How to cite this article:
Authors: Tatiana Miller, Krzysztof Gajda, Aneta Łętocha
Title of article: „Wiarygodność pomiarów wykonywanych w akredytowanym laboratorium IZTW w zakresie topografii powierzchni oraz geometrii wyrobów" ("Reliability of measurements performed in the IAMT accredited laboratory in the field of surface topography and product geometry")
Mechanik, Vol. 91, No. 4 (2018): pages 307–310
DOI: https://doi.org/10.17814/mechanik.2018.4.47

Reliability of measurements performed in the IAMT accredited laboratory in the field of surface topography and product geometry

Wiarygodność pomiarów wykonywanych w akredytowanym laboratorium IZTW w zakresie topografii powierzchni oraz geometrii wyrobów

TATIANA MILLER
KRZYSZTOF GAJDA
ANETA ŁĘTOCHA *

The scope and the reliability of measurements performed in the accredited laboratory in the Section of Length and Angle Measurements in Department of Geometrical Quantities Metrology of the IAMT (IZTW) were presented. The scope of services include the performance of tests and measurements in a very wide range related to surface texture analysis, research tests of dimensional and shape accuracy and product quality control. The capabilities of equipment and software available in the laboratory were characterized.
KEYWORDS: accredited research laboratory, geometrical product specification, roughness, form, geometry, surface topography, coordinate measurements

Most of the measurements performed in the Geometric Dimension Metrology Department are carried out as part of the IAMT (IZTW) accredited research laboratory, in the Section for Measurements of Length and Angle. Since 1998, the laboratory has accreditation No. AB 197 of the Polish Center for Accreditation for compliance with the requirements of PN-EN ISO/IEC 17025: 2005.

The laboratory staff has many years of experience in the field of geometry measurements as well as surface topology measurements and analyzes. Experience and equipment allow for the implementation of many complex research tasks.

A wide range of competences is confirmed by annual audits, carried out by the Polish Center for Accreditation (PCA), and is constantly increased thanks to participation in training and conferences related to product quality control.

The laboratory (fig. 1 and fig. 4) provides services for enterprises and research units. It is open to cooperation with the industry. Its offer includes the implementation of measurement tasks, often impossible to perform in other laboratories, as well as the construction and execution of special devices.

* Mgr inż. Tatiana Miller (tatiana.miller@ios.krakow.pl), inż. Krzysztof Gajda (krzysztof.gajda@ios.krakow.pl), mgr inż. Aneta Łętocha (aneta.letocha@ios.krakow.pl) – Instytut Zaawansowanych Technologii Wytwarzania

The laboratory uses apparatus ensuring measurement coherence, through the use of standards calibrated by the laboratories of the Central Office of Measures and perimeter measurement offices. Measurements are carried out in accordance with PCA accredited testing procedures. For each measurement a certificate (according to the PCA model) is issued, in which the uncertainty of measurement is determined for each measured value, determined in accordance with the standard PKN-ISO / TS 14253-2: 2011.

TABLE. Scope of accredited measurements performed in the Section for Length Measurements and Angles of the IAMT (IZTW) laboratory

Geometric dimensions	ranges: – length to 200 mm (class IT2), to 700 mm (class IT5), – angle in full range
Straightness and flatness	– measuring range for straightness deviation: 5 mm on length up to 4000 mm – measuring range for flatness deviation: 3 mm on length up to 4000 mm
Surface topography parameters for the roughness profile, waviness profile, primary 2D profiles and 3D stereometric parameters	ranges: – axis *X* do 120 mm – axis *Z* 2 mm – axis *Y* 25 mm
Linear displacements and positioning errors	range: to 4000 mm

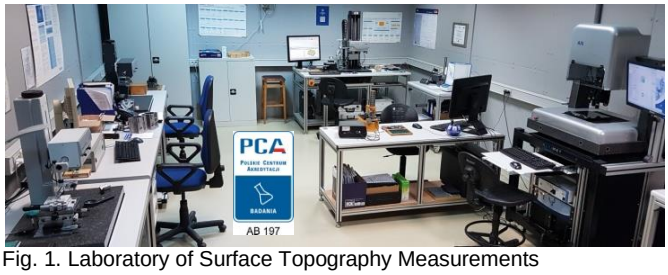


Fig. 1. Laboratory of Surface Topography Measurements

Measurements may refer to single copies of products or more identical details selected from serial production, components intended for assembly or complex geometries of assembled stations intended for production control in industrial plants.

For measurements are used, among others devices developed at IAMT (IZTW), for which many measurement procedures and computational algorithms included in dedicated software have been verified as part of the research and development work.

Noteworthy is the measurement system TOPO 02 developed in IAMT (IZTW), intended not only for research works, but also for wide application in industry. The system is equipped with various measuring heads that enable comprehensive metrological tests:

- roughness – up to a 2 mm amplitude of surface irregularities,
- dimensions and shapes of elements (including those with very small dimensions) – up to 50 mm amplitude and below 1 µm.

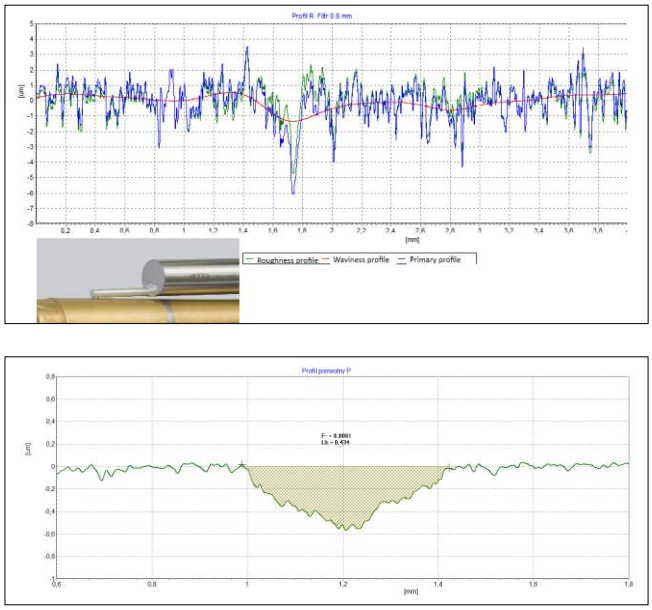


Fig. 2. Roughness measurement with TOPO 02 profilometer

Fig. 2 and 3 show examples of measurements made with TOPO 02 profilograph and shapeograph.

Due to the variety of shapes and the often complex geometry of the tested products, a 2 mm head is widely used, working with interchangeable measuring tips with different blade heights and a 2 µm rounding radius. This construction allows to verify the surface quality of samples that could not be measured using previous (standard) solutions. The head with a range of 2 mm is especially designed for roughness measurements in holes, recesses and grooves and for the measurement of microspheres. Exchangeable tips of this head expand the measuring capabilities and facilitate the measurement of the outlines of small elements.

The software for analyzing the results of measurements of the TOPO 02 system developed in IAMT (IZTW) allows to calculate practically all parameters included in the ISO and PN-ISO standards describing the tested surfaces and related to their functional properties. It is fully compliant with the recommendations on measurements of surface topography presented in the standards.

The software allows not only quantitative and statistical analysis of the calculated parameters, but also a qualitative analysis based on a number of charts, such as: stereometric view of the surface, contour map, material share curve, graphs containing markings of the roughness core and parameters related to the volume. The strength of this software is the option of various processing of measured data. In addition to the standard Gauss filter, the Topography program also includes algorithms for: morphological, resistant Gauss, spliced and wavelet functions, so that each user can adjust the data analysis to obtain only relevant information for a given research problem.

As a result of works carried out in IAMT (IZTW) in the TOPO 02 measuring system, modifications have been introduced in measurement data processing algorithms, including the correction of measuring head guiding.

Shape measurements are made with the TOPO 02 formograph, equipped with a digital head with a measuring range of 50 mm and a resolution of 0.1 µm.

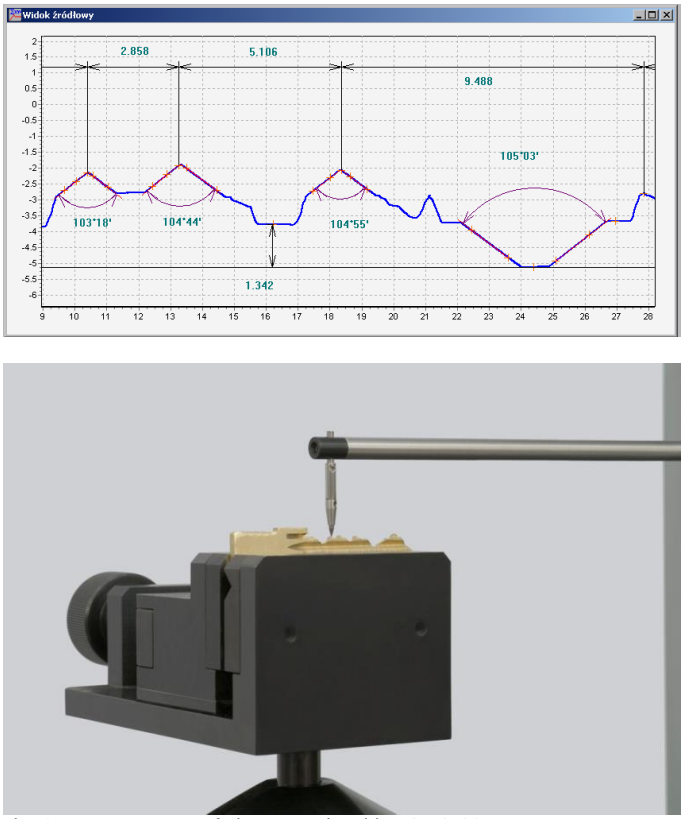


Fig. 3. Measurement of shape made with TOPO 02

The program for analyzing the shape of the shape, including algorithms for dimensioning distances, angles and radii and other geometrical quantities, is very user-friendly. In the case of repeatable measurements of products, it is possible to use the automatic dimensioning algorithm, which is particularly useful in the control of serial production.

In the Longitude and Angle Measurement Laboratory (fig. 4), the coordinate measuring machine Linea 10.7.5, developed in IAMT (IZTW), is used with a measuring range of 700 mm × 1000 mm × 500 mm.

Fig. 4. Laboratory of Length and Angle Measurements

In the software of the machine used for measurements performed as part of the accreditation, procedures of spatial geometry correction and temperature compensation were used, which improved the metrological parameters of the machine, and hence – increased the quality of measurements.

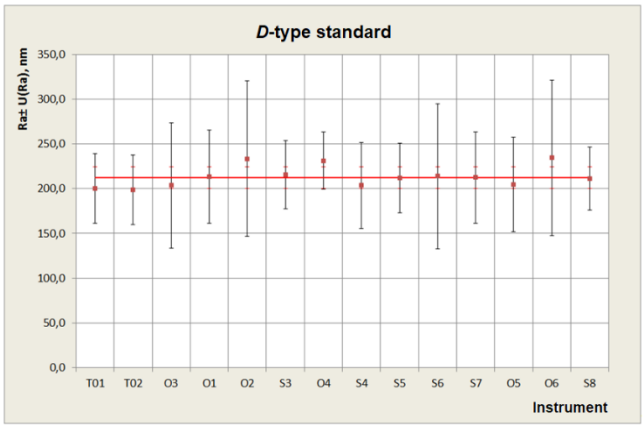


Fig. 5. Example of comparison of the *Ra* parameter determined for the *D*-type standard

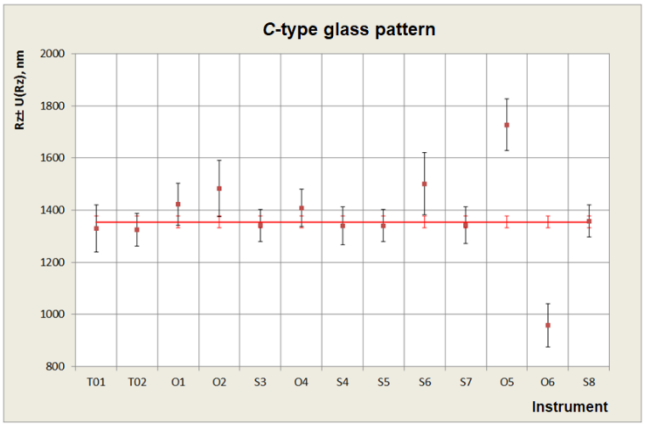


Fig. 6. Comparison of the *Rz* parameter determined for the *C*-type glass pattern

Research carried out at IAMT (IZTW) as part of research and development works concerned, inter alia, the influence of temperature on the stability of the machine and problems related to the determination of the error map and their compensation [1, 2]. The basic parameters defined in the thermal compensation system of machines are the coefficients of thermal expansion (CTE) of the machine axis and the measured object. Proper determination of them is the basis for the correctness of the system operation, because improperly introduced coefficients in extreme cases lead to incorrect results, worse than in the absence of thermal compensation. Similar research was carried out in the field of surface topography.

Fig. 5 and fig. 6 present sample comparisons of measurement results made using instruments from different companies in different laboratories. *Si* markings apply to instruments in which surfaces were mapped using contact methods, *Oi* – using optical methods; *T01* and *T02* are the designations of the TOPO 01 and TOPO 02 systems.

Fig. 5 compares the *Ra* parameter designated for the *D*-standard in measurements using various devices and various programs with which these instruments cooperate. On the basis of the comparison of test results, it can be concluded that *Ra* parameter measurements are or are close to the determined confidence interval and to the determined mean value. However, the areas of uncertainty given by some laboratories are very large, which may have been caused by the results.

The results obtained for the *Rz* parameter determined using some instruments, in particular optical ones, differ significantly from the determined confidence interval and mean value (fig. 6). This may be due to the material of the surface being tested (glass pattern). The results of measurements made with IAMT (IZTW) instruments are close to the mean value and are within the confidence interval. The tests have shown that the measurements carried out with instruments developed in IAMT (IZTW) do not depend on the type of material being tested

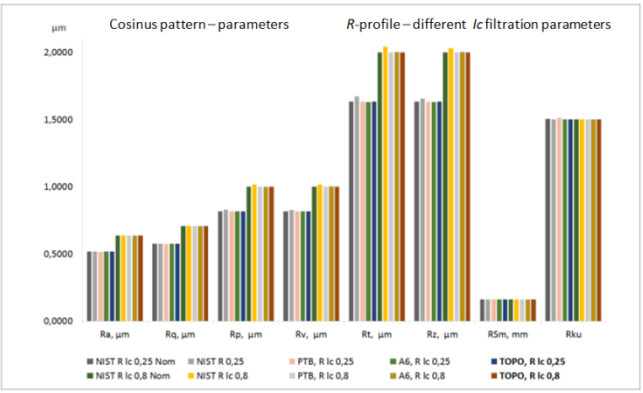
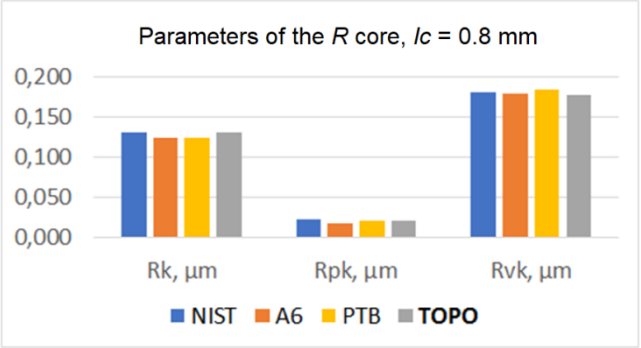


Fig. 7. R profile parameters for the "cosine" standard calculated in different programs with different *lc* filtrations



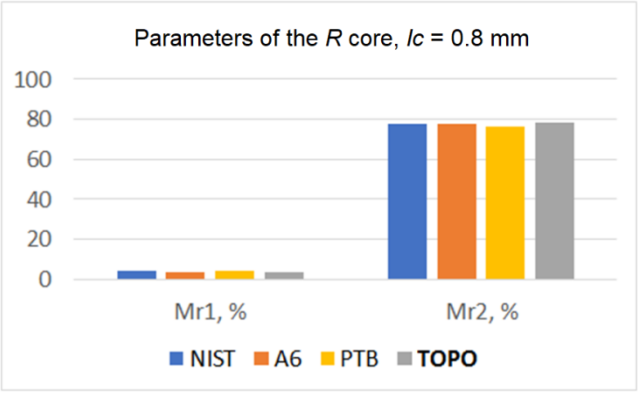


Fig. 8. Parameters of the *R* profile roughness core for the "polish" pattern calculated in various programs for *lc* = 0.8 mm

Fig. 7 and fig. 8 compare calculations performed in the Topography software (TOPO) and other programs, such as the National Institute of Standards and Technology (NIST), Physikalisch-Technische Bundesanstalt (PTB) and Altimap (MountainsMap from Digital Surf – marked as A6).

This proves that the calculation algorithms used in the Topography program for determining parameters are correct. The Topography software can be considered reliable in terms of proven algorithms.

Many articles and books have been published about methods of dealing with equipment in laboratories and errors that can be made during measurements [3–9], but

nothing substitutes for reliable knowledge, practice and experience. Therefore, the confirmed competences of the personnel performing the measurements are extremely important and must meet the highest standards.

High reliability of measurements performed in the IAMT (IZTW) accredited laboratory was achieved as a result of research and development works and projects implemented in IAMT (IZTW). The tests also verified the repeatability of results under the conditions of confirmed reproducibility of measurement conditions, the comparability of measurement results with results obtained from measurements of the same samples with devices of other manufacturers, in other laboratories, and comparability of calculated parameters of surface topography by comparison with calculations of the same data in other programs. The research and analysis carried out by the laboratory staff showed that the results obtained in the IAMT (IZTW) laboratory do not differ from the results obtained with the use of other devices and programs to analyze the geometric structure of the surface, considered correct and included in the calculation of average values, in accordance with the compliance indicator *En*.

The research was carried out as part of the statutory activity of IAMT (IZTW), and the analyzes concerning the comparison of the results of surface topography measurements with measurements using other devices were carried out as part of the project No. PBS2/A6/20/2013 "Research and assessment of reliability of modern methods of surface topography measurements in micro and nano scale" , financed by the NCRD.

REFERENCES

1. Gogól J. „Zagadnienia termiczne w obrabiarkach i współrzędnościowych maszynach pomiarowych – różnice i podobieństwa”. *Mechanik*. 11 (2014): pp. 892–895.
2. Gogól J. „Analiza zjawisk termicznych we współrzędnościowych maszynach pomiarowych z użyciem systemów CAD”. *Mechanik*. 12 (2015): pp. 950–953.
3. Leach R.K., Giusca C.L., Haitjema H., Evans C., Jiang X. “Calibration and verification of areal surface texture measuring instruments”. *CIRP Annals – Manufacturing Technology*. 64, 2 (2015): pp. 545–548.
4. Miller T., Adamczak S., Świderski J., Wieczorowski M., Łętocha A., Gapiński B. “Influence of temperature gradient on surface texture measurements with the use of profilometry”. *Bulletin of The Polish Academy of Sciences. Technical Sciences*. 65, 1 (2017): pp. 53–61. DOI: 10.1515/bpasts-2017-0007, impact factor 1,087 (2015), https://www.degruyter.com/view/j/bpasts.2017.65. issue-1/issue-files/bpasts.2017.65.issue-1.xml.
5. Miller T. „Źródła niewiarygodności pomiarów topografii powierzchni”. *XVI Krajowa VII Międzynarodowa Konferencja Naukowo-Techniczna „Metrologia w technikach wytwarzania”* MWTW, 22–23.09.2016, Opole. *Mechanik*. 11 (2016): pp. 1722–1723.
6. Pawlus P., Wieczorowski M., Mathia T. “*The errors of stylus methods in surface topography measurements*”. Szczecin: ZAPOL, 2014.
7. Vorburger T.B., Renegar T.B., Zheng A.X., Song J.-F., Soons J.A., Silver R.M. “*NIST Surface Roughness and Step Height Calibrations, Measurement Conditions and Sources of Uncertainty*”, www.nist.gov/pml/div683/grp02/upload/nistsurfcalib.pdf (access: 19.03.2014).
8. Wieczorowski M., Gapiński B., Grochalski K., Miller T. „Badania doświadczalne wybranych źródeł błędów w profilowych pomiarach nierówności powierzchni” (“Experimental research of selected sources of errors in profile measurements of surface asperities”). *Mechanik*. 4 (2017): pp. 339–343.
9. Wieczorowski M., Gapiński B., Grochalski K., Miller T. „Teoretyczne aspekty analizy wybranych źródeł błędów w profilowych pomiarach nierówności powierzchni” (“Theoretical aspects of analysis of selected sources of errors in profile measurements of surface asperities”). *Mechanik*. 4 (2017): pp. 335–338.

Translation of scientific articles, their computer composition and publishing them on the website www.mechanik.media.pl by original articles in Polish is a task financed from the funds of the Ministry of Science and Higher Education designated for dissemination of science.

Ministry of Science and Higher Education
Republic of Poland