CHARACTERISATION OF ABRASIVE WORN SURFACES BY SURFACE MICROTOPOGRAPHY PARAMETERS

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Abstract: Surface microtopography plays a dual role in the course of friction and wear processes. It affects the contact and temperature conditions, and it undergoes significant changes in accordance with the wear mechanism. The amplitude, spacing, hybrid and functional parameters of microtopographies provide opportunities for understanding more deeply the wear process. Wear experiments and surface roughness measurements before and after the wear were performed. The aim of this study was to define the availability of the roughness parameters to describe the microtopography modification during the abrasive tribological process.
Keywords: microtopography, abrasion, wear, PSD

1   INTRODUCTION

In the past decades new roughness measuring systems and methods have been developed. With the help of the new systems researchers provided experts involved in surface microtopography research. The new methods make an opportunity to make detailed analyses of the machined surfaces. This knowledge base is utilized only in a small degree in tribological researches. The developed new mathematical methods and a number of tools have been used only to characterise the manufactured microtopography and the cutting tool life.

The most of the researchers use two dimensional roughness measurement technologies to describe the surfaces before and after the wear process. With the help of the evaluation algorithm and the measurement standards the "general" roughness parameters have been determined: the average roughness (Ra), root mean square roughness (Rq), skewness (Rsk), kurtosis (Rku). The enumerated parameters help the engineers to define the real microstructure. Some of these parameters are sensitive and the others are insensitive to the local errors, and the Rsk and Rku describe the first stage of the tribological process (skewness and Kurtosis are strongly influenced by isolated peaks and valleys, fact which reduces their practical importance)[1].

In the present study full length scale analysis and traditional methods performed to examine the abrasion tribological process in different sliding distance and load in a case of dry lubrication system.

2   MATHEMATICAL BACKGROUND AND CHARACTERISATION TECHNIQUE

In this study two dominant trend were used: the first is the traditional 3D evaluation technology, the second is the Fourier based analysis[2].

In the case of 3D dimensional evaluation technology we use traditional parameters without filtering technology. Sa and Sq are the average roughness and root mean square roughness are evaluated over the complete 3D surface respectively. Mathematically, Sa and Sq are evaluated as follows[3]:

$$Sa = \iint_A Z(x,y)dxdy \tag{1}$$

$$Sq = \sqrt{\iint_A Z(x,y)^2 dxdy} \tag{2}$$

Ssk and Sku are the Skewness and Kurtosis of the 3D surface texture respectively[4]. Figuratively, a histogram of the heights of all measured points is established and the symmetry and deviation from an ideal Normal (i.e. bell curve) distribution is represented by Ssk and Sku. Mathematically, the Ssk and Sku are evaluated as follows:

$$Ssk = \frac{1}{S_q{}^3} \iint_A (Z(x,y))^3 dxdy \tag{3}$$

$$Ssk = \frac{1}{S_q{}^4} \iint_A (Z(x,y))^4 dxdy \qquad (4)$$

Sp, Sv, and Sz are parameters evaluated from the absolute highest and lowest points found on the surface. Sp, the Maximum Peak Height, is the height of the highest point, Sv, the Maximum Valley Depth, is the depth of the lowest point (expressed as a negative number) and Sz the Maximum Height of the Surface), is found from Sz = Sp – Sv.

PSD analysis transforms the profile from the spatial domain to frequency one using Fourier transformation. Transformation gives complex result. The power spectral density assigns "amplitude" – magnitude of the complex number – to the frequency. There are two possibilities of showing results. One is to represent the amplitude of PSD in the function of wavelength. The other prevalent method is logarithmic scale frequency-PSD amplitude visualization. In the second method the height frequency range of the curve can be approximated by a line. The discrete transformation made as follows[5]:

$$F(q) = \Delta x \sum_{i=1}^{M} Z(x)e^{-j2\pi qx} \qquad (5)$$

3   INVESTIGATED MICROTOPOGRAPHIES

The investigated surface topographies made by turning. The investigation was steel-sandpaper sliding pair. The sliding distance was 13 m and 26 m, the sliding velocity was 25 mm/s and 50 mm/s and the load was 200 N without lubrication.

The steel part microstructure was recorded a Mahr Perthen Concept 3D type stylus instrument. The size of the surface measured was 1x1 mm and the sampling distance was 2 μm in both directions. Measurements were performed on identical surface sections before and after the wear process; therefore the changes of a given surface section can be traced accurately, not only statistically, in the course of the wear process.

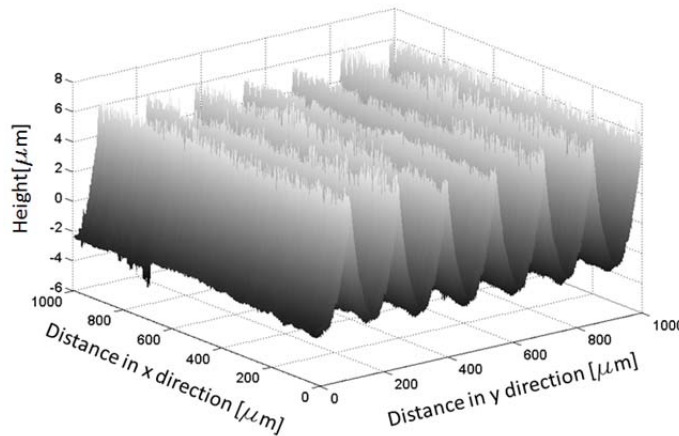Figure 1. shows the surface microtopography before the wear process:

Figure 1. The microtopography before the wear process

Figure 2. shows the worn microtopography. The original surface texture has not disappeared, but the peak zone of microtopography changed: scratches were formed in the sliding direction. In the case of Fig.2b, and 2c, the valley zone changed, because the abrasion particles detached from the sanding paper. Table 1 summarise the wear tests parameters.
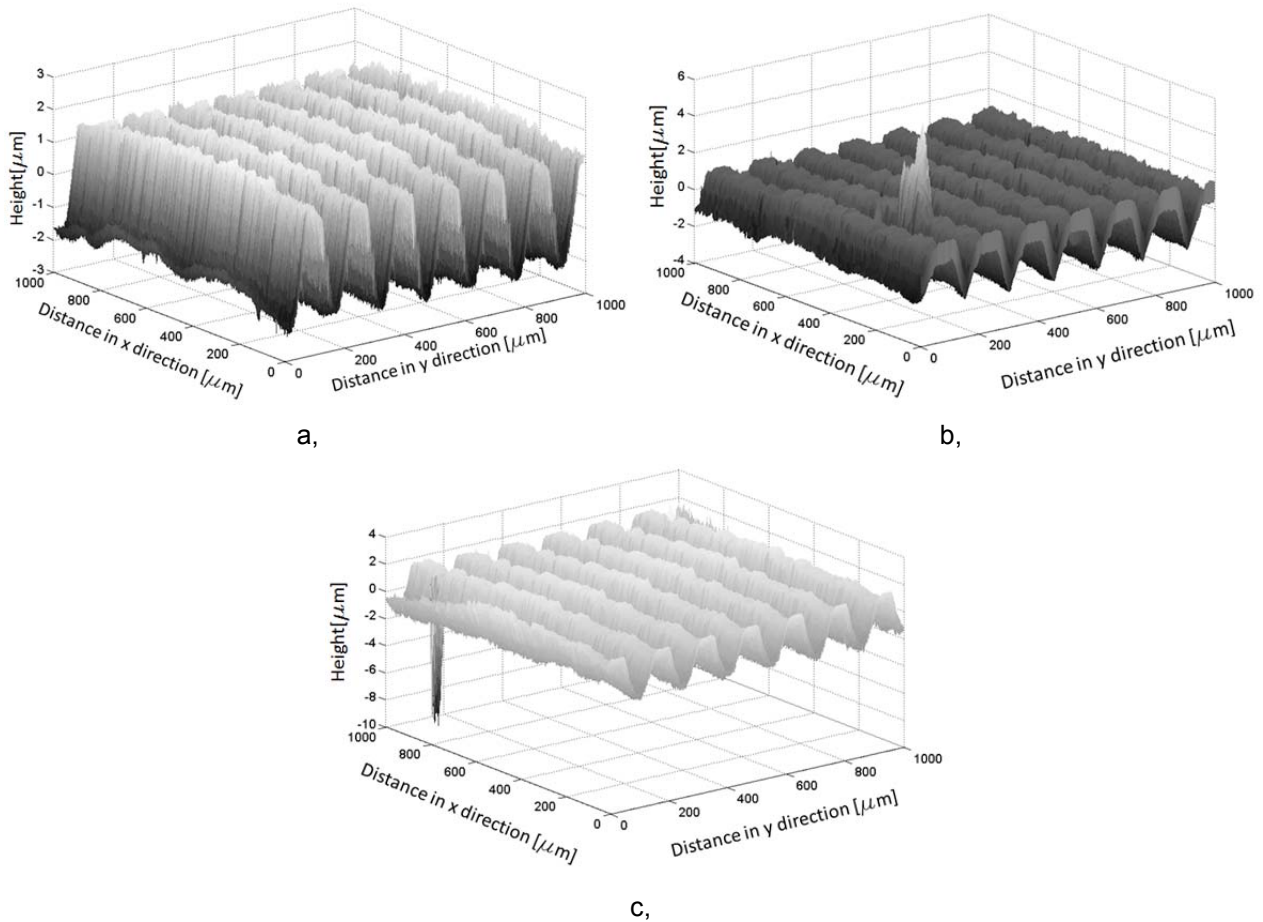
a,

b,

c,

Figure 2. the worn microtopographies with different sliding distance, and velocity

Table 1. The operating and the roughness parameters

	F [N]	s [m]	v [mm/s]	sa [mm]	sq [mm]	sz [mm]	ssk	sku	maximum of the Fourier amplitude
original (Fig 1)	-	-	-	2	2.38	16.11	0.65	2.66	2.96
worn1 (Fig 2a)	200	13	25	1.14	1.31	12.91	-0.58	5.06	1.75
worn2 (Fig 2b)	200	13	50	1.16	1.29	9.68	-0.48	3.29	1.64
worn2 (Fig 2c)	200	26	50	0.89	1.13	19.62	-2.95	31.74	1.77

Figure 3. shows the Fourier based evaluation. With the help of this method we can solve the Fourier coefficients of all of the measured profile in a direction of parallel with the sliding direction. This special extension of the 2D PSD analysis makes an opportunity, to define the local errors and gives an opportunity to compare the investigated microtopographies regardless of location and the start point of measurement.
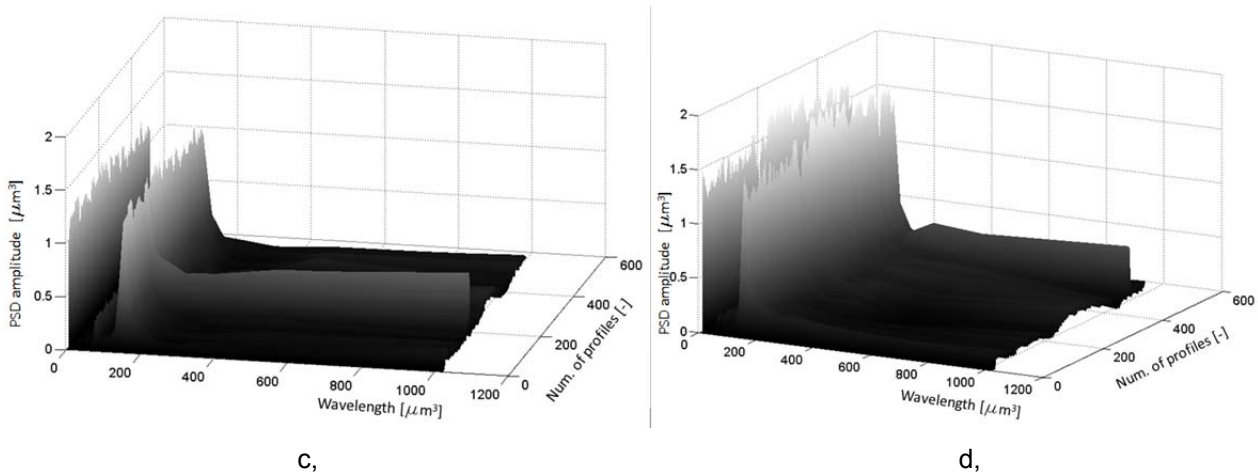

a,

b,

c,   d,
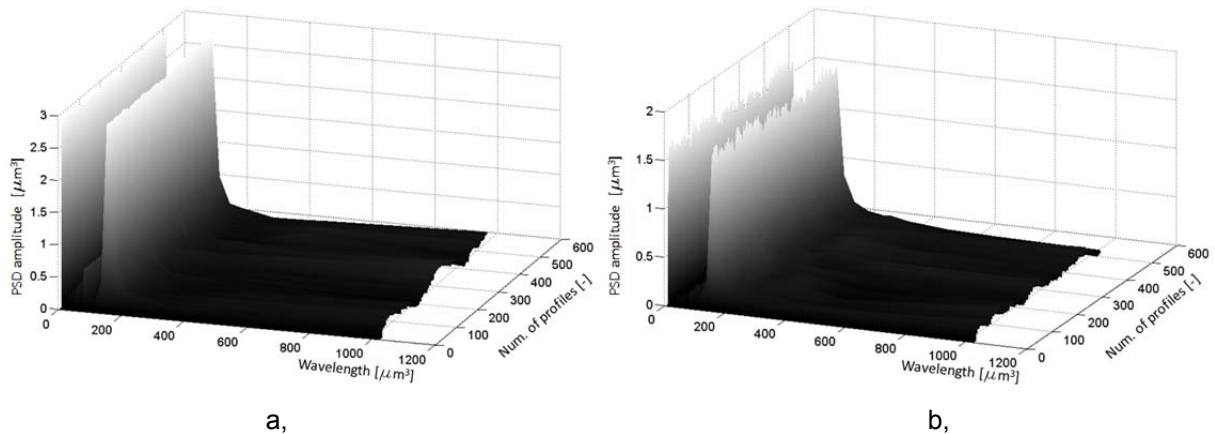
Figure 2. the original (a) and worn microtopographies (b,c,d) in wavelength space

4   RESULTS AND CONCLUSIONS

As Table 2 shows, the values of the roughness parameters are changed and the average roughness and the root mean square roughness decreased. The values of these parameters strongly depend on the sliding distance. These parameters not affective to local errors and show only a little changes in a function of speed. The value of 3D skewness and kurtosis strongly depend of the local errors. As we can see in the Fig 2c the locally disappeared valley zone increased the Ssk form 2.66 to 31.74. This skewness is defines a hardly disappearable microstructure, but it makes only a valley zone error. It represents the negative (-2.95) kurtosis too.

The Fourier coefficients are reduced and it depends to the distance and the speed too. These coefficients belong to the main wavelength. The amplitude of the other wavelengths changed. After the wavelength based transformation the profiles with local error can be found.

5   NOMENCLATURE

Sa	average roughness	μm
Sq	root mean square roughness	μm
Sz	max height of surface	μm
q	frequency	kHz
z(x)	height coordinate located in x	μm
M	number of points in profile	--
Δx	sampling distances	μm
z(x,y)	height coordinate located in x	μm

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