Bifractal Nature of Engineering Surfaces

Á. Czifra[1], E. Ancza[1]

[1]Institute of Mechanical Engineering and Security Sciences, Óbuda University, Népszínház u. 8, 1081 Budapest, Hungary

Abstract. Nowadays, full length characterisation of engineering surfaces is a serious challenge for tribologists and surface engineers. Among other techniques, fractal characterisation tries to provide full length scale characterisation of surfaces, based on the experience that many engineering surfaces have fractal behaviour. In this study, fractal characterisation of a brake plunger was carried out, using different scale length topography measurements. Based on the results, it can be stated, that the examined surface cannot be characterised with a single fractal dimension. Therefore, theoretical explanation of bifractal nature of engineering surfaces is presented.

Keywords: micro topography, fractal, bifractal, tribology

1 Introduction

Nowadays – beyond the parameter based technique – two dominant research trends can be observed in field of surface roughness measurement. One is the technique when the local features of topographies are characterized based on the identification of asperities and scratches, while the other is the "global" surface characterisation method using complex mathematical tools. For global characterisation of the topography by power spectral density (PSD) analysis and height-difference correlation function [1, 2] and [3] show examples. These global techniques give information on the waviness of surfaces, which is very important in their tribological behaviour.

Fractal characterisation of surfaces is based on Mandelbrot's theory [4]. Thomas [5] and many others have proved that engineering surfaces have fractal character and fractal dimension can be obtained from power spectral density (PSD). However many scientists (such as [1]) use the fractal dimension for "full-length scale" characterisation, others (see [6] or [3]) pointed that more than one fractal dimension is needed to characterise the microgeometry or microtopography. Le Gal et. al. [3] concluded, that "... decomposition of surface texture into two scalingregimes can be put in relationship with the usual partitionof road morphology into micro- and macrotexture."

This paper deals with break plungers to study the bifractal nature of mechanical engineering surfaces using three dimensional topographic measurements in wide frequency range.

2 Materials and methods

2.1 Measurements

In a typical automobile brake system the force exerted on the brake pedal is converted into hydraulic pressure in the master cylinder. A modern master cylinder contains two plungers; each of them operates a separate brake circuit. In our work primary plunger of a brake system was examined. Figure 1. shows the scheme of the brake system and a picture of the measured plunger.

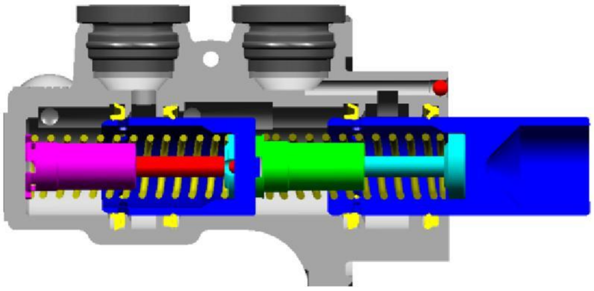

Fig. 1. Scheme of brake system (left) and the measured primary plunger (right)

Table. 1. Measuring conditions

Equipment	Measuring area [μm^2]	Sampling distance (same in both directions) [nm]	Number of measurements
Stylus instrument	3000x3000	3000	1
	1000x1000	1000	1
AFM	90x90	352.9	3
	50x50	196.1	2
	25x25	98.04	2
	10x10	39.21	2
	5x5	19.61	2

The surfaces were examined on the one hand by a Mahr Perthometer Concept type stylus instrument with an FRW750 diamond cone stylus of 5 μm peak radius and 90° peak angle at Óbuda University, Bánki Donát Faculty of Mechanical and Safety

Engineering and on the other hand atomic force microscope (AFM) measurements, were carried out at the Chemical Research Center of Hungarian Academy of Sciences. Table 1 summarizes the parameters of measurements.

2.2 Characterisation technique

PSD analysis transforms the profile or a topography from the spatial domain to frequency one using Fourier transformation. The method has been well-known for decades in the field of surface roughness measurement of 2D profiles and it was extended to 3D in the '90s. The logarithmic scale frequency-PSD amplitude visualization gives a possibility to find the fractal dimension of the surface. The slope of the line is in correlation with the fractal dimension (D_f) of the profile. Details of the used method can be found in [7].

3 Results and discussion

Fig. 2. shows two topographies of the measured surface. One is measured by stylus while the other by AFM. Based on topographic images it can be proved that dominant topographic elements are relatively height, they are in micrometric range. It is important in "traditional" topography characterisation for instance in case of parametric method. The surface parameters are connected to dominant topographic elements, so the measuring area can greatly influence them. In our case (see Fig. 1.) the stylus topography "z" scale extent is about 4500 nm, while AFM measurement is only a part of it, about 380 nm. Power spectral density analysis reveals the fractal character of the surface, so – if the studied surface is a fractal one – it does not depend on the measuring area, and takes all frequency information into consideration.

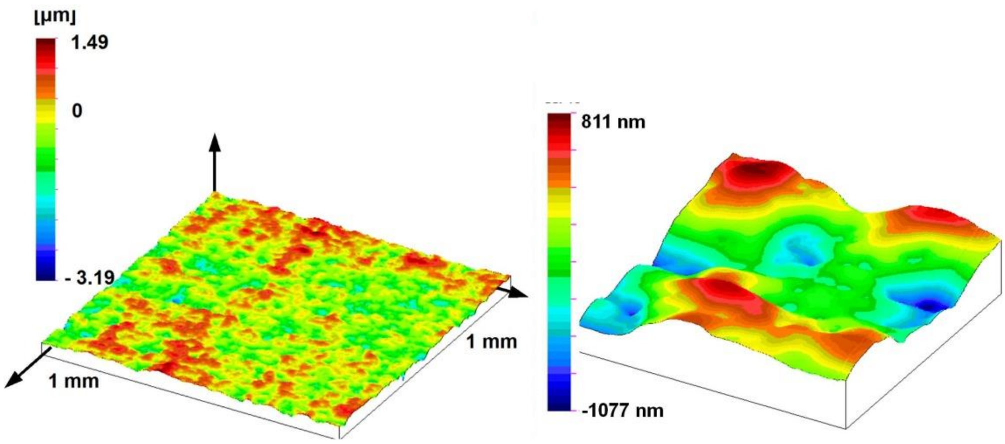

Fig. 2. Topographies measured by stylus (left) and measured by AFM (right)

Figure 3. shows the fractal dimension result as a function of sampling. As the figure shows in nano-scale and in micro-scale different fractal dimensions can be seen. The break point is in range 0.05635 – 0.8239 1/µm (90x90 µm AFM measurements).

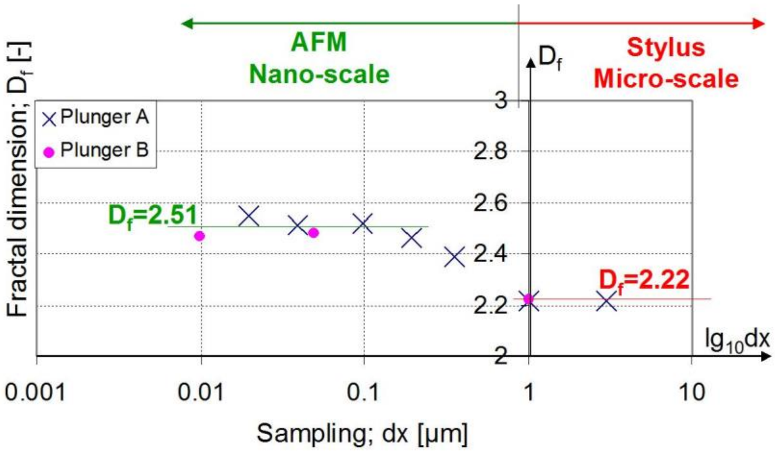

Fig. 3. Fractal dimensions of the plunger in different scales

4 Conclusions

Based on the results it can be proved that the topography of the examined brake plunger has bifractal nature: fractal dimensions in nano- and in micro range are different.

The PSD based fractal characterisation gives a possibility to find the brake point exactly between the two regimes.

References

[1] Barányi I., Czifra Á., Horváth S.: Height-Independent Topographic Parameters of Worn Surfaces, *ÓBUDA UNIVERSITY E-BULLETIN* 1:(1) pp. 1-9., 2010)

[2] Persson, B. N. J., Albohr, O., Trataglino, U., Volokitin, A. I., Tosatti, E.: On the nature of surface roughness with application to contact mechanics, sealing, rubber friction and adhesion. *J Phys Cond Matter* 17, R1-R62, 2005

[3] Le Gal, A., Guy, L., Orange, G., Bomal, Y., Klüppel, M.: Modelling of sliding friction for carbon black and silica filled elastomers on road tracks. *Wear* 264, 606-615, 2008

[4] Mandelbrot BB. *The fractal geometry of nature*. San Francisco, CA: Freeman; 1983.

[5] Thomas, T. R.: *Rough Surface*, Imperial Collage Press, London, 1998

[6] Jiunn Jong Wu: Structure function and spectral density of fractal profiles, *Chaos, Solitons and Fractals* 12, 2481-2492, 2001

[7] Árpád Czifra, Tibor Goda, Enrique Garbayo: Surface characterisation by parameter-based technique, slicing method and PSD analysis, *MEASUREMENT* 44:(5) pp. 906-916., 2011