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An analysis of the application of the protective chamber of the stylus profilometer on measurement results of the surface texture

Wpływ zastosowania osłony termicznej profilometru stykowego na wyniki pomiarów stereometrii powierzchni

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The article presents an impact of the temperature change in time on measurement results of the surface texture and efficiency of the application of the protective chamber of the contact profilometer in order to minimize variations of the temperature affecting measuring instrument.

KEYWORDS: surface texture, contact profilometry

In industrial practice, spatial analysis is increasingly used to describe the state of the surface, because measurement of a single profile does not give a full information about the geometric structure of the surface of the object under study. In spatial measurements of the geometric structure of the surface, inter alia, profilometric methods, based on the acquisition of measurement data by scanning the surface in two perpendicular directions [1,2].

The main disadvantage of the profilometric methods is the long measurement time, which depends on: the area being measured, the speed of the blade projection along the *X* axis, perpendicular to the machining marks, and the sampling density along the *Y* axis (number of measured profiles). The size of the area to be measured is determined by the surface roughness of a given element - surfaces with greater roughness require measurements on a larger area. Typical head travel speeds in contact profiling devices are in the range of 0.1÷2 mm/s. At speeds above 0.5 mm/s, there is a risk of the so-called flight, i.e. loss of contact between the cutting edge and the measured surface. Measurement of too few profiles in the Y axis direction may result in the loss of relevant information about the measured area.

The quoted requirements and limitations affect the time of measuring the geometric structure of the surface - it can range from several dozen minutes to several hours. For this reason, when building the budget of uncertainty of measurement, special attention should be paid to changes in ambient temperature, which in laboratory conditions result from the air conditioning operation (periodic temperature change with amplitude depending on the precision of the air conditioning used).

Potential sources of errors in contact measurements of the geometric structure of the surface relate to areas related to: the measuring instrument and the standards used to calibrate it, environmental conditions, properties of the measured element, software used to determine the parameters and metrologist performing the measurement [4, 5].

The article discusses the influence of cyclic changes in ambient temperature on the reliability of the measurements of the geometric structure of the surface and the effectiveness of limiting this influence due to the use of a standard cover provided with the contact profilometer [3].

The measurements were carried out using the Form Talysurf PGI 1200 contact profilometer (fig. 1), which, due to the use of an interferometer head with a measuring range of 12.5 mm and a resolution of 0.8 nm, enables surface stereometry measurements with simultaneous consideration of the contour, waviness and surface roughness. The device is equipped with a table allowing for moving the measured object in the *Y*-axis with a maximum resolution of 1 μm and for measurements at a speed in the range of 0.1÷2 mm/s. The active vibro-isolation system isolates the device from vibrations occurring at the place of its installation.

The measurement was made using a probe head with a measuring tip with a diamond imaging blade, in the form of a cone with a tip angle $\alpha = 90°$ and radius $r_{tip} = 2$ μm.

The measurements were carried out on a material pattern of the AFL type - a flat class interference plate of the first class of accuracy [6].

During the surface stereometry measurements, the temperature was recorded: in the laboratory, inside the profilometer cover, the column and the stage enabling measurement in the *Y* axis.

Fig. 1. Talysurf PGI 1200 Form contact profilometer

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Research program

To determine the effect of cyclic changes in ambient temperature on the results of measurements of the geometric structure of the surface and to examine the effectiveness of limiting this influence by using a profilometer cover, the following measurements were carried out:

- straightness of the table movement in the Y axis has been checked,
- measurement of the interference plate in the area $X \times Y$: 5.7 mm × 5.6 mm, with sampling intervals ΔX = 0.5 µm and ΔY = 15.6 µm (360 profiles), with the speed of the projection blade during measurement V_x+ = 0.5 mm/s and during return to the initial position V_x- = 1.0 mm/s. With these parameters, the measurement time was exactly 180 minutes. The measurement was carried out for two cases of external conditions: with the air conditioning in the laboratory turned on and the profilometer cover open and with the air conditioning in the laboratory turned on and the profilometer cover closed.

Analysis of results

The result of checking the straightness of table movement is shown in fig. 2. The straightness error in the entire 100 mm measuring range does not exceed 1.16 µm.

Results of temperature measurements at individual measuring points for the case with an open and closed profilometer cover are shown in fig. 3 and fig. 4.

Closure of the profilometer cover causes a five-fold reduction in the amplitude of temperature changes inside the profilometer cover in relation to the case with the open cover (tab. I). At the same time, there is a decrease in the amplitude of the temperature changes of the basic elements of the profilometer included in the measurement loop (table, column). When the cover is closed, there is also a phase shift of the temperature changes of the measuring points inside the sheath in relation to the temperature changes in the laboratory.

The results of flat interference plate measurements for both cases included in the test program are presented in the form of an isometric image and a separate profile in the Y axis (fig. 5 and fig. 6).

Fig. 7 and fig. 8 compare the temperature changes inside the profilometer cover and the measured Y-axis profile for the open case and the closed case.

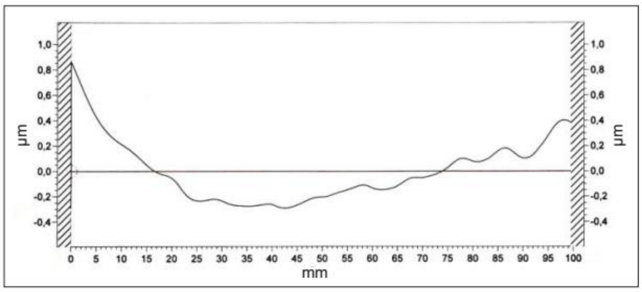

Fig. 2.Result of the measurement of the straightness of the table movement in the Y axis

TABLE I. Amplitude of temperature changes at individual measuring points in the case of open and closed profilometer cover

Cover	Temperature change amplitude, °C			
	Laboratory	Cover	Table	Column
Open	1,3	1,0	0,2	0,1
Closed	1,3	0,2	0,06	0,06

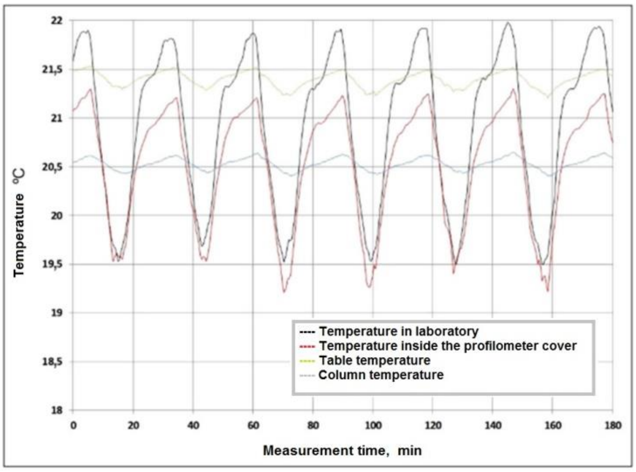

Fig. 3. Results of temperature measurements at individual measuring points in the case of an open profilometer cover

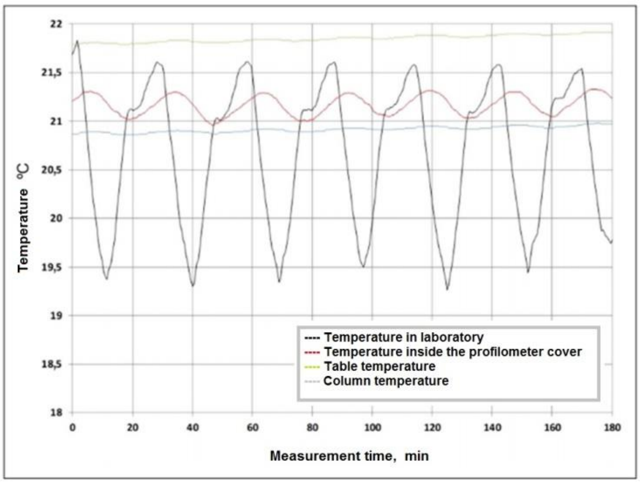

Fig. 4. Results of temperature measurements at individual measuring points in the case of a closed profilometer cover

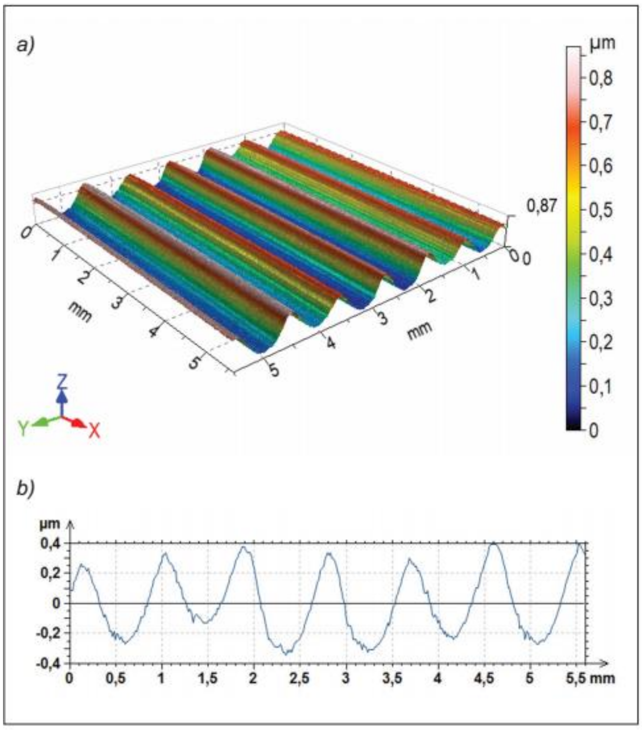

Fig. 5. Measurement results of the interference plate in the case of the open profilometer cover: a) isometric image of the surface, b) separated profile in the direction of Y axis

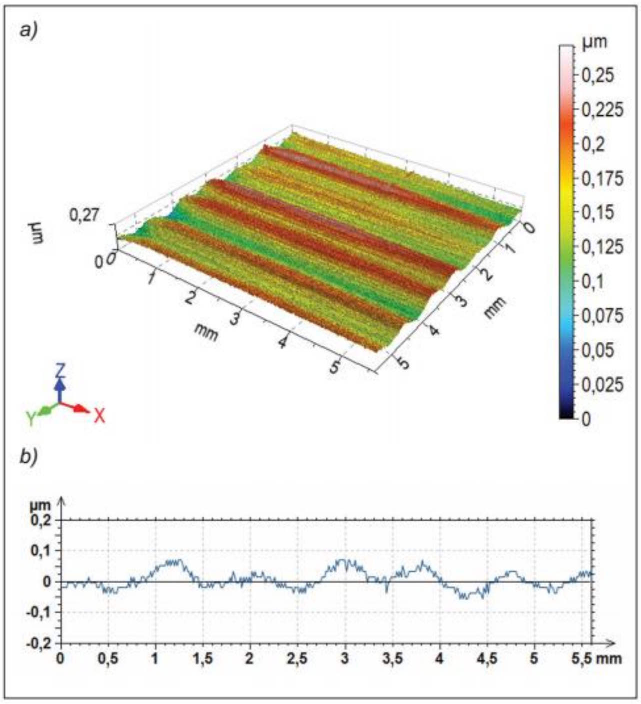

Fig. 6. Measurement results of the interference plate in case of closed profilometer cover: a) isometric image of the surface, b) separated profile in the direction of *Y* axis

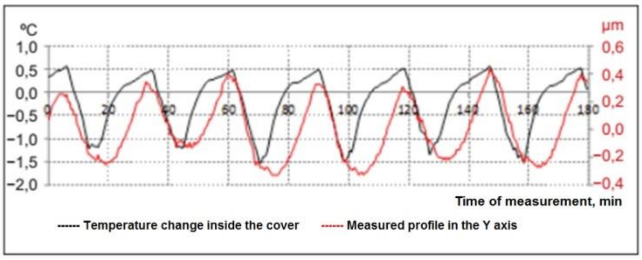

Fig. 7. Comparison of temperature and profile changes in *Y* axis in the case of the open profilometer cover

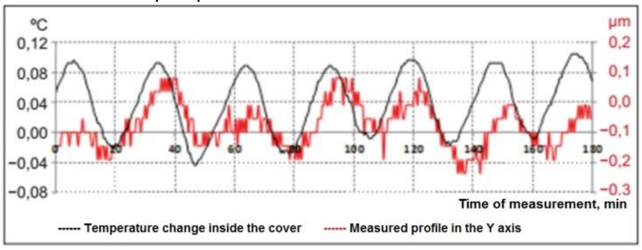

Fig. 8. Comparison of temperature and profile changes in *Y* axis in the case of closed profilometer cover

From the comparison of temperature changes and the outline of the waviness in the *Y* axis it results that the reason for irregularities in this axis are cyclical temperature changes affecting the elements of the measuring loop of the contact profilometer. Despite the significant suppression of the amplitude of temperature changes in the case of a closed profilometer cover, this unfavorable phenomenon still occurs, but its scale is much smaller. The calculated Pearson correlation coefficients between the *Y*-axis profile and temperature changes - r = 0.63 for the open cover and r = 0.46 for the closed guard - confirm this relationship.

Tab. II and tab. III show calculated parameters of the surface geometry structure for both cases foreseen in the test plan (for open and closed covers). Presented results concern unfiltered surfaces - S-F surface (tab. II), containing components resulting from temperature changes, and surfaces filtered with a Gauss filter of 0.08 mm - S-L surface (tab. III) [7].

TABLE II. Results of calculations of geometric structure parameters of unfiltered surfaces

Cover	Parameters, mm				
	Sa	*Sq*	*Sp*	*Sv*	*Sz*
Open	0,19	0,21	0,45	0,42	0,87
Closed	0,02	0,03	0,11	0,16	0,27

TABLE III. Results of calculating parameters of the geometric structure of the filtered surfaces with a Gauss filter 0.08 mm

Cover	Parameters, mm				
	Sa	*Sq*	*Sp*	*Sv*	*Sz*
Open	0,006	0,008	0,098	0,14	0,24
Closed	0,006	0,007	0,074	0,11	0,19

After filtering the components resulting from temperature changes, calculated values of the geometric parameters of the surface are very similar to each other.

Conclusions

The conducted studies confirmed the significant influence of cyclic changes in the temperature of the environment during long-term measurements of the geometric structure of the surface on the obtained results. This effect is revealed in the form of a waveform occurring in the *Y* axis. An effective way to minimize this impact is to use a thermal shield that clearly suppresses the amplitude of temperature changes and consequently significantly reduces the amplitude of the *Y*-axis waveform, which is a systematic temperature error.

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