good, the cutting tool may be scrapped due to decrease in machining accuracy of granite special-shaped products. Therefore, the uniform wear for diamond forming tool is a key technology to ensure accuracy, extend tool life and reduce material consumption.

Fig. 1 Quarter arc granite surface schematic diagram

Therefore, the diamond forming tool to meet the conditions of processing performance, as far as possible to achieve uniform wear to ensure accuracy, extended tool life, reduce material consumption.

The research program for diamond forming tool was proposed based on segments thickness dimension compensation. Through experimental data analysis the wear trend of different diamond area was calculated, and then compensated for the thickness of the segments in order to achieve the uniform wear for diamond forming tool.

2. Experimental Procedure

**Equipment and Material.** The test machine is SPEED Y03. Cutting tool is diamond forming tool (grinding wheel ASS10105, produced in Italy. The detecting device is made up of microscope system (Leica DMLM, 2500 times), digital height gauge (0.01mm), digital vernier calliper (0.01mm) and so on. Qilu red granite (G3754) was selected as experimental materials, the main physical properties of Qilu red granite was shown in Table 1. The test device was shown in Figure 2.

| Physical Properties                        | Unit        | Value  |
|--------------------------------------------|-------------|--------|
| Bulk Density                               | [kg/m³]     | 2661   |
| Water absorption                           | [%]         | 0.11   |
| Dry compressive strength                   | [MPa]       | 224.0  |
| Compressive strength of water saturated    | [MPa]       | 218.6  |
| Dry bending strength                       | [MPa]       | 16.9   |
| Flexural strength of water                 | [MPa]       | 16.2   |
| Dry Modulus of Rupture                     | [MPa]       | 19.6   |
| Modulus of Rupture of water saturation     | [MPa]       | 16.8   |
| Abrasion resistance                        | [1/cm³]     | 54     |
Fig. 2 Experimental device

Five groups tool diameters of five cross-section 1-1, 2-2, 3-3, 4-4, 5-5 were selected to measure in Figure 3, the section between separated by distance of 6mm, 4mm, 3mm and 2mm. For each set of measurements were measured five times, and then calculate the change after processing the value of tool diameter, the average value as a tool in this section of the wear on the change in diameter. Test parameters were selected cutting speed 30m/s, feed rate 500mm/min, depth of cut 15mm, length of processing 60m.

Fig. 3 Schematic diagram of experimental data selected

**Analysis of test results.** As the processing of the arc radius is 15mm and depth of cut is 15mm, so the 1-1 cross-section of diamond particles on the base did not participate in cutting, there is no changes in diameter. With 1-1 cross-section as measuring datum, the test measurement results were shown in Table 2. The trend chart of measured sections diameters of diamond tool was shown in Figure 4.

| Table 2 Experimental measurements |
|-----------------------------------|
| Measurement section                | 1-1 | 2-2 | 3-3 | 4-4 | 5-5 |
| Section corresponds to length dimension (mm) | 0   | 6   | 10  | 13  | 15  |
| Variation of section diameter (mm)   | 0   | 0.038 | 0.112 | 0.22 | 0.57 |
Fig. 4 The measured cross-section diameter of trend chart

The trend in Figure 4 can be seen, the tool wear rate arc region can be fitted parabola. The mathematical model can be establishment

\[ y = a_0 + a_1x + a_2x^2 \]  

(1)

In the formula: \( x \) is 1-1 as the base of cross-section to correspond to the length dimension, \( y \) is the change in cross-section diameter.

By the regression statistic in Table 2, the equation of diamond forming tool wear rate obtained is

\[ y = 0.0184132 - 0.032443x + 0.0042932x^2 \]  

(2)

3. Improved design tools

To achieve uniformity wear of diamond forming tool, it is necessary to compensate the diamond thickness dimension based on Figure 4. Making the basic segment thickness dimension 3mm, then the compensated thickness dimension of each section of segment was shown in Table 3, the schematic diagram of the thickness of segment was shown in Figure 5.

| Measurement section | 1-1 | 2-2 | 3-3 | 4-4 | 5-5 |
|---------------------|-----|-----|-----|-----|-----|
| Section corresponds to the length of size(mm) | 0   | 6   | 10  | 13  | 15  |
| Agglomeration section thickness(mm) | 3   | 3.63| 4.87| 6.67| 12.5|
The ligature 3 in Figure 5 was fitted by three-point arc method, the segment thickness dimension compensation cross-section was shown in Figure 6. In Figure 6, $AB$ is the segment of the outer circular arc of radius 15mm, the thickness of area $ABCD$ is no compensation for the segment dimension, $ABED$ is the segment compensated area, $CED$ is the dimension of compensation area.

Based on diamond segment compensated, a new diamond forming tool was innovatively designed as shown in Figure 7.
To test the new diamond forming cutting tools, the machining parameters were selected as cutting speed 30m/s, feed rate 500mm/min, depth of cut 14.2mm, processing length 30mm. In these parameters combination, the new tool cutting efficiency was 19.4385cm³/min, tool wear rate was 0.0812mm/dm³. The tool wear rate was decreased significantly, the arc area uniform wear was obtained, the new designed diamond forming tool has been achieved the desired results.

4. Conclusion
(1) Established by experiments of diamond forming tool quarter circular cross-section area of the mathematical model of wear rate.

\[ y = 0.0184132 - 0.032443x + 0.0042932x^2 \]

(2) Through the diamond forming tool segments thickness dimension compensation, the tool wear of irregular area can be uniformly achieved, the performance of diamond forming tool has been increased highly and the diamond forming tool life is greatly extended.

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