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SURFACE ROUGHNESS MEASUREMENTS METHOD BASED ON NON-CONTACT OPTONCDT SENSOR

Radomir Majchrowski[1], Krzysztof Morawski[1]

[1] Division of Metrology and Measurement Systems, Institute of Mechanical Technology, Poznan University of Technology, Poznan, Poland, radomir.majchrowski@gmail.com

Abstract – Most of the roughness surface measurement instruments work basing on stylus measurement method. In this paper, the authors present the result of comparing surface roughness and form measurements based on stylus measurement method and non-contact optoNCDT sensor. The results of measurements of surface parameters for different surfaces are presented. It can make further possible to take this method into industry as fast surface measurement method in the systems of in-process control.

Keywords: surface roughness, non-contact sensor

1. BASIC INFORMATION

In last decades, the metrology of the surface layer evaluation notes dynamical development as a science. This trend is the result of new technologies, especially in the motor, aircraft or electronic industry. At present, the customer' requirements led to the measurement not only simple geometrical values, but also more advanced analysis like surface roughness. Surface roughness of any work-piece are among the most important ones in length and angle metrology, both in theory, and practice. Most of the roughness and form surface measurement instruments work basing on stylus measurement method. However, a disadvantage is a large measurement time resulting from the necessity of collecting a great number of measuring data. In order to obtain a reliable surface representation the tracing speed must be low. If it is not the stylus may lose contact with the surface being inspected and a flight may occur [1]. A number of papers were devoted to this phenomenon [2,3] as its influence on the results of roughness measurements is significant. If and when the flight occurs is dependent not only on the drive system but also on the stylus and surface geometry. One of the possibilities of time consumption reduction in surface roughness and form measurement is to apply a non-rectangular grid [4,5] or a non-contact sensor.

The measurement system analysis is one of the most important issues in the topic of quality management. Optic sensors are well known and widely applied devices for dimensional measurement with numerous merits, among others, ability to perform non-contact measurement and wide range of different measuring applications. The non-contact displacement optoNCDT series Fig. 1 and Fig. 2 [6], uses optical triangulation as a measuring principle was tested. The visible laser that is used is rated as laser class 2. A position sensor measures with a large stand-off distance and a very small measuring spot diameter. A digital CCD array is used as the position-sensitive measuring element. It was necessary to create an algorithm of data collection and analysis, transmission and converting as well as basic construction of a device set. In this paper, the authors present the result of comparing surface roughness and form measurements based on stylus measurement method and non-contact optoNCDT sensor. The results of measurements of surface parameters for different surfaces are presented. It can make further possible to take this method into industry as fast surface measurement method in the systems of in-process control.

2. NON-CONTACT OPTONCDT 1700-10 SENSOR

Triangulation means the measurement of distance by calculating the angle. In measurement technology a Sensor projects a laser spot onto the Measurement object. The reflected light falls incident onto a receiving element at a certain angle depending on the distance. The distance to the Measurement object or Target is calculated in the Sensor by the position of the light spot on the Receiver element and from the distance of the transmitter to the receiving element. The optoNCDT 1700-10 is laser displacement sensor with multi-functional features. The unique Real-Time Surface Compensation (RTSC) feature enables measurement against a wide range of material surfaces.

Details of optoNCDT 1700-10:

- measuring ranges: 10 mm,
- linearity: ± 0.08 % FSO,
- resolution: 0.01 % FSO,
- sampling rate (adjustable): 2,5 kHz.

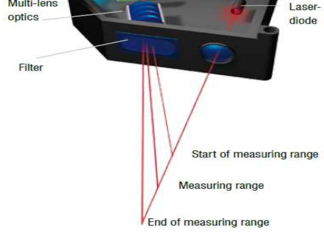

Fig. 1. OptoNCDT sensor using laser optical triangulation method [6].

Fig. 2. Non-contact optoNCDT 1700-10 sensor [6].

3. DATA ANALYSIS WITH MATLAB SOFTWARE

Nowadays, measuring devices are not isolated units, most of them require cooperation with external computer, software or database. Unfortunately, external software for control and data transmission is sold optionally, and generally is expensive [7]. Moreover, it is impossible to change anything in most of the programs, to fit it to the particular task dependent on the enterprise. The Matlab software set contains functions that enable data transmission and receiving from outer devices connected to a computer. This way, the control commands may be sent to the device, and the data collected by the device may be received. Matlab in standard version enables to program all the devices connected to the computer via the serial interface RS 232. For example our team tested [8] the procedures of RS 232 connection with a profilometer HOMMELWERKE T500.

In order to complete the analysis of profile surface measurement method based on non-contact optoNCDT 1700-10 sensor, the program 2D measurement application had to be created. It was based on Matlab software, but our team worked out original program for surface analysis, 2D and 3D alike. Four modules were worked out:

- the initial data processing module (Fig. 3),
- digital filtration module (Fig. 4),
- basic 2D parameters calculating and data visualization module (Fig. 5).

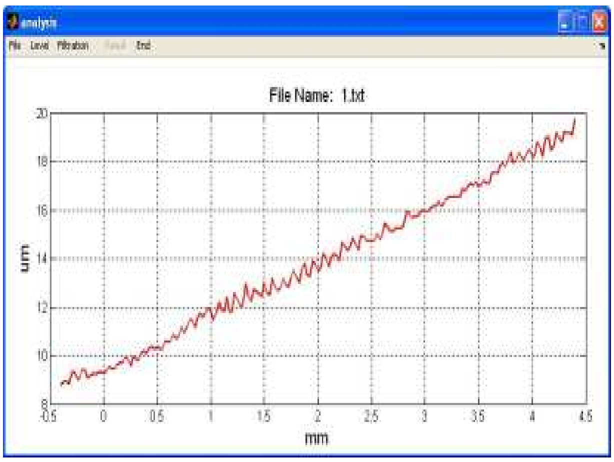

Fig. 3. The initial data processing module – visualization of collected profile.

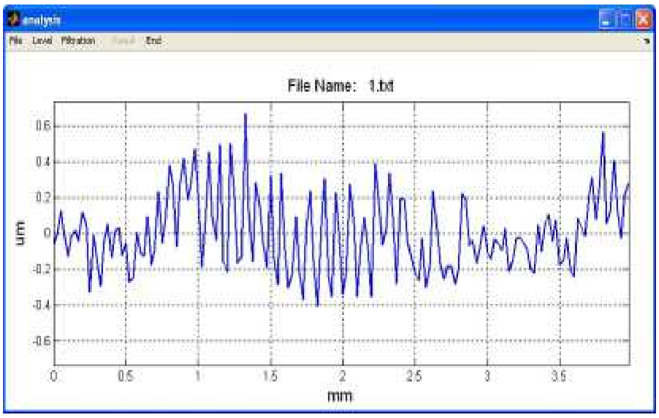

Fig. 4 The collected profile after detrend.

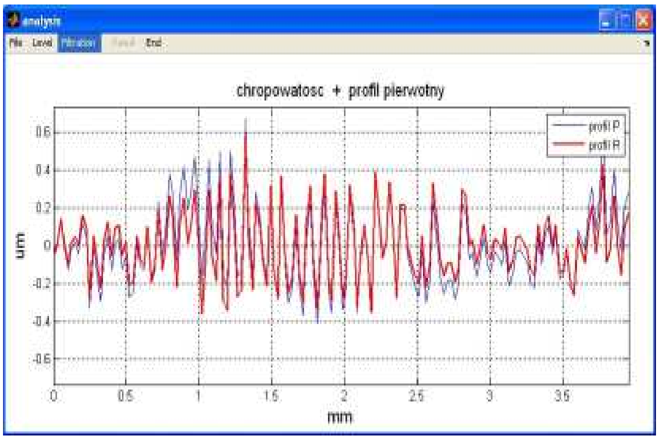

Fig. 5. The digital filtration module and basic parameters calculating module

3. SURFACE ROUGHNESS MEASUREMENTS

Four kinds of surface pattern (milling and planning) were investigated, Fig 6:

- surface pattern- planning, Ra = 6.3 um,
- surface pattern- planning, Ra = 12.5 um,
- surface pattern- milling, Ra = 3.2 um,
- surface pattern- milling, Ra = 6.3 um.

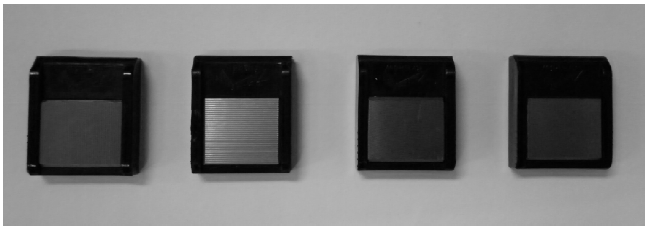

Fig. 6. Four kinds of surface pattern.

The data points for surface roughness were collected by means of a TOPO L50 stylus profilometer. The stylus instrument is one of the main techniques for obtaining profilometric quantitative measurement of surfaces. In last decades, the metrology of the surface layer notes dynamical development as a science, however stylus profilometry is still wide used in industry.

Some TOPO L50 system technical data:

- probes measurement range 250 μm (BS250 probe),
- measurement segments: nominal 0.4; 1.25; 4.0; 12.5; 40 mm and unspecified up to 50,
- measurement speed 0.1; 0.2; 0.5 mm/s,
- measuring probe inductive – contact, without skidless,
- standard mapping tip: diamond, radius of tip sphere 2 ± 0.5 μm, angle at top of tip 90º,
- scanning table with control unit.

During the experiment was used one measurement speed of the stylus instrument TOPO L50.

Then optoNCDT 1700-10 sensor was mounted on the TOPO L50 Fig. 7 and Fig. 8. Measurement rate were 5 mm/s and 1 mm/s. The sampling rate were: 312.5 625 Hz and 1.25, 2.5 kHz. The measuring distance for both methods was 20 mm. Sample plots of surface profile obtained by an optical method shown in Figure 9.

Fig. 7. Surface roughness measurements method based on non-contact sensor – top view.

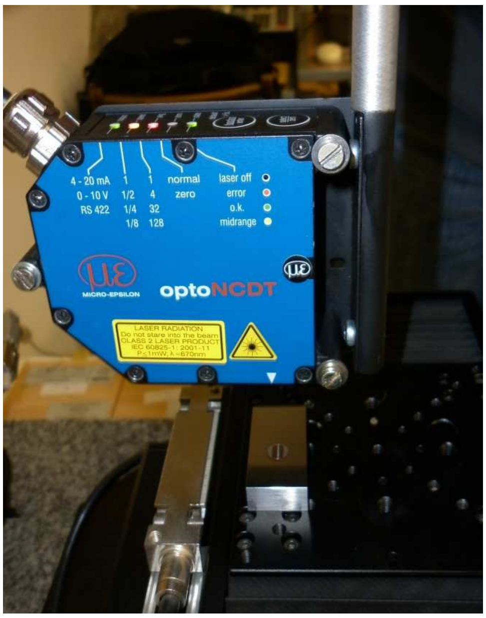

Fig. 8. Surface roughness measurements method based on non-contact sensor – side view.

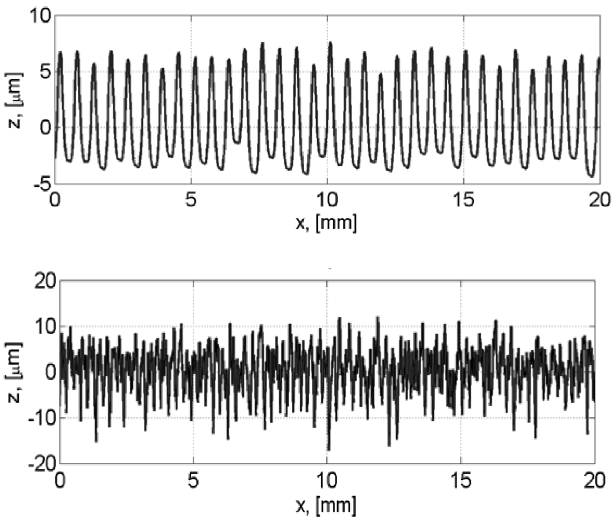

Fig. 9. The example plots of surface profile obtained by an optical method.

For the above mentioned samples, the following parameters [9,10,11] were calculated and evaluated: Ra, Rq, Rz, Rt, Rku, Rsk. They are defined as:

- Ra — arithmetic mean deviation of the assessed roughness profile (1):

$$Ra = \frac{1}{n}\sum_{1=1}^{n}|Z_i| \tag{1}$$

- Rq — root-mean-square (RMS) deviation of the assessed roughness profile (2):

$$Rq = \sqrt{\frac{1}{n}\sum_{1=1}^{n}(Z^2)} \tag{2}$$

- Rz — maximum height of the roughness profile within a sampling length (3):

$$Rz = \frac{1}{5}\left(\sum_{i=1}^{5}|Z_{pi}| + \sum_{i=1}^{5}|Z_{vi}|\right) \tag{3}$$

- Rt — total height of the profile on the evaluation length (4):

$$Rt = Zp_{max} + Zv_{max} \tag{4}$$

- Rsk — skewness (asymmetry) of the assessed profile (5):

$$Rsk = \frac{1}{Rq^3}\frac{1}{n}\sum_{1=1}^{n} Z_i^3 \tag{5}$$

- Rku — kurtosis of the profile (6):

$$Rku = \frac{1}{Rq^4}\frac{1}{n}\sum_{1=1}^{n} Z_i^4 \tag{6}$$

- Rsm — mean width of the roughness profile elements (7):

$$Rsm = \frac{1}{n}\sum_{1=1}^{n} Xs_i \tag{7}$$

- Rdq (RΔq) — root mean square slope of the roughness profile (8):

$$Rdq = \sqrt{\frac{1}{n}\sum_{1=1}^{n}\left[\frac{\Delta Z_i}{\Delta X_i}\right]^2} \tag{8}$$

4. RESULTS AND CONCLUSIONS

An examples of the results for all analyzed parameters for profile obtained from roughness measurements method based on non-contact sensor are presented in Tables from 1 to 3.

Table 1. The results for the milled surface pattern, Ra = 3.2 um.

	stylus Topo	**non-contact optoNCDT 1700-10 sensor**			
	0.5 [mm/s]	**0.5 [mm/s] 1.25 [kHZ]**	**0.5 [mm/s] 312.5 [HZ]**	**1 [mm/s] 2.5 [kHZ]**	**1 [mm/s] 1.25 [kHZ]**
Ra [um]	3.03	3.89	3.76	3.86	3.83
Rq [um]	3.46	4.82	4.46	4.80	4.77
Rt [um]	12.05	28.55	27.31	29.26	29.18
Rku [um]	2.00	2.84	2.86	2.94	2.95
Rsk [um]	0.67	-0.41	-0.44	-0.45	-0.47
RSm [mm]	1.28	0.45	0.47	0.44	0.42
Rdq [deg]	18.48	11.90	18.37	12.11	15.22

Table 2. The results for the milled surface pattern, Ra = 6.3 um.

	stylus Topo	**non-contact optoNCDT 1700-10 sensor**			
	0.5 [mm/s]	**0.5 [mm/s] 1.25 [kHZ]**	**0.5 [mm/s] 312.5 [HZ]**	**1 [mm/s] 2.5 [kHZ]**	**1 [mm/s] 1.25 [kHZ]**
Ra [um]	5,02	5,52	5,44	5,54	5,52
Rq [um]	5,68	6,67	6,57	6,70	6,67
Rt [um]	19,24	36,52	34,62	36,76	36,11
Rku [um]	1,81	2,52	2,48	2,51	2,51
Rsk [um]	0,46	-0,40	-0,40	-0,40	-0,40
RSm [mm]	1,28	0,63	0,70	0,55	0,63
Rdq [deg]	16,23	12,32	19,10	12,61	15,67

Table 3. The results for the planning surface pattern, Ra = 12.5 um.

	stylus Topo	**non-contact optoNCDT 1700-10 sensor**			
	0.5 [mm/s]	**0.5 [mm/s] 1.25 [kHZ]**	**0.5 [mm/s] 312.5 [HZ]**	**1 [mm/s] 2.5 [kHZ]**	**1 [mm/s] 1.25 [kHZ]**
Ra [um]	10,40	10,63	10,50	10,62	10,63
Rq [um]	11,94	12,42	12,26	12,40	12,40
Rt [um]	40,73	66,96	65,11	66,63	66,58
Rku [um]	2,06	2,33	2,30	2,34	2,34
Rsk [um]	0,61	-0,47	-0,48	-0,47	-0,48
RSm [mm]	1,71	1,54	1,65	1,53	1,12
Rdq [deg]	18.48	11.90	18.37	12.11	15.22

The measurement system analysis is one of the most important issues in the topic of quality management. Optic sensors are well known and widely applied devices for dimensional measurement with numerous merits, among others, ability to perform non-contact measurement and wide range of different measuring applications. It was necessary to create an algorithm of data collection and analysis, transmission and converting as well as basic construction of a device set. The authors have compared surface roughness measurements based on stylus measurement method and non-contact optoNCDT sensor. The obtained results of measurements of surface parameters for different surfaces allow to conclude that is possible to take this non-contact method into industry as fast surface measurement method in the systems of in-process control.

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