INFLUENCE OF FILTERING IN SURFACE ROUGHNESS CHARACTERISATION

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Abstract

The article deals with a special problem area of the filtering and evaluation techniques of surface roughness measurement and calls attention to the contradictions of parameters to characterize surface microgeometry. Differences in the value of parameters are presented through analysis of the operating surfaces of three different component types. Power spectral density function were used to characterize the wavelength components of measured profiles.

It was stated that the parameter-based evaluation system is very sensitive to the filtering. Power spectral analysis could be an effective tool to interpret the parametric results.

Keywords: surface roughness, filtering, power spectral density

1. Introduction

A number of measurement and evaluation techniques are known to analyze surface microgeometry [1]. At the same time, parameter-based characterization is used nearly exclusively in industrial practice and dominantly in tribological research, however it is known, that parameter-based characterization is uncertain and limited in many respects because results depend, to a great extent, on sampling length and resolution [2].

This list of parameters has considerably expanded by today and the applicable standard [3] accurately defines the method and parameters of evaluation. As recommended by the standard, sampling and evaluation length are closely correlated with filtering, which is the separation of roughness and waviness, and it is used since 1950s.

The modern process engineering produces several type of surfaces, and many of them are greatly differ from surfaces produced some decades before. It means new challenges of experts of surface roughness measurement [4].

This study calls attention to a special problem of filtering and parameter based characterization techniques: with different standard sampling length different roughness values can be yield, all of which are within the value ranges prescribed by the standard for the respective measurement lengths.

Three different components were used as test pieces for the measurements: a turbo loading blade, a carburetor nozzle and a fuel feeder. Our paper characterizes the profiles measured by not only parameters but also by power spectral density function, thereby seeking an explanation and solution for the problems arisen.

2. Applied measuring and characterization techniques

2.1. Measuring technique

The measurements were performed using a Mahr Perthometer Concept type stylus instrument according to the measurement arrangement shown in Figure 1. The tests to be presented in later chapters were performed using an RHT 3-50e type stylus with standard defined adjustment. The measured test pieces can be seen on Figure 2.

Figure 1: Measurement arrangement

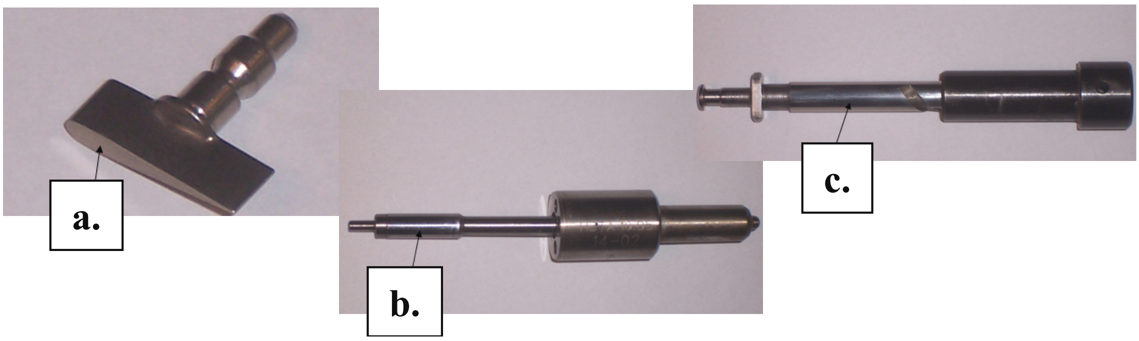

Figure 2: Test pieces (a. turbo loading blade, b. carburetor nozzle, c. fuel feeder)

2.2. Parameter based characterization

This procedure is the most frequently applied evaluation technique in both scientific research and industries. The reason for this is that surface topography data reveal statistical features, so the measurement points specified in an *x-y-z* coordinate system can be used for specifying parameters and functions by statistical means. [5]

Surface microgeometry can be characterized wholly with the so-called complete profile (*P*) without filtering. However, roughness (*R*) and waviness (*W*) as the components of this profile play a more important role in the application of measuring and evaluation techniques. The differentiation and the separation of the profiles is based on the wave-length components of the profile elements. Separation is performed on the basis of the wavelength of the two profile components, which is characterized by λ_c (Cut-Off). λ_c is identical with the evaluation length l_r, which can be used to interpret a considerable part of roughness parameters. The sampling length is a multiple of the evaluation length (in general: $l_n = 5 \cdot \lambda_c$). The basic measurement and evaluation settings of the instruments are also specified by standards. The prescribed values of settings are selected depending on the roughness of the surface, according to the Table 1. In parametric characterization the unfiltered and filtered profile were evaluated also using *P* and *R* parameters.

Table 1: Cut-Off and sampling distance

Recommended Cut-Off	ISO 4288-1996			
Periodic Profiles	Non-Periodic Profiles		Cut-Offs	Sampl. / Eval. Length
Spacing Distance S_m [mm]	R_z [µm]	R_a [µm]	λ_c [mm]	l_r/l_n [mm]
>0.013 to 0.04	To 0.1	to 0.02	0.08	0.08/0.4
>0.04 to 0.13	>0.1 to 0.5	>0.02 to 0.1	0.25	0.25/1.25
>0.13 to 0.4	>0.5 to 10	>0.1 to 2	0.8	0.8/4
>0.4 to 1.3	>10 to 50	>2 to 10	2.5	2.5/12.5
>1.3 to 4	>50	>10	8	8/40

2.3. Power spectral density

Time and space dependent signal can be transformed to frequency domain with Fourier transformation. Discrete Fourier transformation of a simple profile of surface is defined as follows:

$$F(\lambda_k)=\sum_{i=1}^{N} z(x_i)e^{-j2\pi\frac{1}{\lambda_k}x_i}$$, where:

λ	wavelength
$z(x_i)$	height coordinate of measured point located in x_i
N	number of measured points in profile

The Fourier transformation gives complex results. Technical practice does not use this complex results, otherwise the real amplitude of the Fourier transform. It calls power spectral density (PSD) and it is defined as follows:

$$A(\lambda)=[\mathrm{Re}(F(\lambda))]^2+[\mathrm{Im}(F(\lambda))]^2$$

The local maximum points of PSD gives information about the frequency component of analyzed profile.

3. Results

3.1. Parameter-based characterization

Table 2 shows filtered roughness profile parameters while Table 3 shows unfiltered profile parameters for the three different components, where the signage is the following:

Turbo loading blade: a,
Carburetor nozzle: b,
Fuel feeder: c.

Table 2: Filtered profile parameters

Component sign	Sampling length [mm]	Sampling type	R_a [µm]	R_z [µm]	R_{Sk} [-]	R_{Ku} [-]	R_S [µm]
a	1.75	Short	0.088	0.463	0.035	2.303	8.254
	5.6	Long	0.217	1.379	-0.914	4.623	12.18
b	0.56	Short	0.013	0.083	-0.858	4.1	5.841
	1.75	Long	0.023	0.275	-3.663	24.43	6.958
c	0.56	Short	0.015	0.086	-0.433	2.989	5.842
	1.75	Long	0.022	0.151	-1.25	6.446	6.524
Parameter rate [-]			1.9	2.683	6.319	3.374	1.261

When examining measurement results, conspicuous discrepancies can be seen in the case of the most frequently used parameters. Average and maximum surface roughness values sometimes present high discrepancies at the same test piece, while each measurement can be deemed as a standard test.

Table 3: Unfiltered profile parameters

Component sign	Sampling length [mm]	Sampling type	P_a [µm]	P_t [µm]	P_{Sk} [-]	P_{Ku} [-]	P_S [µm]
a	1.75	Short	0.308	2.266	-1.339	5.306	12.667
	5.6	Long	0.327	2.835	-0.925	4.32	14.758
b	0.56	Short	0.016	0.146	-1.319	6.676	5.963
	1.75	Long	0.023	0.444	-3.528	25.32	7.083
c	0.56	Short	0.018	0.124	-0.607	3.136	6.059
	1.75	Long	0.022	0.252	-1.357	7.030	6.599
Parameter rate [-]			1.240	2.108	1.867	2.283	1.147

Parameter rate serving as a basis for evaluation were provided by the following formula:

$$Parameter \quad rate = \frac{\frac{a_l}{a_s} + \frac{b_l}{b_s} + \frac{c_l}{c_s}}{3}$$

In the formula, the indices refer to measurement lengths. Out of the average values calculated, those parameters can be considered as appropriate surface characteristics where the values are in the range of 1 to 1.5. The reason for this is that such degrees of discrepancy may result from other measurement errors as well.

It can be established on the basis of the results that filtered parameters present significant differences in case of dissimilar measurement lengths, in spite of the fact that they refer to the same surface. Contradictory results can arise for two reasons: on the one hand, the difference in measurement lengths; and on the other hand, the different filters applied in the course of measurements.

As regards roughness indices, amplitude-type characteristics presented (R_a, R_z) 2 to 2.5-fold differences. Even greater discrepancies arose in distortion characteristics (R_{Sk}, R_{Ku}). Measurement results fell in the acceptable range only for the spacing parameter R_S.

As regards the results in Table 3, it can be established that the value differences of measurements pertaining to identical surfaces are smaller than in the case of filtered profile parameters. These characteristics refer to identical test surfaces more specifically. Discrepancies can be explained by the various profiles detected, from which it directly follows that roughness indices react sensitively to the filters set.

In the case of the height parameters derived from unfiltered profile evaluation, discrepancies account for up to 75% of the differences experienced with filtered profiles. The smallest difference can be detected in longitudinal characteristics (R_S, P_S), which could also result from a measurement errors or surface inhomogenities.

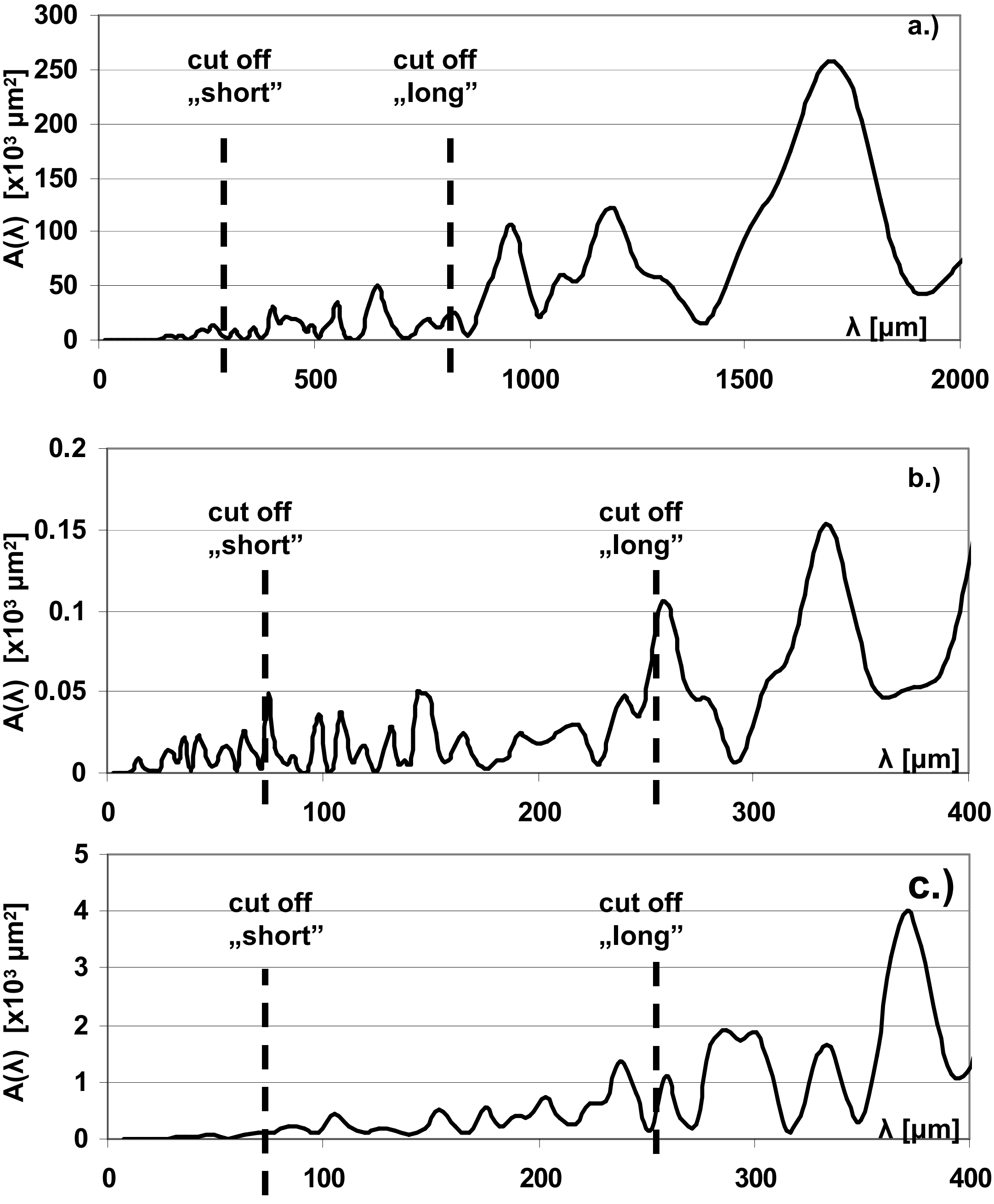

Figure 3: PSD functions of 2D measured profiles

3.2. Power spectral density results

PSD functions were also studied in case of the three different test pieces to see their wavelength informations. The analyses were done only on „long” profiles in all cases. Fig. 3. shows the results.

The first important note is that profiles have no dominant wavelength, bat many wavelength component can be found. Most of them are after the “short” cut off, what means that the “short” measurements contain only the small part of information. It is also important that after the “long” cut off significant wavelength components can be found. So, different wavelength component are analyzed in “short”, “long” and unfiltered cases, hence the results are different.

3.3. Uncertainty of results

Serial was measured in case of carburetor nozzle to check the credibility of results, and confirm that these results are not based on random sampling. The average roughness (R_a) results are summarized in Table 4.

Table 4: R_a parameters of carburetor nozzle measurement serial

Test	Sampling length: short R_a^{short} [µm]	Sampling length: long R_a^{long} [µm]
1.	0,012	0,018
2.	0,018	0,016
3.	0,012	0,021
4.	0,016	0,017
5.	0,015	0,018
6.	0,015	0,019
7.	0,016	0,019
8.	0,017	0,021
9.	0,017	0,019
10.	0,013	0,021
Average	0,0151	0,0189
Deviation	0,0021	0,0017

For serial the T-probe [6] was carried out to analyze the difference of “short” and “long” results. The calculated $t = 4{,}38$ value is higher than $t_{99} = 3{,}85$, which means that the difference is certain, so the results does not come from measuring failure.

4. Conclusions

In summary, it can be stated that the parameter-based evaluation system is very sensitive to the measurement length and the filter set. Differences between standard measurements performed at various sampling lengths can reach or even exceed 200 to 300 % in case of some parameters.

Based on PSD analysis we can find out whether the difference to be observed is characteristic of the surface in case of the same component or a consequence of the measurement length difference.

Contradictory parameter values were detected mostly at nominal roughness values near or at the borderline of a range of the filtering technology table. So it would be expedient to formulate extended rules for such limit values.

It can also be established that the differences detected are the smallest in the case of spacing parameters (R_S, P_S).

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