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Morphological Analysis of Wear Particles using Fractal Parameters

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The fractal dimension is the characteristics that can quantitatively define the irregularity in natural. It is useful in describing the morphology of various rubbed surface for hydraulic piston motor instead of the stylus profiling method. But fractal parameters had not constructed on the morphological characteristic of rubbed surface because of the insufficient knowledge about a conception of fractal dimension. In this study, for the purpose of applying fractal parameters practically, we have suggested way to establish the morphological characteristic of rubbed surface with fractal parameters, and we carried out an experiment on the lubricant friction and wear by using Ball-ON-Disk type tester. Materials were the brass and the bronze which are used to slipper-pad in the hydraulic piston motor. We searched for fractal parameters of surface structure with the digital image processing. Surface fractal dimension can be determined by sum of intensity difference of surface pixel. Using the image processing and fractal parameters for rubbed surface in the friction and wear test, morphology of rubbed surface can be effectively obtained by fractal dimensions.

Keywords : Fractal dimension, Fractal parameters, Morphological characteristic, Digital image processing.

1. INTRODUCTION

The fractal dimension is quantitatively to define the irregular characteristic of the shape in natural. It is useful in describing morphological characteristics of various wear particles. But fractal parameters had not been constructed on the morphological characteristic information of wear particles because of the insufficient knowledge about a conception of fractal dimension.

In this study, for the purpose of applying fractal parameters practically, a method using the fractal parameters was suggested to establish the morphological characteristics information of wear particles and we carried out a lubricated friction and wear experiment by using Ball-ON-Disk type tester. Materials were the high tension brass and the bronze which are used for rubbed member as slipper-pad in the hydraulic piston motor. And wear particles within base oil were extracted by a membrane filter. Fractal parameters of the boundary and surface of wear particles are calculated by digital image processing.

Therefore, the purpose of this experiment is to establish a more effective practical technique for predicting a working condition and damage of a wetting dynamic member through a fractal dimension for applying to analysis of wear particles shape and morphological characteristics.

2. EXPERIMENT

The Ball-On-Disk type tester was used for this friction and wear experiment. A Ball specimen was a STB2 (780Hv) bearing ball with 5mm in diameter, and a disk specimen was HBsC3 (160Hv) and LBC3 (85Hv) with 50 mm in diameter. Lubricating oil used in experiment was pure paraffin base oil. In experiment condition, Applied loads were 29.4N, 58.8N, 88.2N, 117.6N and 147N, and the sliding distance was from 0 m to 234m. The wear particles occurred in each experimental condition were extracted by 0.45 ㎛ membrane filter.

2.1 Image processing and boundary detection

The image processing system had been used. For extracting image information of wear particles in every experimental condition. These images were captured by color CCD camera on the optical microscope, and were saved to HDD (hard disk drive) by the frame grabber within the computer. The resolution of image was 640×480 pixels, and the grayscale was 8 bit per pixel. And the optical microscope had a objective and ocular lens of 10 magnification.

The reflected and transmitted images were captured though frame grabber within the computer. Transmitted images were transformed into the threshold image with threshold value selected from the histogram of them. And the reflected images were added to threshold image, and so, the boundary and the morphology of wear particles were extracted through the image processing definitely.

As stated above, through the image processing, shape and boundary of wear particles were extracted clearly, and were used in order to calculate the fractal dimension of wear particles boundary and surface.

2.2 Fractal parameter

2.2.1 Fractal dimension of particle boundary

In order to analyze irregular shape characteristics as coast line, the boundary, and surface characteristics of wear particles were analyzed through the fractal dimension which is suggested by Mandelbrot and R.F.Voss.

In the wear particles boundary extracted by image processing,

the pixel step and the pixel perimeter were changed to logarithm value. And the line of best fit was represented for these two parameters by the method of least squares. Fractal dimension was calculated by the line gradient (1-D). The D means fractal dimension. When the shape of wear particles was more rough and irregular, the fractal dimension had high value.

In this study, this fractal dimension is defined as texture fractal dimension (D_t) under 10 pixels, and structure fractal dimension (D_s) over 10 pixels. As above, morphological characteristics of wear particles was represented as numerical value.

2.2.2 Fractal dimension of particles surface

In order to analyze shape of wear particles, this study was represent morphological characteristics of particles boundary as well as morphological characteristics of particles surface with the surface fractal dimension by the sum of light intensity difference.

These fractal parameters were also defined as surface texture fractal dimension (D_t') under 10 pixels, and surface structure fractal dimension (D_s') over 10 pixels.

Morphological characteristics of particles surface was also represented as numerical value.

3. RESULT AND DISCUSSIONS

3.1 Morphological characteristics of particle boundary

In this study, in order to analyze shape of wear particles synthesized the texture and structure morphological characteristics in each condition, total fractal dimensions of particles boundary were used.

Fig. 1 shows the variation of total fractal dimension for applied load. Values of fractal dimension decrease according to the applied load increasing in all material. It represent that shape of wear particles is complex and irregular in the low applied load. In the result of this study, the structure fractal dimension well present the morphological characteristics of wear particles in the materials, and, the characteristics of the wear particles are well presented by fractal dimension effectively.

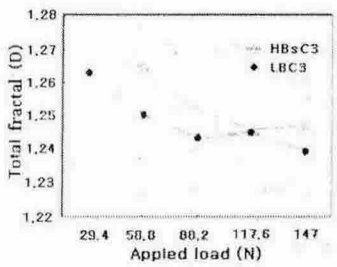

Fig. 1 Effect of applied load on total fractal dimension of boundary

3.2 Morphological characteristics of particle surface.

Fig. 2 shows total fractal dimensions of particle surfaces. It is to synthesize texture and structure fractal dimension.

As shown in Fig. 2, total fractal dimensions had similar values for the material and applied load. The fact represented that total morphological characteristics of particle surfaces was similar to each other in all working condition.

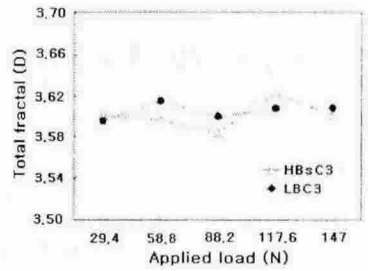

Fig. 2 Effect of applied load on total fractal dimension of surface

In the result of this study, the characteristics of particles surface was effectively analyzed by texture and structure fractal dimension.

4. CONCLUSION

Using the image processing and fractal parameters for wear particles analysis in the friction and wear test, we have following conclusion.

1) HBsC3 wear particles have more complicated shape characteristics than LBC3 for structure fractal dimensions of wear particles boundary
2) When the applied load is low, in total fractal dimension of particles boundary according to applied load, wear particles have more irregular and complex morphological characteristics.
3) In particle surface characteristics of the texture and structure fractal dimension, the particle surface characteristics was more effectively analyzed by texture and structure fractal dimension than total fractal dimension.

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