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Influence of the use of stitching function on the surface texture parameters

Wpływ wykorzystania funkcji łączenia pomiarów na parametry stereometrii powierzchni

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In order to analyze the stereometry of the surface over a larger area than that resulting from the measurement capabilities of the device used, the function of stitching multiple measurements into a single surface is used. The article presents the influence of the applied method on the obtained values of surface texture parameters

KEYWORDS: surface texture, coherence correlation interferometry

One of the limitations of optical devices used to assess spatial topography is the dependence of the measured area on the capabilities of the optical system. In the case of atomic force microscopes, the limitation of the measured area results from the construction of piezoelectric drives responsible for surface scanning in the *X* and *Y* axes [2, 3].

Selection of the area, which should be given to the measurement of the geometric structure of a surface, depends on the height of the unevenness and average distance between inequalities. The larger irregularities and the distances between them, the larger the surface should be measured. Most often, these surfaces are larger than the measuring capabilities of the instrument.

In addition to the limitation of the measured area with the magnification of the lens, the sampling intervals ΔX and ΔY are associated with the optical instruments. The use of a higher magnification lens reduces the measured area, but at the same time increases the density of the horizontal sampling.

Optical aperture of the lens, which limits the possibility of measurement on slopes with a high slope, is also a limitation of optical methods when measuring surface topography. Choosing to measure surfaces with steep slopes of the lens with too little aperture means that points in some areas remain unmeasured. Too many unmeasured points are the reason for obtaining unbelievable results [1].

Information presented indicates that in order for the results to be as accurate as possible, you should have a lens with the largest possible magnification due to thereduction of sampling intervals ΔX and ΔY and the limitation of the number of unmeasured points. However, then the measured area will be too small in relation to the area resulting from unevenness on the surface.

One solution to this problem is to use the numerical function of combining multiple measurements into a single surface - "stitching". It can be equipped with both software for operating the measuring instrument and software for measuring the measurements.

The surfaces to be joined must be measured on a regularly spaced grid with regular rows and columns. Each surface should have the same size and the same resolution. Adjacent surfaces must have overlapping zones (recommended overlap is 20% of the area). The size of the overlapping zone must be identical between all surfaces.

Measuring device

The measurements were made with an optical device using the Coherent Correlation Interferometry Method - Talysurf CCI - equipped with a system of three lenses with a magnification of: ×10, ×20, and ×50. A single measurement consists of a 1024 × 1024 pixel matrix containing coordinates of surface irregularities.

Type of lens depends on the area being measured, the density of the horizontal sampling, the maximum angle of inclination of the measured slopes and the numerical aperture, i.e. factors that have a significant impact on the measurement results (table). To illustrate a surface with dimensions of 5 × 5 mm with lens with the smallest magnification of ×10, 16 measurements have to be made, and then the components should be merged into one surface. Because one scanned area consists of 1 048 576 measuring points, the area is sized around 12 million. Such a number of data requires the use of strong units of computation to analyze the geometric structure of the surface [4, 5].

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TABLE. Metrological specification of lenses

Lens	Measured area, mm	Resolution, µm	Tilt, °	Numeric aperture
×10	1,65 × 1,65	1,65	7,7	0,30
×20	0,82 × 0,82	0,83	14,6	0,40
×50	0,33 × 0,33	0,33	27,7	0,55

Test results

The first part of the measurements was carried out on the material pattern of PPS type (sine profile) with nominal parameters: *Ra* = 0.67 µm and *RSm* = 0.08 mm [6]. As a reference point, profile measurement was carried out on a FormTalysurf PGI 1200 contact profiler on a length of 4 mm. Then, measurements were taken on the Talysurf CCI optical instrument with lenses: ×10, ×20 and ×50, using "stitching". To ensure the required length in the *X* axis (4 mm), the individual measurements consisted of the following number of component surfaces:

- lens ×10 - 3 surfaces (1.65 mm × 1.65 mm),
- lens ×20 - 6 area (0.82 mm × 0.82 mm),
- lens ×50 - 12 area (0.33 mm × 0.33 mm).

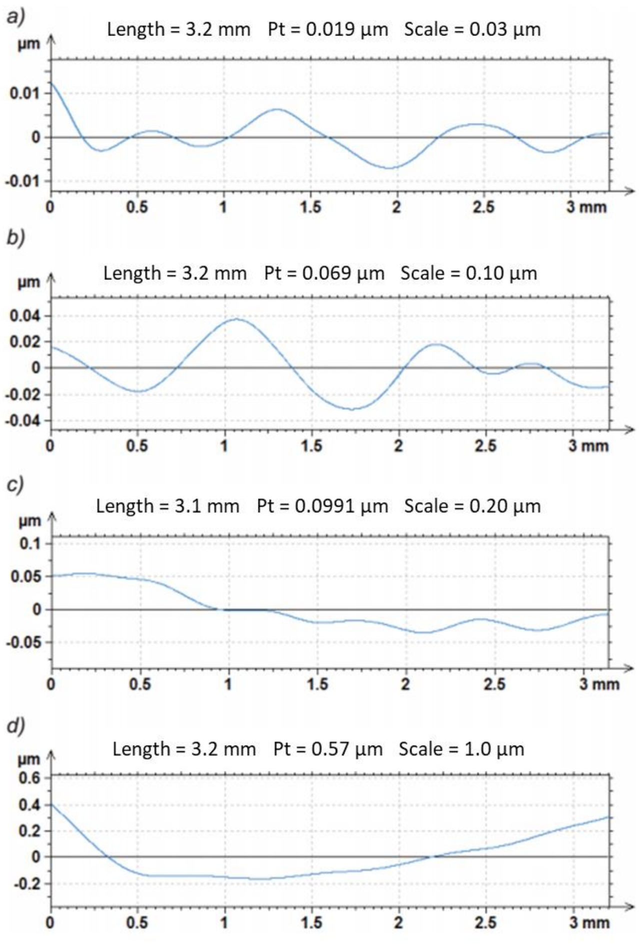


Fig. 1. Corrugation profiles for individual measurements: *a)* contact measurement - FormTalysurf PGI 1200, *b)* optical measurement - Talysurf CCI, lens ×10, *c)* optical measurement - Talysurf CCI, lens ×20, *d)* optical measurement - Talysurf CCI, lens ×50

In order to analyze the effect of combining individual measurements in the resultant surface, a single primary profile was extracted, and then a waviness profile obtained after using a Gaussian filter λc = 0.8 mm. The comparison of obtained waviness profiles is presented in fig. 1.

The smallest value of parameter *Pt* (total profile height), equal to 19 nm, is characterized by the profile of the waveform for contact measurement. The *Pt* parameter values for the waveform profiles of optical measurements increase along with the magnification of the lens, which is closely related to the number of surfaces that make up the result surface: from *Pt* = 69 nm for the lens ×10 up to *Pt* = 570 nm for the lens ×50. The more combined measurements, the greater distortion of the resulting surface due to connection errors and straightness error of the table moving the measured pattern in the *X* axis.

The distortion character of the obtained pattern surface for the ×50 objective with reference to the surface obtained for the ×10 objective is shown in fig. 2.

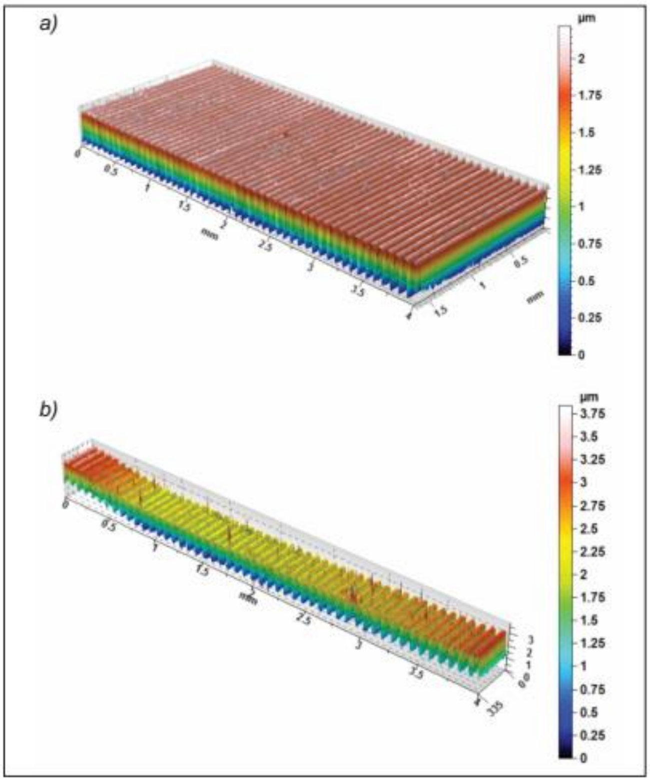


Fig. 2. Characteristic of the measured area of the standard: *a)* isometric image of the surface of the standard for the measurement using the lens ×10, *b*) isometric image of the surface of the standard for the measurement using the lens ×50

The second part of the measurements was made on samples after cold surface treatment. Fig. 3 shows the characteristics of the tested surface. It is a random, isotropic surface.

The lenses ×20 were used for the measurements using the "stitching" function. The resultant surface of 1.5 mm × 1.5 mm was obtained from the combination of four component surfaces with dimensions 0.82 mm × 0.82 mm with a overlap of approx. 20%.

Resulting surface was obtained by the following methods:

- **method 1** - surface obtained as a result of "stitching" made in the Talysurf CCI instrument software,
- **method 2** - surface obtained as a result of the option of stitching the surface with leveling LS (least-squares method) in the TalyMapPlatinium software,
- **method 3** - surface obtained as a result of the option of stapling the surface without LS leveling (using the least squares method) in the TalyMapPlatinium software,
- **method 4** - surface obtained as a result of the surface update option with automatic Z offset in the TalyMapPlatinium software,
- **method 5** - surface obtained as a result of using the surface update option with a Z offset, using common zones in the TalyMapPlatinium software.

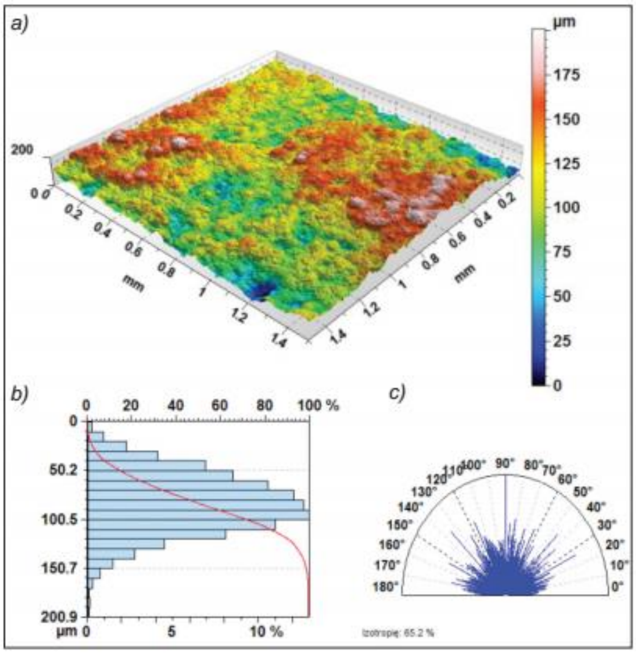


Fig. 3. Characteristics of the measured surface: *a*) isometric image of the surface, *b*) distribution of surface ordinates, *c*) directionality of the structure

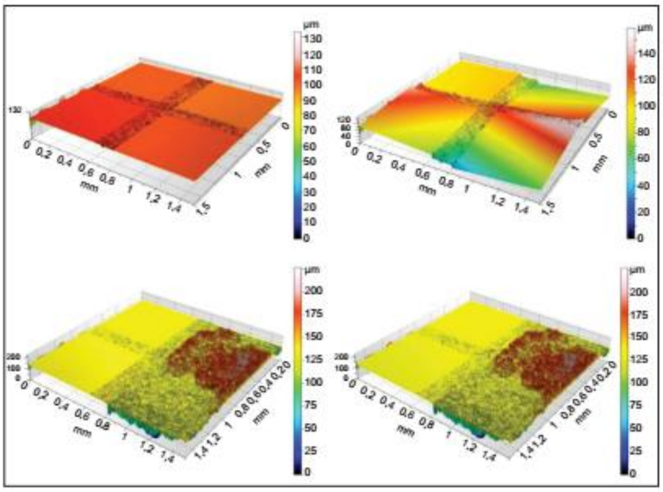
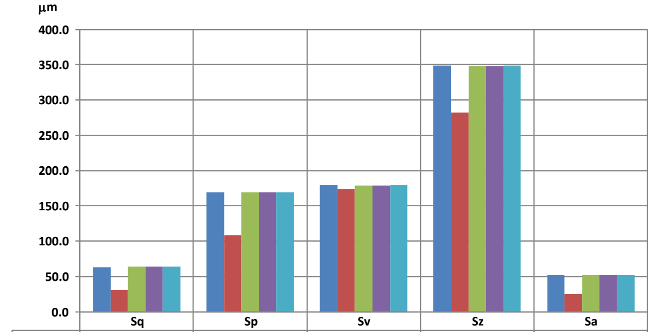


Fig. 4. Results of subtracting reference surfaces and surfaces obtained with other methods

The first method of joining the measured areas was treated as a reference method. To illustrate the joining errors, the surface subtraction operator was used, using methods from 2 to 5 in relation to the reference surface. The results of the use of this operator are shown in fig. 4. The greatest surface joining errors occur in method 2.

Values of the parameters of the geometric structure of the surface obtained by individual methods of combining measurements are shown in fig. 5.

Parameters calculated on the basis of the surface stitching option with *LS* leveling (least squares) in the TalyMapPlatinium software (method 2) are the most different from the parameters obtained with the other methods. The asymmetry of the *Ssk*surface is the parameter most sensitive to the method of surface joining used.



	Sq	Sp	Sv	Sz	Sa
Method 1	63.29	169.15	179.66	348.81	52.27
Method 2	31.01	108.11	174.47	282.58	24.78
Method 3	63.46	169.06	179.01	348.07	52.23
Method 4	63.51	168.95	179.12	348.07	52.27
Method 5	63.45	169.55	179.32	348.87	52.37

	Sku	Ssk	Sal
Method 1	2.377	0.125	0.336
Method 2	3.090	-0.626	0.304
Method 3	2.397	0.142	0.339
Method 4	2.393	0.141	0.339
Method 5	2.380	0.124	0.336

Fig. 5.Values of selected geometric structure parameters obtained for the result surface obtained by various methods

Conclusions

The research has shown that the use of the function of combining measurements during the measurement of the geometric structure of the surface to obtain a larger area for analysis is associated with the risk of reducing the reliability of such measurements. Particular numerical algorithms of combining measurements are the source of potential errors affecting parameter values. At the same time, during this kind of measurements, the device's table is used to move the measured object in the *X* and *Y* axes. Table flatness errors will additionally affect the measurement result.

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