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COMPARATIVE ANALYSIS OF SURFACE ROUGHNESS MEASUREMENTS OBTAINED WITH THE USE OF CONTACT STYLUS PROFILOMETRY AND COHERENCE SCANNING INTERFEROMETRY

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Abstract – The paper presents comparison of measurements of geometrical surface structure obtained by the contact stylus profilometer and an optical profilometer applying a coherence scanning interferometry method. The measurements were performed on type D1 roughness etalon.

Keywords: surface texture measurement, contact stylus scanning, coherence scanning interferometry

1. INTRODUCTION

The problem of measurements of surface texture is considered as a one of the most difficult in modern metrology [1-5].

The most important methods of measurements of surface topography are: contact stylus interferometry, phase shift interferometry [6-9], coherence scanning interferometry, confocal microscopy, holographic microscopy, scanning tunneling microscopy and atomic force microscopy [10, 11]. The most common instruments are contact profilometers [12-16]. However, optical profilometers are more and more often applied as they offer very high measurements speed. Despite efforts of numerous research centres comparative studies revealed large differences between the results of an evaluation of determined roughness parameters obtained with the use of different measurement methods.

This is the reason why authors made an attempt to compare results of surface roughness measurements obtained by different methods: a contact and an optical one.

The quality of the surface of machine parts is one of the most important factor deciding about proper operation of whole mechanical devices, because it influences such properties as sliding ability, wear resistance, fatigue strength, thermal and electrical conductivity, corrosion resistance, impermeability of joints, etc. This is the reason why it is fundamental to identify sources of errors contributing to uncertainty of measurements of surface texture carried out with the use of various methods.

In the case of measurements conducted by the same method under repeatability conditions factors that contribute to observation of differences between measurement results are for example external disturbances affecting a measuring device, internal disturbances having its source in the components of a measuring instrument and inaccurate positioning on a studied surface.

External disturbances can be of a low or high frequency. Low frequency disturbances are for example thermal disturbances. Thermal expansion of the components of the measuring instrument as well as a workpiece should be considered as a very important factor affecting measurement results. High frequency disturbances are usually the result of vibrations of mechanical units of a measuring instrument and vibrations of the ground influencing measurement circuit of the instrument.

Contact profilometry is the most common method applied in measurements of surface texture. Contact profilometers are equipped with a stylus, ended with a tip, whose moves depend on surface irregularities and, a transducer that converts the moves of the stylus into measuring signal. Typical measuring tip is conical with a cone angle equal to 60 or 90 degrees and the radius equal to 2 μm.

Coherence scanning interferometry (CCI) is based on acquisition of images of interferometric fringes and its localization during a vertical scanning. It combines the technique of vertical scanning with optical interferometry.

The limitation of this method when measuring irregularities with steep slopes is a numerical aperture of the lenses applied. Too low aperture results in obtaining a high number of non-measured points of the surface (blanks spaces on the surface topography image will be noticeable).

2. MEASUREMENT EQUIPMENT, A SAMPLE AND THE RESEARCH METHODOLOGY

The measurements were carried out with the use of a contact profilometer Talysurf PGI 1200 by Taylor Hobson and an optical profilometer applying a coherence scanning method Talysurf CCI by Taylor Hobson.

Talysurf PGI 1200 is equipped with the interferometric transducer probehead. The vertical resolution of the head is 0,8 nm and its range is 12,5 mm. The tip was a diamond needle with radius 2 μm and a cone angle 90°.

The optical profilometer Talysurf CCI has vertical range 2,2 mm and the resolution 10 pm. The image analysis is based on the matrix consisting of 1024 x 1024 points.

The comparative studies were performed on type D1 reference (according to PN-EN ISO 5436-1, whose nominal value was *Ra* = 0,2 µm (see Fig. 1)

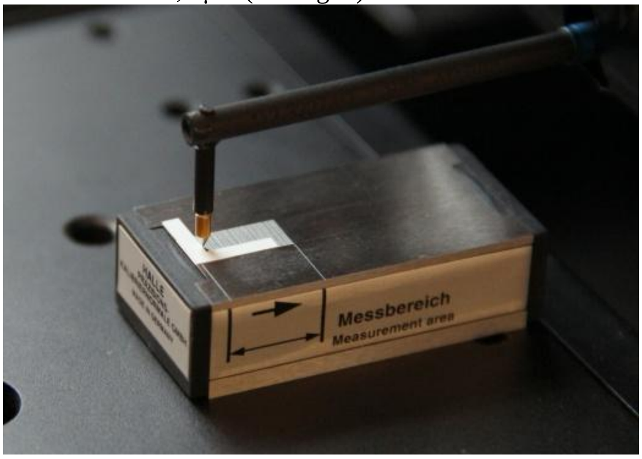

Fig. 1. Measurement of the studied D1 etalon by the contact profilometer.

There were three measurements of surface topography conducted with the use of both instruments. Each measurement carried out with the use of the optical instrument was done applying different magnification of the lens. The area to be measured depended on measuring ability of applied lens and required cut-off length *lr* = 0,8mm for the profile and it was as follows:

lens x10 - x = 4,8mm; y = 1,66mm
lens x20 - x = 4,8mm; y = 0,83mm
lens x50 - x = 4,8mm; y = 0,33mm

Measurements by the optical profilometer were conducted with the use of stitching of singular measurements along X axis.

Measurements by the contact profilometer were conducted on the analogical area and with the use of horizontal resolution corresponding to the resolution of the optical instrument applying measurement speed v = 0,5mm/s.

Roughness parameters were calculated for 100 profiles and filtered by the Gaussian method with λc=0,8mm, and then mean values of the parameters were determined.

Spatial parameters were calculated for the whole measured area after removing form deviations.

3. MEASUREMENT RESULTS

An izometric view of the type D etalon that was measured is presented in Fig. 2 and one of the measured profiles is shown in Fig. 3.

For each measurement of the surface conducted by the contact and optical method a one hundred of profiles were observed. For these profiles roughness parameters were determined and then mean values of the parameters were computed.

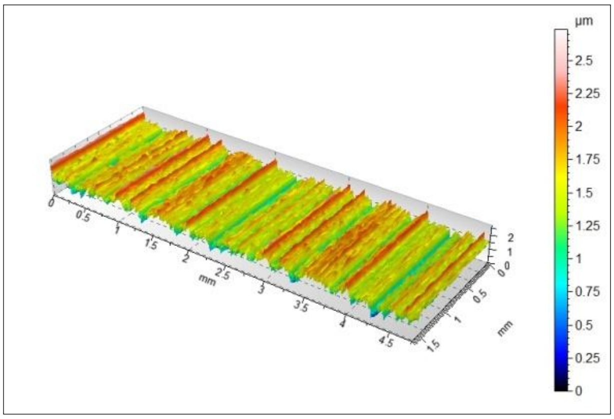

Fig. 2. An isometric view of the type D1 etalon

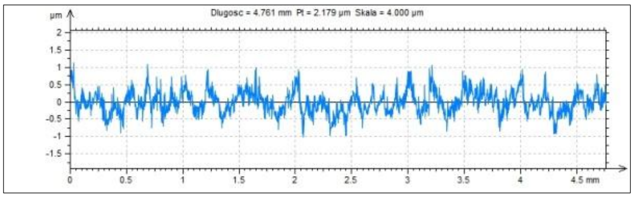

Fig. 3. One of measured profiles

The mean values of the roughness parameters are given in Table 1 and shown as bar charts in Fig. 4. Table 1 gives also relative differences between the values in relation to the contact instrument. Following amplitude roughness parameters were analyzed in the study:

Rp - Maximum Peak Height of the roughness profile.
Rv - Maximum Valley Depth of the roughness profile.
Rz - Maximum Height of roughness profile.
Rc - Mean height of the roughness profile elements.
Rt - Total Height of roughness profile.
Ra - Arithmetic Mean Deviation of the roughness profile.
Rq - Root-Mean-Square (RMS) Deviation of the roughness profile.

Table 1. Obtained values of 2D roughness parameters.

Symbol	Average PGI [µm]	Average CCI [µm]	Relative difference [%]
Rp	0.781	0.923	18.2
Rv	0.896	0.959	7.1
Rz	1.676	1.881	12.2
Rc	0.554	0.657	18.5
Rt	1.814	2.133	17.6
Ra	0.209	0.238	13.8
Rq	0.266	0.299	12.2
RSm	0.781	0.923	18.2

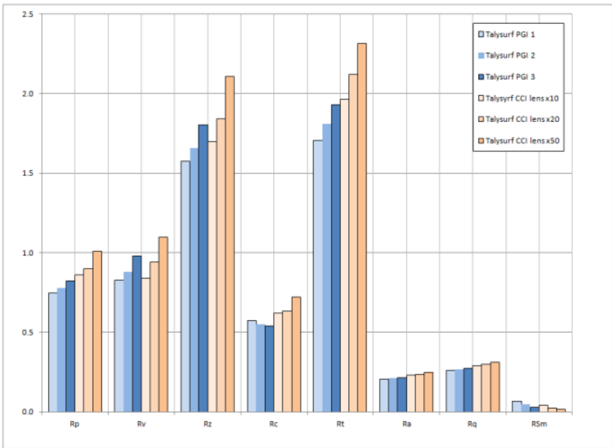

Fig. 4. Results of 2D roughness measurements

Except for mean values also standard deviations as well as changeability coefficients CV were calculated on the basis of obtained measurement results. The CV values were calculated from the following equation:

$$CV = \frac{s}{\overline{R}} \cdot 100\% \qquad (1)$$

where:

CV – the changeability coefficient,

s – standard deviation

$\overline{R}$ - mean value of a roughness parameter

Results of calculation of CV coefficients for individual roughness parameters are shown in Fig. 5

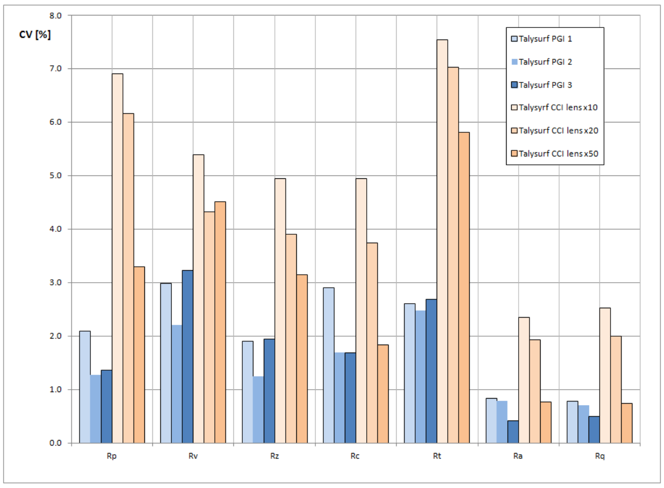

Fig. 5. Changeability coefficients for analyzed roughness parameters

An analysis of obtained values of CV coefficients indicates that for optical measurements these values are in most cases two times higher than respective values obtained for contact measurements.

The next stage of the research was an analysis of 3D roughness parameters.

Following 3D roughness parameters were analyzed in the study: *Sq* - Root mean square height

Sp - Maximum peak height

Sv - Maximum pit height

Sz - Maximum height

Sa - Arithmetic mean height

The mean values of 3D roughness parameters are given in Table 2. Table 2 provides also values of relative differences between parameters obtained by the contact and the optical system.

Table 2. Obtained values of 3D roughness parameters.

Symbol	Average PGI [μm]	Average CCI [μm]	Relative difference [%]
Sq	0.292	0.337	15.3%
Sp	0.977	1.501	53.5%
Sv	1.188	1.734	46.0%
Sz	2.165	3.235	49.4%
Sa	0.231	0.267	15.3%

Fig. 6 shows obtained values of 3D roughness parameters in the form of bar charts.

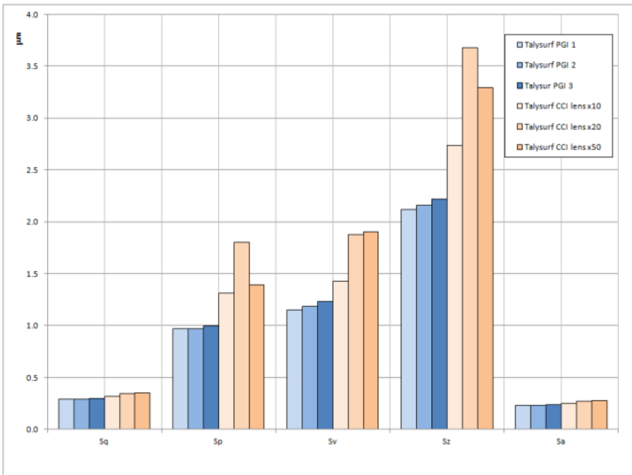

Fig. 6. Results of 3D roughness measurements

An analysis of results shows strict correlation between horizontal sampling density in X and Y axis and between values of calculated roughness parameters (both: 2D and 3D). Mean values of amplitude parameters gained for contact profilometer are higher than corresponding ones obtained by the optical instrument.

4. CONCLUSIONS

Presented study revealed that the very important parameter influencing obtained roughness parameters is horizontal sampling density in axes X and Y. Increasing the horizontal density results in increasing values of 2D and 3D amplitude roughness parameters and in decreasing the horizontal parameters RSm. Mean parameters values obtained by the contact profilometer are lower than the corresponding ones obtained by the optical coherence scanning profilometer. The difference is a dozen percent and it may be a result of an operation of the stylus tip as a mechanical filter. Simultaneously, changeability coefficients of individual parameters calculated for observed profiles are higher in the case of the optical instrument. The reason for this is that the image of the surface topography obtained with the use of coherence scanning interferometry is affected by the noise, which is similar to random irregularities.

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