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Application of Fractal Dimension for Rubbed Surface Morphology of Hydraulic Members

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The surface morphology of oil-lubricated surface for hydraulic piston motor is believed to be extremely effective in contact mechanics, adhesion, friction and wear. In order to describe morphology of various rubbed surface on driving condition, the wear test was carried out under different experimental conditions in oil-lubricated system. And fractal descriptors was applied to rubbed surface of hydraulic members with image processing system. These descriptors to analyze surface structure are fractal dimension. Surface fractal dimension can be determined by sum of intensity difference of surface pixel. Morphology of rubbed surface can be effectively obtained by fractal dimension.

Keywords : Surface Morphology, Rubbed Surface, Image Processing System, Fractal Dimension

1. INTRODUCTION

In order to diagnose working conditions and damages of wetting dynamic members used as high tension brass and bronze, friction and wear characteristics of these materials must be researched certainly.

Generally, the stylus profiling, the electronic microscope, and the optical method are used to analyze rubbed surface in lubricating system. The stylus profiling is most general method to analyze surface roughness and status. But it depends on the stylus radius and surface direction. The electronic microscope method has the advantage to measure microscopic portion precisely, but It is required very expensive equipments and technical knowledge for using. The optical method by the CCD camera is only used to save captured image in computer hard disk drive and to observe by a man of experience, and is not constructed algorithm to get objective shape information of rubbed surface with complex and various morphology in captured image. Thus, it is necessary to construct such algorithm. For that, the digital image processing and the fractal dimension is proposed to analyze shape characteristics of rubbed surfaces in lubricated system.

The fractal dimension pioneered by Mandelbrot defines irregularity of natural object and is numerical parameter of natural morphology such as a roughness, a break and a crack.

Therefore, in this paper, for the purpose of applying fractal parameters practically, a method with fractal parameters will be suggested which establish the morphological characteristics of rubbed surface, and we carried out a lubricated friction and wear experiment by using Pin-On-Disk type tester. The material was high tension brass and bronze which are used for lubricated member as slipper-pad in the hydraulic piston motor. Fractal dimensions of rubbed surface shape are calculated by digital image processing. Using the image processing and fractal parameters, morphology of rubbed surface can be effectively obtained by fractal dimensions.

2. EXPERIMENT

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

2.1 Extracting rubbed surface by image processing.

Image information of rubbed surface was extracted by the image processing system. Images were captured by color CCD camera on the optical microscope, and saved to HDD (hard disk drive) by a frame grabber in 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.

2.2 The Fractal dimension of rubbed surface.

In the rubbed surface image, for the purpose of finding Fractal dimensions, the sum of light intensity differences (SID) among pixels for different step size along a column or row of the surface image was calculated, and then steps and SID values were transformed into logarithm values. And, at the logarithm coordinate system, the gradient of the line of best fit was found as using them and defined as 1-D, where D was fractal dimension.

3. Result & discussion

3.1 The surface roughness of rubbed surface

Fig. 1 shows the surface roughness Ra for the applied load in 624 m sliding distance. According to an increase of applied load, surface roughness was increased. It could be considered that much more abrasive and adhesion wear were occurred because temperature and contact pressure increase in the rubbed surface with the increase of the applied load.

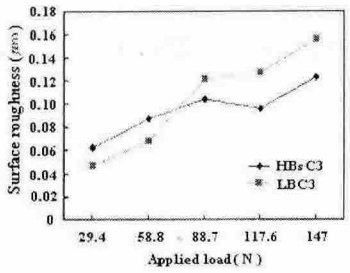

Fig. 1 Relation between surface roughness and applied load

3.2 The step size of pixels and fractal dimension.

In order to calculate the fractal dimension, it is need to find the sum of light intensity differences for the given step size. For the purpose of instituting the suitable step size, the fractal dimensions were calculated through the different step size on each condition.

The relation of surface roughness and the fractal dimension for each applied loads in the step size with 2, 4, 6 pixels and the sliding distance 234m is shown in Fig. 2.

It is demonstrated that the fractal dimension according to increase of applied load is similar to the variation of the surface roughness Ra in the step size of 2 pixels less than 4 pixels.

Therefore, in this study, the step size is set up 2 pixels for researching the fractal dimension of the rubbed surface.

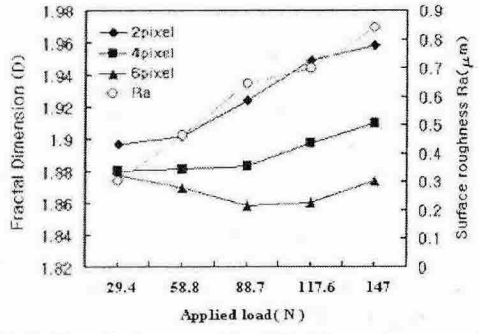

Fig. 2 Relation between fractal dimension, surface roughness and applied load

3.3 The fractal dimension by the variation of the applied load.

Fig. 3 show fractal dimension of HBsC3 for the applied loads in sliding distance 234m and 624m. Fractal dimensions increase according to the increase of the applied load in all sliding distance conditions. It represent that the status of the rubbed surface is more rough and complex according to the increase of the applied load, and the width of the rubbed track is more wide. In addition to, the abrasive wear is occurred to the surface more widely. But, in the long sliding distance, Fractal dimension value is smaller than the short sliding distance value under the applied load 88.7N as shown in the Fig 3, and this value is bigger than the short sliding distance value over 117.6N.

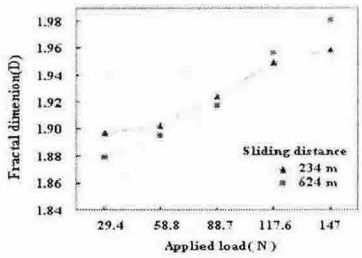

Fig. 3 Effect of load on fractal dimension

It represent that the surface have much more oxides in the long sliding distance under the 88.7N and it is the result of more abrasive wear occurring by the contact pressure over the 117.6 N. In this case, the contact pressure is formed to track direction by the increase of the applied load and the sliding distance.

4. Conclusions

After performing the friction and wear experiment using the pin-on-disk type in each experiment condition, using the image processing, fractal dimensions were calculated from the rubbed surface image of the each disk captured by the CCD camera. After analyzing morphological characteristics of the rubbed surface, we have concluded the following result:

1) The surface roughness Ra is increased by a rise of a surface temperature and contact pressure according to the increase of the applied load.
2) When we compared the fractal dimension with the surface roughness Ra, a increase of a fractal dimension was similar to a increase of a surface roughness Ra.
3) The status of the rubbed surface is rough and complex, and abrasive wear increase according to the increase of the applied load.
4) The fractal dimension is small under the applied load 88.7N in the sliding distance 624m, but great over the 117.6N.
5) In the material HBsC3, less the applied load 88.7N, fractal dimension in the long sliding distance is smaller than in the short sliding distance. But the fractal dimension is large over the 117.6N.

7. REFERENCES

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