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COMPARISON OF RESULTS OF SURFACE TEXTURE MEASUREMENT OBTAINED WITH STYLUS METHODS AND OPTICAL METHODS

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Abstract

The results of surface texture measurements obtained with the stylus equipment, white light interferometer and confocal profilometer of the same samples were compared. Machined isotropic and anisotropic surfaces, of symmetric and asymmetric ordinate distribution were measured. Forms were removed using polynomials. Sampling intervals and measuring areas during computations of parameters were the same. Discrepancies between the results obtained with various methods were observed and discussed. It was found that errors of surface texture measurement with the optical methods depend on the type of surface topography.

Keywords: surface texture, stylus, white light interferometer, confocal method.

1. Introduction

The initial assessment of surface topography was initially made simply by running a fingernail across the surface. This technique survives to this day as the tactile comparison. The subject of surface roughness measurement began when a tactile profilometer was developed. The measurement process was achieved by drawing a stylus across a surface and recording its vertical deviations. From the late 1970s analogue instruments were replaced by those supported by computers. The stylus technique has several significant disadvantages, like bulk, complexity, relative fragility, high cost, limitation to a section of a surface. There are a lot of factors affecting uncertainty in the surface geometry measurement using the stylus technique. They are caused by environment, measuring equipment, measured object, software and stylus. The measurement using the stylus equipment caused a lot of measurement errors. The errors typical for stylus instruments can be associated with the following factors: the shape and size of stylus tip, skid and stylus flight [1–7]. The minimum size of tip radius (around 2 μm) which hinders exploration of the bottom of small holes is the first of them. This limitation acts as a badly defined mechanical filter, but only for valleys since peaks seem to be well fitted. The effects of some types of errors on values of surface texture parameters were not yet systematised.

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Despite a great development of optical and other techniques a stylus profilometer is still the most common roughness measuring device in the mechanical industry. Surface irregularities can be easily measured over as much as a 200 mm long and 100 mm wide area, with the drive unit errors less than a micrometre [8–10].

The surface topography is three-dimensional in nature. Three-dimensional (3-D) surface parameters are more reliable than profile (2-D) parameters. In the early 1980s many researchers in the academic community experimented with the characterization of surfaces in 3 dimensions. Somicronic, a small company near Lyon in France, delivered a prototype 3D stylus system in 1990. Somicronic was also the first manufacturer that introduced a comprehensive range of parameters to its software [10]. The time required to collect real data for areal (3-D) measurements by a stylus method is long compared with the working time of optical light techniques.

During development of the traditional stylus-type equipment for areal measurement a substantial progress was made in development of optical systems. Contrary to the stylus method which is robust but slow, the optical methods are fast but more sensitive to extraneous effects. The optical methods are non-contact ones and have many options for improvement. The confocal methods and white light interferometry are the most popular. The optical methods like a stylus technique need isolation of devices from the external environment [11]. Both thermal and vibration changes influence reliability of the result. Very careful cleaning of the measured surface is necessary [6]. The optical measurement suffers from identical intrinsic constrains as the stylus method but also faces an additional problem that the scattered light from the surface does not completely react normally to the surface, which can restrict its optical use in some applications [12]. Surfaces with varying optical properties can cause errors in optical measurements. Topography measurements with the optical methods are limited to moderate slopes. Sharp edges, inclusions, defects and other peculiarities of a surface can cause outliers and dropouts of data points in the topographic images measured with the optical methods. Nonlinearity in the measured z position is also a possible source of errors associated with the optical sensing techniques [13, 14].

A confocal system has a pinhole positioned near to a specimen that protects light from hitting the detector and increases the signal to noise ratio of the system. Confocal methods are widely used in biology and engineering because of a very high clarity of the produced images; when the range is increased the resolution tends to decrease; this factor does not occur when using interferometric methods [12]. A white light scanning interferometer is at present the most useful optical instrument used for measuring surfaces, films and coatings [15]. This type of instrument has grown popular due to the fact that it can be used as an absolute measure of length.

Vorburger *et al.* [13, 14] compared the optical (white light interferometric and confocal microscopy) and stylus methods to measure deterministic and random profiles, whose Ra values ranged up to 0.5 μm. They found prominent discrepancies between results obtained by the white light interferometer and the stylus instrument for the Ra parameter values between 0.1 and 0.2 μm, that seemed to be unrelated to a specific instrument and specimen shape. Demircioglu *et al.* [16, 17] compared the roughness data observed on steel samples. They used the stylus measurement and two optical methods (including the confocal one) observing that all devices yield comparable results for reflective but not very smooth surfaces. On very fine surfaces the optical methods yielded larger values than the stylus methods.

Merola *et al.* [18] measured ceramic femoral heads. A satisfying agreement was found when stylus and confocal profilometers were used. The study described in [19] was performed for different types of insert drills. For comparatively rough surfaces from a titanium layer, the values of Sa parameter (arithmetic mean height) obtained with the focus-variation optical technique were by 35% – 85% higher than those obtained with the stylus profilometry.

Although comparisons of the results obtained with the stylus and optical surface topography measuring equipment were done previously, the authors of papers [13–19] focused only on discrepancies concerning the height parameters.

In this paper we compare the results of areal surface texture measurements with several techniques, including stylus and confocal profilometers as well as a white light interferometer. Not only height but also spatial, hybrid, functional and selected feature parameters are taken into consideration.

2. Materials and methods

Isotropic and anisotropic surfaces of symmetric and asymmetric ordinate distributions were measured using various measuring devices. Several surfaces were studied, however the results of measurements of four surfaces were subjected to a detailed analysis. They were steel surfaces after grinding (surface 1) and vapour blasting (surface 2), a surface from bronze after precise turning and burnishing (surface 3) and a surface from grey cast iron after plateau honing (surface 4). A stylus profilometer Hommel-Etamic T8000 was used, the radius of tip was 2 μm, the measurement speed was 0.5 mm/s, the sampling interval was 5 μm, the measurement area was 4×5 mm. These surfaces were measured also with a Talysurf CCI Lite white light (coherence correlation) interferometer. The measurement area was 3.29×3.29 mm (1024×1024 points). An Altisurf 520 profilometer with confocal measuring head was the third measuring instrument. The measurement speed was 5 mm/s, the sampling interval was 5 μm, the measurement area was 4×5 mm. Measuring devices were previously calibrated. After the measurement of surface RMS they were qualified as capable. In order to compare the results, similar areas were measured and approximately the same areas were analysed after applying a relocation method (mechanical and then digital). The sampling interval substantially affects the results of surface texture measurement [6, 20]. Therefore, the surfaces measured by the interferometer were resampled (the sampling interval used for calculation of parameters was 5 μm). During surface texture measurements with optical methods the skewing effect leads to spikes in the surface data near step edges. In order to minimize distortions, the surface height was truncated corresponding to material ratios between 0.1 and 99.9%. The same procedure of form removal was applied in three measurement cases. The digital filtration was not used. Parameters from ISO 25178 standard [21] were analysed using TalyMap software.

3. Results and discussion

Surface 1 after grinding has anisotropic texture of ordinate distribution similar to the Gaussian one. Table 1 presents the results of its measurement using various equipment, Fig. 1 shows contour plots and selected profiles, while Fig. 2 material ratio curves; relative differences Δ between parameter values obtained in relation to the stylus equipment are also presented. The ratio of *non-measured points* (NMP ratio) was comparatively low – 0.0019% when measured by the confocal profiler and 0.2% – by the interferometer.

The *Sq* parameter is the mean square value of the surface departures $z(x, y)$ within the sampling area [21].

$$Sq = \sqrt{\frac{1}{A} \iint_A z(x,y)dxdy}. \tag{1}$$

Table 1. The results of measurement of surface 1.

Method	Stylus	Interferometer	Δ, %	Confocal	Δ, %	Units
Height Parameters						
Sq	1.53	1.47	3.92	1.5	1.96	µm
Ssk	0.117	–0.093	179.49	0.028	76.07	
Sku	3.43	3.32	3.21	3.52	2.62	
Sp	5.5	5.25	4.55	5.61	–2.00	µm
Sv	5.4	5.72	–5.93	5.31	–1.67	µm
Sz	10.9	11	–0.92	10.9	0	µm
Sa	1.19	1.22	–2.52	1.15	3.36	µm
Functional Parameters						
Smr	0.509	0.544	–6.88	0.369	27.5	%
Smc	1.91	1.96	–2.62	1.81	5.24	µm
Sxp	3	3.28	–9.33	3.06	–2.0	µm
Spatial Parameters						
Sal	0.0241	0.0224	7.05	0.0254	–5.39	mm
Str	0.0236	0.0215	8.90	0.0284	–20.34	
Hybrid Parameters						
Sdq	0.141	0.176	–24.82	0.135	4.26	
Sdr	0.978	1.5	53.37	0.889	9.10	%
Functional Parameters (Volume)						
Vm	9.05e–005	8.06e–005	10.94	8.45e–005	6.63	mm^3/mm^2
Vv	0.00198	0.00203	–2.53	0.00189	4.55	mm^3/mm^2
Vmc	0.00129	0.00138	–6.98	0.00127	1.55	mm^3/mm^2
Vvc	0.00181	0.00183	–1.1	0.00171	5.52	mm^3/mm^2
Vvv	0.000178	0.000193	–8.43	0.000179	–0.56	mm^3/mm^2
Feature Parameters						
Spd	60.5	157	–159.5	103	–70.25	$1/mm^2$
Spc	30.6	47.3	–54.58	42.7	–39.54	1/mm

The *Ssk* parameter (skewness) can be calculated using the following formula [21]:

$$Ssk = \frac{1}{Sq^3} \iint_A z^3(x,y)\,dxdy. \tag{2}$$

This parameter characterises the shape of the surface height distribution.
The *Sku* parameter (kurtosis) describes sharpness of the topography height distribution.

$$Sku = \frac{1}{Sq^4} \iint_A z^4(x,y)\,dxdy. \tag{3}$$

The *Sq* parameter is more stable than the *Ssk* and *Sku* parameters sensitive to the presence of isolated peaks and valleys.

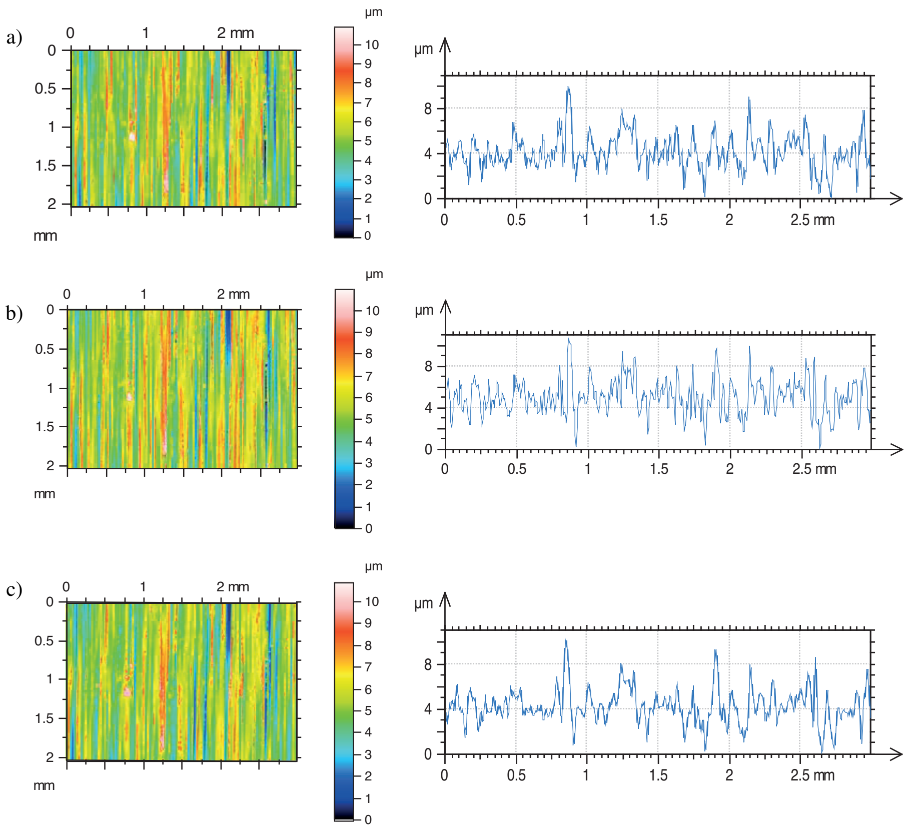

Fig. 1. Contour plots and profiles of surface 1 measured by stylus profilometer (a); white light interferometer (b) and confocal head (c).

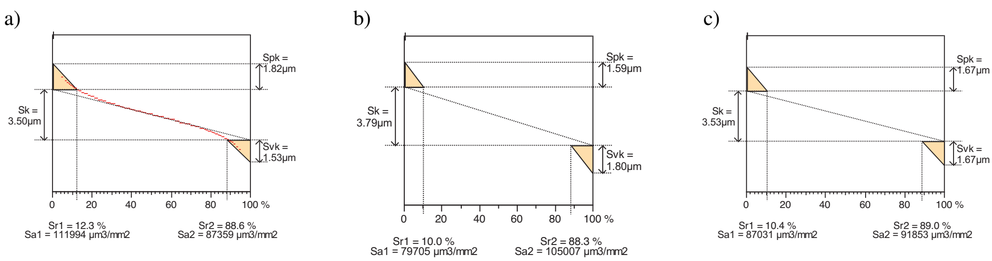

Fig. 2. Material ratio curves of surface 1 measured by stylus profilometer (a); white light interferometer (b) and confocal head (c).

Similar values of the *Sq* parameter were obtained using 3 methods, the maximum difference was about 4%. Deviations between maximum heights (*Sz* parameter values) were negligible. Maximum discrepancies between height parameters, excluding the skewness *Ssk* (close to 0) were smaller than 6%. The maximum relative difference between the areal material ratio *Smr* parameter obtained using various methods was about 30%. Discrepancies between other functional parameters obtained by various methods: inverse areal material ratio *Smc* and extreme peak height *Sxp* were smaller (not exceeding 10%). The white light interferometer yielded the highest values of the root mean square slope, developed interfacial areal ratio *Sdr*, arithmetic mean peak height *Spc* and mean peak density *Spd* from all applied methods; the values of these parameters were 1.25, 1.5, 1.6 and 2.6 times larger, respectively, than those obtained with the stylus method. The smallest values of spatial parameters: the autocorrelation length Sal and the texture aspect ratio *Str* were obtained using the white light interferometer, though discrepancies between autocorrelation lengths were smaller than 12.5%. From among parameters from the *Sk* family, the core roughness depth *Sk* was the most stable (its discrepancies were smaller than 8%). However, deviations of other parameters: the reduced peak height *Spk* and the reduced valley depth *Svk* were higher, up to 16%. Functional volumetric parameters were similar for measurements made by three methods; deviations between them were typically smaller than 10%. Three profiles shown in Fig. 1 are similar to each other.

Surface 2 after vapour blasting has isotropic texture of ordinate distribution similar to the Gaussian one. The NMP ratio was 0.0032% and 17.8% when measured with the confocal head and interferometer, respectively. Table 2 shows the results of its measurement using various equipment, Fig. 3 isometric views and selected profiles and Fig. 4 material ratio curves.

Table 2. The results of measurement of surface 2.

Method	Stylus	Interferometer	Δ, %	Confocal	Δ, %	Units
Sq	3.31	3.98	−20.24	4.02	−21.45	μm
Ssk	0.0256	−0.316	1334.38	−0.027	205.47	
Sku	3.21	3.49	−8.72	3.43	−6.85	
Sp	11.1	12.2	−9.91	13.8	−24.32	μm
Sv	13.1	18	−37.4	15.9	−21.37	μm
Sz	24.2	30.2	−24.79	29.7	−22.73	μm
Sa	2.57	3.11	−21.01	3.13	−21.79	μm
Smr	0.186	0.155	16.67	0.097	47.85	%
Smc	4.13	4.83	−16.95	5.01	−21.31	μm
Sxp	6.39	8.68	−35.84	8.15	−27.54	μm
Sal	0.033	0.024	27.27	0.029	12.12	mm
Str	0.88	0.86	2.27	0.86	2.27	
Sdq	0.35	0.53	−51.43	0.54	−54.29	
Sdr	5.74	12.2	−112.54	12.3	−114.29	%
Vm	0.00017	0.00018	−5.88	0.00021	−23.53	mm^3/mm^2
Vv	0.0043	0.005	−16.28	0.0052	−20.93	mm^3/mm^2
Vmc	0.0018	0.0018	0	0.0022	−22.22	mm^3/mm^2
Vvc	0.0039	0.0045	−15.38	0.0047	−20.51	mm^3/mm^2
Vvv	0.00037	0.00053	−43.24	0.00049	−32.43	mm^3/mm^2
Spd	218	335	−53.67	284	−30.28	1/mm^2
Spc	50	106	−112.00	117	−134.00	1/mm

Surface heights measured with the optical methods were higher than those measured with the stylus method; the relative differences between the *Sq* and *Sa* parameters were about 20%, while deviations of the maximum height parameters *Sz*, *Sv* and *Sp* were larger. The stylus profilometer yielded a higher value of the *Smr* parameter and lower of the *Smc* and *Sxp* parameters than the optical methods. The spatial parameter *Sal* was smaller when measured with the optical methods, especially the white light interferometer (about 30%), compared with the results of stylus measurement.

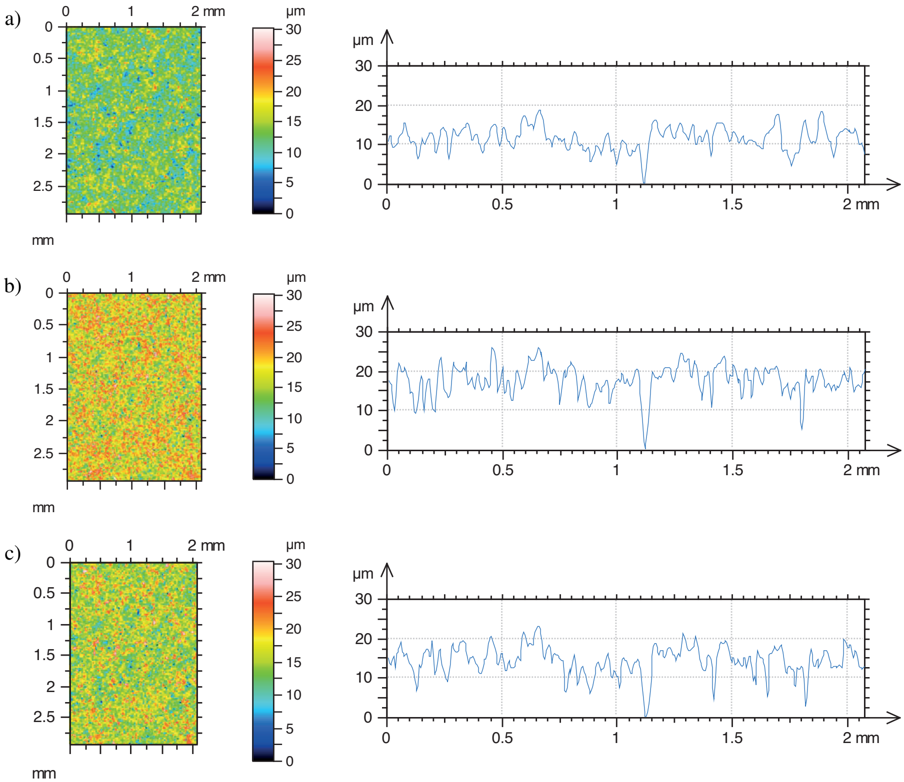

Fig. 3. Contour plots and profiles of surface 2 measured by stylus (a); white light interferometer (b) and confocal head (c).

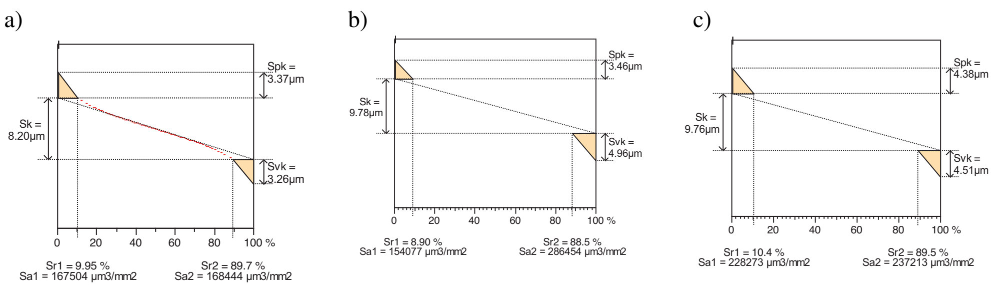

Fig. 4. Material ratio curves of surface 2 measured by stylus (a); white light interferometer (b) and confocal head (c).

The optical methods led to a decrease in the *Str* parameter of about 2%. Different values of the main surface direction *Std* resulting from errors in relocation are typical for isotropic textures. the values of *Sdq*, *Sdr*, *Spc* and *Spd* parameters obtained with the optical methods increased by more than 30%, compared with those being a result of the stylus method. The values of functional volumetric parameters were higher when measured with the confocal method, compared with those obtained with the stylus method; deviations were typically about 20%, except for the pit void volume *Vvv* different by more than 30%. Similarly, the parameters from the Sk family obtained with the optical methods were higher: *Sp* of 20%, *Spk* up to 30% and *Svk* up to 50%.

Surface 3 with large dimples was created by precise turning followed by burnishing (Table 3, Figs 5 and 6). The NMP ratio was 0.33% when measured with the confocal head and 1.6% – by the interferometer.

Table 3. The results of measurement of surface 3.

Method	Stylus	Interferometer	Δ, %	Confocal	Δ, %	Units
Sq	34.3	33.3	2.92	33.6	2.04	µm
Ssk	−1.03	−1.08	4.85	−1.02	−0.97	
Sku	2.69	2.84	−5.58	2.7	−0.37	
Sp	35.8	34.6	3.35	36.7	−2.51	µm
Sv	91.2	93.5	−2.52	91.9	−0.77	µm
Sz	127	128	−0.79	129	−1.57	µm
Sa	29.3	29	1.02	28.5	2.73	µm
Smr	0.167	0.291	−74.25	0.184	−10.18	%
Smc	28.1	27.9	0.71	27.8	1.07	µm
Sxp	98.6	99.9	−1.32	96.4	2.23	µm
Sal	0.409	0.411	−0.49	0.41	−0.24	mm
Str	0.312	0.313	−0.32	0.315	−0.96	
Sdq	0.237	0.293	−23.63	0.311	−31.22	
Sdr	2.73	3.97	−45.42	4.5	−64.84	%
Vm	0.000252	0.000195	22.62	0.000279	−10.71	mm^3/mm^2
Vv	0.0284	0.0281	1.06	0.0281	1.06	mm^3/mm^2
Vmc	0.0396	0.0389	1.77	0.0386	2.53	mm^3/mm^2
Vvc	0.0236	0.0231	2.12	0.0235	0.42	mm^3/mm^2
Vvv	0.00481	0.00502	−4.37	0.00462	3.95	mm^3/mm^2
Spd	0.561	3.18	−466.84	1.31	−133.51	$1/mm^2$
Spc	50	551	−1002.00	143	−186.00	1/mm

Differences between amplitude parameter values obtained with various measuring methods were small (discrepancies between the height parameter values were smaller than 5%). The values of functional parameters *Smc* and *Sxp* were also similar, contrary to those of the unstable *Smr* parameter, that were the highest when measured with the white light interferometer. Discrepancies between the values of spatial parameters *Sal* and *Str* were also small (up to 1%). The optical methods yielded higher values of the parameters *Sdq*, *Sdr* (up to 1.7 times) as well as a high increase of the peak density *Spd* and the mean peak curvature *Spc*, compared with those obtained with the stylus equipment.

Functional volumetric parameters were typically similar with discrepancies of up to 8%, the largest differences between the results of optical and tactile methods were found for the *Vm* parameter (about 15%). From the *Sk* group parameters, *Svk* was the most stable (deviations up to 4%), followed by *Sk* (up to 10%). The white light interferometer gave a decrease of the *Spk* parameter value by 27%, compared with the result obtained with the stylus profilometer. Contour plots and extracted profiles shown in Fig. 5 look similar.

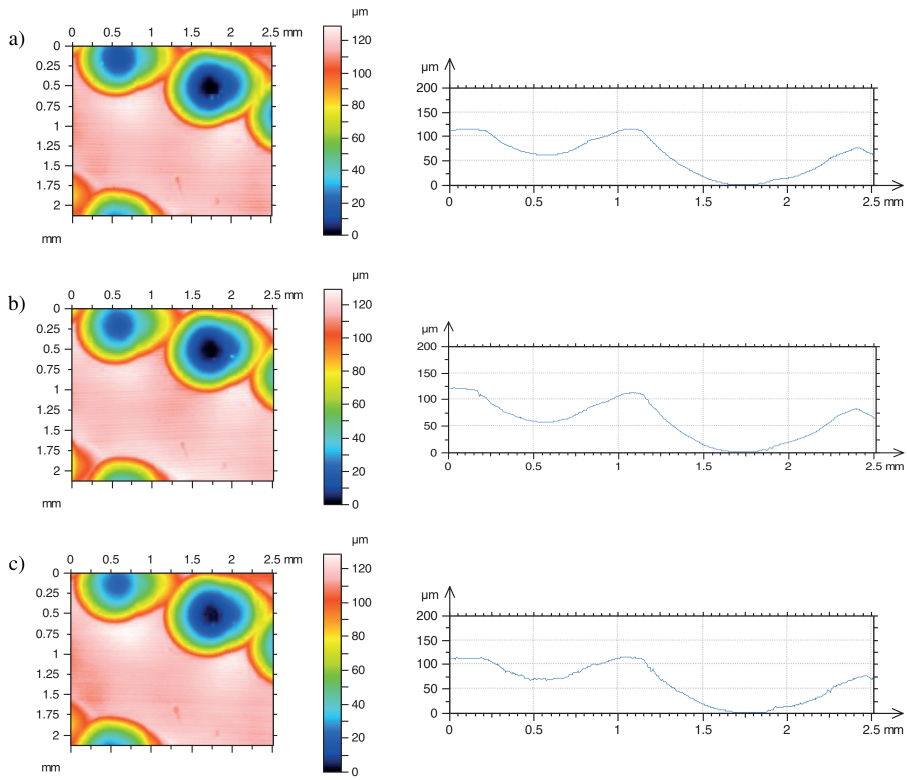

Fig. 5. Contour plots and profiles of surface 3 measured by stylus profilometer (a); white light interferometer (b) and confocal head (c).

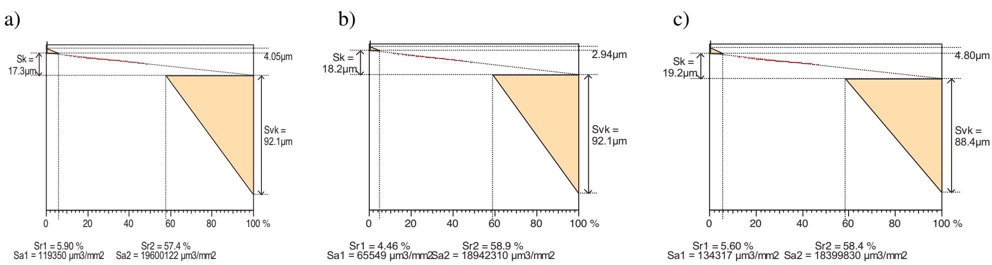

Fig. 6. Material ratio curves of surface 3 measured by stylus profilometer (a); white light interferometer (b) and confocal head (c).

Surface 4 from the cylinder liner after plateau honing has two-process anisotropic texture (Table 4, Figs 7 and 8). The NMP ratio was 0.3% and 0.049% when measured with the interferometer and confocal head, respectively.

Table 4. The results of measurement of surface 4.

Method	Stylus	Interferometer	Δ, %	Confocal	Δ, %	Units
Sq	0.56	0.76	−35.71	0.87	−55.36	µm
Ssk	−4.42	−3.22	27.15	−2.1	52.49	
Sku	29.1	17	41.58	9.6	67.01	
Sp	0.6	1.17	−95.0	2.23	−271.67	µm
Sv	5.1	6.28	−23.14	6.28	−23.14	µm
Sz	5.7	7.42	−30.18	8.51	−49.30	µm
Sa	0.31	0.48	−4.84	0.61	−96.77	µm
Smr	91.2	53.7	41.12	1.5	98.36	%
Smc	0.4	0.596	−49.0	0.78	−95.0	µm
Sxp	1.59	2.47	−55.35	2.78	−74.84	µm
Sal	0.0257	0.0236	8.17	0.0309	−20.23	mm
Str	0.0269	0.0249	7.43	0.074	175.09	
Sdq	0.047	0.105	−123.4	0.149	−217.02	
Sdr	0.113	0.538	−376.11	1.09	−864.6	%
Vm	2.85e−006	1.12e−005	−292.98	2.24e−005	−685.96	mm^3/mm^2
Vv	0.000402	0.000607	−51.0	0.000805	−100.25	mm^3/mm^2
Vmc	0.00022	0.000407	−85.0	0.000568	−158.18	mm^3/mm^2
Vvc	0.00028	0.00042	−50.0	0.000605	−116.07	mm^3/mm^2
Vvv	0.000121	0.000184	−52.07	0.000201	−66.12	mm^3/mm^2
Spd	21	236	−1023.81	671	−3095.24	$1/mm^2$
Spc	10.6	28.4	−167.92	47.9	−351.89	1/mm

The application of optical methods, especially the confocal one, led to an increase of amplitude parameter values, compared with the results obtained by using the stylus profilometer. The smallest growth was obtained for the *Sv* parameter (23%). Also, there were obtained higher values of the skewness *Ssk*, smaller of the kurtosis *Sku* and the emptiness coefficient Sp/Sz (which is visible in Fig. 8) than those obtained with the stylus profilometer.

With both optical methods there were obtained much lower values of the *Smr* parameter, but higher of the *Smc* and *Sxp* parameters. Similar values of the spatial parameters *Str* and *Sal* were achieved with the stylus and the interferometer (parameter values differed by less than 8%). However, the confocal head yielded higher values of these parameters than the stylus equipment, especially the *Str* parameter (175%). Similarly to other measured surfaces, the optical methods led to much higher values of the *Sdq*, *Sdr*, *Spc* and *Spd* parameters than the stylus profilometer; the relative differences were higher than 123% for the white light interferometer and 217% – for the confocal head. The *Spk* parameter value was about 20% higher when measured with the interferometer than that obtained with the stylus profilometer. However, the discrepancies between values of other parameters from the *Sk* family were larger. Similar to other amplitude parameters, the optical methods, particularly the confocal head, led to higher values of these parameters. A similar situation occurred with regard to the volumetric parameters; the variations were the highest for the *Vm* parameter. Contour plots and extracted profiles (Fig. 7) look similar for the stylus and the interferometer, contrary to those obtained with the confocal head, which was probably caused by the presence of high-frequency noise.

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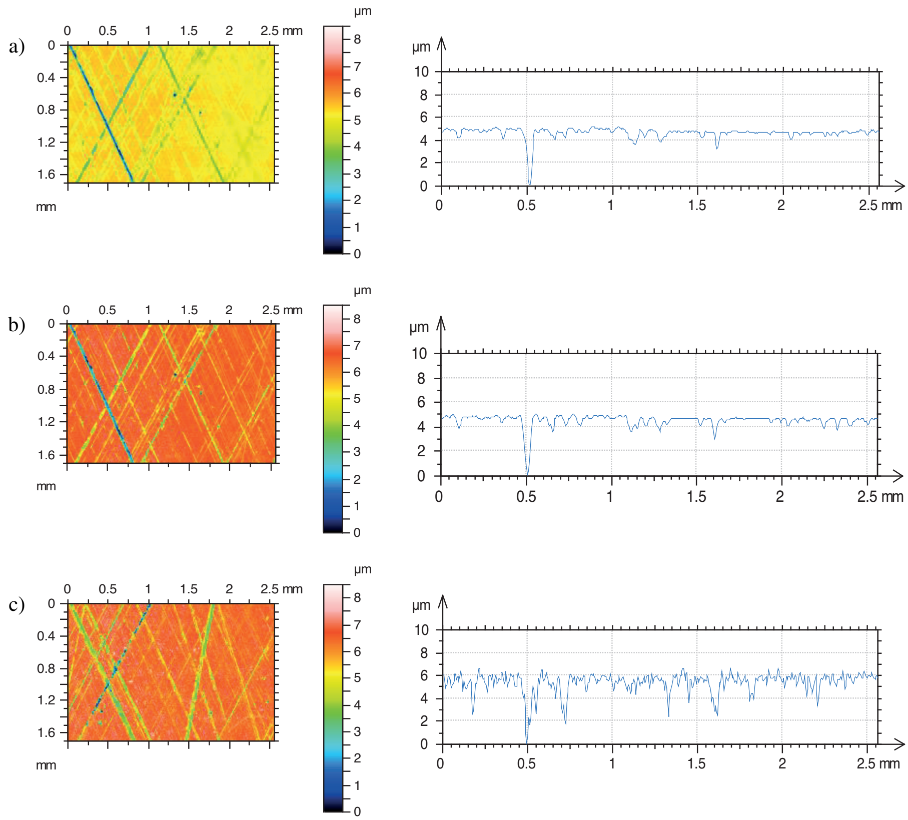

Fig. 7. Contour plots and profiles of surface 4 measured by stylus profilometer (a); white light interferometer (b) and confocal head (c).

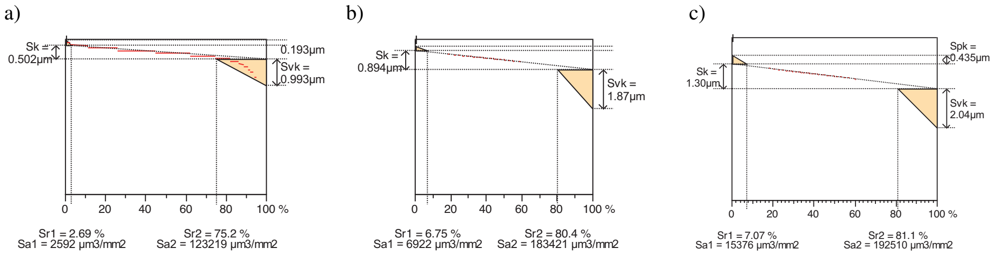

Fig. 8. Material ratio curves of surface 4 measured by stylus profilometer (a); white light interferometer (b) and confocal head (c).

Regions of high curvature at surface summits or valleys can cause outliers called spikes in the topographic images obtained with the optical measurements. It caused an increase in the maximum surface height. This increase was visible on material ratio curves of surfaces 1, 2 and 4 after the form removal. Nevertheless, this error was reduced by surface truncation. Optical methods are sensitive to the high-frequency noise. Increased values of the following parameters: *Sdq*, *Sdr*, *Spc* and *Spd* in comparison with those obtained with the stylus technique are an effect of the high-frequency noise. A slope is badly affected by this noise [3], however the parameters *Sdr*, *Spc* and *Spd* were more distorted. Since *Sdq* and *Sdr* contain the same information, from among the hybrid parameters the slope *Sdq* is preferred. It is difficult to say which method is the most sensitive to the presence of this noise. Values of the above parameters are the highest for surface 1 when measured with the white light interferometer, while for surface 4 – with the confocal head (see Fig. 7c). The high-frequency noise can be eliminated using low-pass filters (median or Gaussian), though an improper procedure of its removal may cause distortion of measurement results, like a decrease in the *Sq* parameter. Therefore, the hybrid parameters and feature parameters *Spd* and *Spc* should be used with a high care in optical measurements of surface topographies.

Applied to surfaces 1 and 3, various measuring methods yield similar values of a majority of parameters different than hybrid and feature ones. The *Smr* parameter is unstable. From the group of volumetric parameters *Vm* is characterized by the biggest variation, similarly to *Spk* from the *Sk* group.

For two other surfaces 2 and 4 larger values of the amplitude parameters were obtained with the optical methods than with the stylus profilometer. This is because the stylus tends to integrate, while the optical methods enhance edges [4]. The mechanical filtration by a spherical stylus tip causes a decrease in the surface amplitude; this effect is proportional to a surface height and also is larger for a smaller main wavelength [6, 22]. In addition, surface 2 has a diffuse texture; a high (about 20%) ratio of non-measured points was obtained with the interferometer. The presence of non-measured points can cause false estimation of surface texture parameters [23]. It is interesting that the application of both optical methods led to similar values of surface 2 texture parameters. A high amplitude of the high-frequency noise when measured with the confocal head (see Fig. 7c) may cause an increase of the roughness height of surface 4. Similarly to surfaces 1 and 3, the *Smc* and *Sxp* parameters were more stable than the *Smr* parameter of surfaces 2 and 4. A high variation of the *Smr* parameter was also found in another research [24].

Height resolutions of the optical methods were better than that of the stylus profilometer. In the last case the quantisation errors occurred, which is visible in Figs 2a and 8a. However, these errors caused small changes of values of the *Sq* parameter [6].

4. Conclusions

Large discrepancies can exist between the results of surface texture measurement with the stylus and optical methods. Therefore the comparative analysis of measurement results is necessary prior to the frequent measurement of surfaces of a similar type.

The range of discrepancies between the results of surface topography measurement by the stylus and optical methods depends on the kind of surface topography. Small variations are possible during measurement of reflective and not very smooth surfaces. A surface containing oil pockets of large sizes was characterized by the smallest discrepancies of its parameters. For rough diffuse surfaces and two-process textures of small standard deviation of the plateau height the optical methods yielded larger values of amplitude parameters than those obtained with the stylus profilometer.

The statistical height parameters seem to be more robust on a surface than the parameters describing maximum height, sensitive to the presence of spikes. The amplitude parameters tended to increase for optical measurements. The *Smr* parameter is very sensitive to measurement errors.

Larger values of the hybrid parameters *Sdq*, *Sdr* as well as *Sdc* and *Spd* ones were found when measured with the optical methods compared with the stylus technique. This was probably caused by the high-frequency noise, which badly affected these parameters. The *Sdq* parameter should be preferred to *Sdr*.

From the optical methods used in this work, the white light interferometry seems to be better than the confocal technique. However, more in-depth research should be focused on this field in the future.

Nomenclature

Sa	–	arithmetic mean height, μm
Sal	–	auto-correlation length, mm
Sdr	–	developed interfacial area ratio, %
Sdq	–	root mean square gradient
Sk	–	core height, μm
Sku	–	kurtosis
Smc	–	inverse areal material ratio, μm
Smr	–	areal material ratio, %
*Smr*1	–	upper bearing area, %
*Smr*2	–	lower bearing area, %
Sp	–	maximum peak height, μm
Spc	–	arithmetic mean peal curvature, 1/mm
Spd	–	peak density, 1/mm^2
Spk	–	reduced summit height, μm
Sq	–	root mean square height, μm
Ssk	–	skewness
Str	–	texture parameter
Sv	–	maximum pit height, μm
Svk	–	reduced valley depth, μm
Sxp	–	extreme peak height, μm
Sz	–	maximum height of surface, μm
Vm	–	material volume, mm^3/mm^2
Vmc	–	core material volume, mm^3/mm^2
Vv	–	void volume, mm^3/mm^2
Vvc	–	core void volume, mm^3/mm^2
Vvv	–	pit void volume, mm^3/mm^2
Δ	–	relative difference, %

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