ASIATRIB 2002 International Conference
JEJU ISLAND, KOREA

Investigations on Relationship between Fractal Dimension and 3-D Surfaces Topography of C.G. Irons under Dry Sliding

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Based on 3-D surface morphology measurements of C.G. irons, the fractal analyses were made on relationship between dry sliding surface morphology and the fractal dimension. It is revealed that the values of fractal dimensions (D_f) of sliding surfaces are in the range between 1-2, which are closely related to the surface morphologies. With the increase in depths of grooves or pits, the D_f values increase. At the same time, the increases in densities of the grooves also cause the D_f values to increase. At last, relationship among D_f and friction coefficient as well as wear rate is discussed.

Key words: Dry sliding, Fractal analysis, 3-D surface

1. INTRODUCTION

It is well known that tribological behaviors are closely related to surface features[1]. This relationship is more closely under the condition of dry sliding, where direct contacts take place due to no existence of lubricant[2].There are many investigations on describing tribology with surface features, in which 3-D surface topography is one of the effective methods[3,4].

Based on machining surface measurement, many useful 3-D surface topographical parameters are developed to describe the machining surface quality. But those parameters are often not suitable for tribological description of a surface, so it is of value to develop new tribological surface description system.

Fractal analysis are gradually used to many areas. Some investigations on analyzing surfaces of worn debris have proved that the fractal dimension(D_f) obviously corresponds with the wear resistance properties[5]. Based on this suggestion, the investigations are made on fractal analysis of dry sliding surface. Considering the broad application of compacted graphite iron(C.G.iron) in high speed train braking system, the relationship between tribological properties and fractal dimensions are made on the pairs composed of C.G.irons against chromium.

2. EXPERIMENTAL DETAILS

Dry Sliding Tests

The dry sliding tests were made on a pin on disk dry sliding testing apparatus. The sliding velocities and contacting pressures are in the ranges of $4.97 ms^{-1}$ to $9.94 ms^{-1}$ and $0.59 MPa$ to $1.25 MPa$ respectively. microstructures of the specimens are shown in Fig.1.

Tribological properties are described by wear rate(Wr) and friction coefficient(μ). They are obtained by the methods describing in reference[8].

Topographical Measurements

The 3-D sliding surface topography measurements were made on a stylus 3-D surface measure apparatus. The stylus was made of diamond with $2um$ tip radius. The sampling area is made of 8mm in both width and length. The measurement data were automatically acquired by a computer and stored in format of position(X,Y) and surface height.

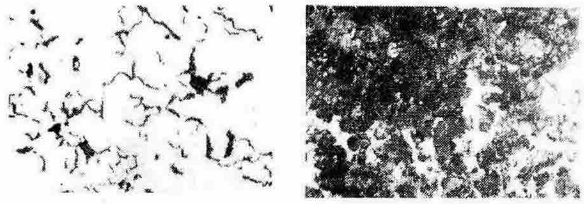

Fig.1 Graphite morphology and microstructure of matrix(40×) of C.G.irons to be tested

Fractal Analysis

The Structural Function had been successfully used to fractal analysis[6]. Thus, it was used to analyze the fractal characteristics of 3-D sliding surfaces.

3. RESULTS AND DISCUSSIONS

3.1 Relationship between Surface Morphology and Fractal Dimension

The authors previous researches have indicated that dry sliding surfaces of C.G.irons can be mainly topographically classified into grooves-ridges like type and pits-island like peaks type[7,8]. The fractal analysis has proved that their fractal dimensions are in the range of 1 to 2, and obviously different. Among two types of surfaces, the fractal dimension of surface with grooves-ridges morphology is bigger for than that of surface with pits-island peaks morphology(Fig.2). This result suggests that the dry sliding surface analysis could be treated by means of fractal.

The fractal dimensions are different not only for surfaces with different morphologies, but for surfaces with same morphologies. Fig.3 and Fig.4 give the fractal dimensions of the grooves-ridges surface with different ridge heights and groove/ridge densities. Clearly, the larger the height of the ridges, the bigger the fractal dimension. At the same time, the more closely the groove /ridge in turn, the bigger in fractal dimensions(Fig.4).

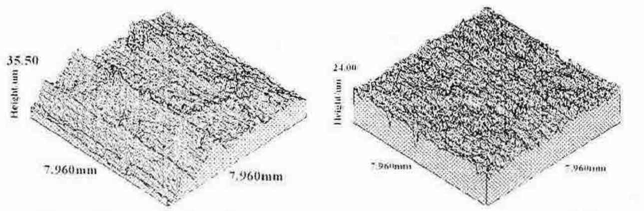

Fig.2 Groove-ridge like surface with D_f=1.44 and Pits-peak like surface(D_f=1.22)

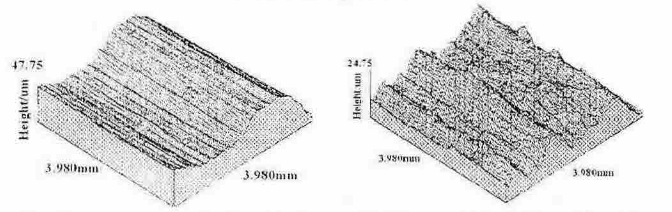

Fig.3 Large groove depth with Smax=24.75 μ m & D_f=1.31 and Small groove depth with Smax=47.75 μ m & D_f=1.47

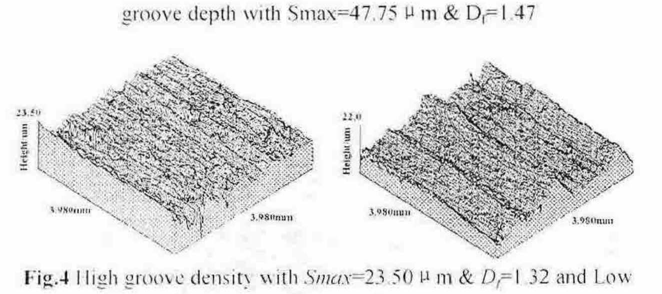

Fig.4 High groove density with *Smax*=23.50 μ m & D_f=1.32 and Low groove density *with Smax*=22.0 μ m & D_f=1.37

For surfaces with pits-island like peak morphology, the larger the depth of pits, the bigger the fractal dimension(Fig.5)

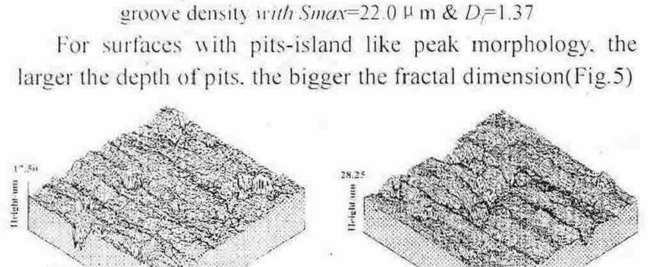

Fig.5 Low pits depth with *Smax*=17.5 μ m & D_f=1.24 and Large pits depth with *Smax*=28.25 μ m & D_f=1.30

The above results have indicated that using fractal dimension to describe sliding surface can give the differentials of the surfaces not only in surface morphology, but also in detailed information of the surfaces, which include peak height, groove number and pit depth.

3.2 Fractal Dimension of Surfaces and Tribological Properties

Fractal dimension can well embody topographical differences of the dry sliding surfaces, and tribological properties are closely related to their topographical behaviors, thus, qualitative relationship between fractal dimension and tribological behaviors exists. It is clearly seen from Fig.6 that with the increase in fractal dimensions, the friction coefficients decrease, while the wear rates increase. Hence, with the accumulation of topographical data of the sliding surface, using fractal dimension to evaluate tribological properties is possible.

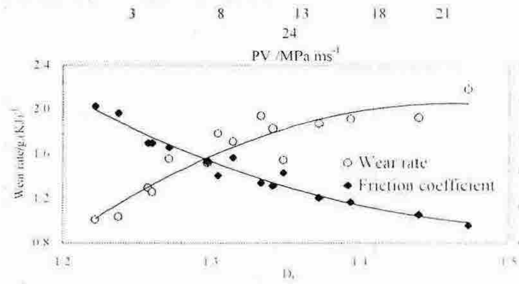

Fig.6 Relationship between fractal dimensions and tribological properties in C.G.iron/chromium steel pair under different sliding velocities and contacting pressures

4 CONCLUSIONS

1.The fractal analysis is one of the suitable methods for sliding surface description. By using fractal dimension(D_f), the differences in surface morphology have obviously differentials in fractal dimension.

2.The fractal dimension has closely relation to the tribological properties. With the increase in fractal dimensions, the friction coefficients increase, while the wear rates decrease.

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