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THE EFFECT OF MEASUREMENT METHOD FOR ASSESSING STEREOMETRIC STRUCTURE OF SURFACE

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Abstract

The article presents the influence of measuring methods of surfaces topography evaluation. Surface topography was measured using a mechanical, contact method by Hommel Tester T-8000-R60 profilometer (Gdynia Maritime University) and using the contactless, optical method by Olympus Lext OLS4100 Confocal Laser Scanning Microscope (Gdynia Maritime University). A pattern of roughness grade 4 sample was studied (standards PN-58/M-02425 (Ra=10 µm, Rz=40 µm)). Seven measurements were made on each of devices, resulting in a more accurate stereometric image of the sample surface. The area of the test was 1.5×1.5 mm. The radius of the edge of the blade imaging the surface used in the contact method was 2 µm. In the case of the optical method, the test sample surface was subjected to a laser light 405 nm long. This article describes the principle of used measuring instrument operation and their advantages and disadvantages. The results and descriptive statistics (Mann–Whitney U test, Kolmogorov–Smirnov test) of surface altitude parameters, such as Sa, Sp, Sq, Sv, Sz. There were statistically significant differences in topography values between measurements by T-8000 profilometer and Confocal Laser Scanning Microscope. It was noted that the values of the parameters Sa, Sq are higher with the T-8000 profilometer as a measuring device. The parameters Sp, Sv, Sz have a higher value, when measured on a Confocal Laser Scanning Microscope.

Keywords: *top layer, roughness, contact profilometer, confocal laser microscope, surface topography*

1. Introduction

All real surfaces are characterized by unevenness, which affects their properties shape and the structure and dimensions of inequalities can vary widely [1]. Finished items have characteristic surface roughness, depending on the various surface treatments tools and materials used [3]. For the needs of many branch of science, a description of the area with very small inequalities is made. One of the uses of surface analysis is to use it to monitor materials produced in machine engineering subjected to a variety of machining operations (for example, turning milling, grinding) resulting in material loss and surface roughness changes [3]. Surface analysis allows to assess the correctness of the cooperation of machine elements, devices and pressure measurements of two surface that are in contact with each other, where the accuracy of shapes and dimensions is important, but also the surface layer of the surface itself [4]. Most processes of machine wear are three-dimensional or topographic phenomena. Three-dimensional images allow to better presenting the nature of machining and operating processes [5]. Methods of measurement of surface inequalities can be divided by the physical phenomena used in them. On this basis, the following are distinguished: mechanical, optical, electrical, pneumatic, electron microscopy and other methods [1].

The mechanical method of measuring surface inequalities used during the test is the contact method where contact between the measuring instrument and the surface to be tested is required. Measurements using the contact method consist in mapping the surface profile with a blade pressed against the surface with a fixed force of several mN. With contact technology, it is important for the contact pressure to achieve the right contact surface. This pressure causes elastic deformation in both the measured object and the measuring instrument used. Often the blade used in these methods may, during the measurement, damage the delicate surface, contaminate or alter its physical properties [2]. Because of this, interest is growing, optical method, contactless, using the phenomenon of light scattering through uneven surfaces [1]. The microscope enables surface observations with precision at the nanometre level of the surface geometry. The Lext microscope minimizes short-wave aberrations allowing the generation of detailed optical images.

Five parameters describing the altitude features (Sg, Sp, Sv, Sz, Sa) were used for the analysis of the topography of the surface by contact and optical methods. Height parameters represent the class of surface finish parameters that quantify the axis perpendicular to the surface. They are included in ISO25178. The reference plane for calculating these parameters is the mean plane of the surface to be measured:

Sq – height of the average quadratic surface (profile), the mean average square deviation of the surface [6],
Sp – maximum peak height, the mean height from the highest peak and middle plane,
Sv – maximum height of recess, the mean depth from the middle plane and the deepest valley,
Sz – maximum height, the mean height from the highest peak and the deepest valley [6],
Sa – arithmetic mean of the Surface deviations being the arithmetic mean of the absolute altitude [4].

2. Advantages and disadvantages of surface topography methods

By choosing a surface topography measurement method, remember that they have defects and advantages that may affect the measurement results. Contact methods have the following disadvantages:

– needle contact with test surface, despite the small amount of pressure force, causes plastic deformation of the surface, depending on the hardness of the test material [2],
– long-time measurement of speed. The speed of the needle travel cannot be too high (from 0.1 to 3 mm/s), because this results in inaccurate surface penetration and incorrect parameter values readings,
– no possibility of measuring low hardness materials.

The advantages of contact methods are:

– lack meaning of optical characteristics of the test surface (light reflection coefficient) on the measurement result [2],
– physical reflection of the surface to be measured,
– optical methods, contactless, have the following disadvantages:
– influence of the optical characteristics of the test surface (light reflection from flat surfaces). No continuity of measurement at partial diffusion or absorption of light [2].

The advantages of optical methods include:

– no physical contact with the test surface. This makes it possible to carry out measurements low hardness materials,
– short measurement time.

3. Methodology of research

As a sample for surface topography, the qualitative roughness standard of class 4 (PN-58/ M-02425 (Ra=10 μm, Rz=40 μm)) was used. Roughness patterns are used to control the quality of the surface of metal products. They allow you to pre-check your research. The surface of the tested sample was 1.5×1.5 mm.

For testing by the contact, method used Hommel Tester T-8000-R60 contact profilometer, located at the Faculty of Marine Engineering of the Gdynia Maritime University. Needle mapping the surface profile is made of diamond. The radius of rounding of the tip of the needle is 2 µm. During measure, the needle moves along the surface. Changes in its position in a direction perpendicular to the direction of travel depend on the dimensions and shapes of the inequality. The data is processed into a measurement signal and recorded as a series of points (point mesh scan). This allows you to determine the exact parameters and functions of surface inequalities [5]. The device is equipped with a table to control the movement in the direction of the Y-axis. Measurement resolution in the X-axis is 0.1 µm, Y-axis 0.5 µm, Z-axis 10 nm. Surface topography measurement using the contactless method was performed on the Olympus Lext OLS4100 Confocal Laser Scanning Microscope, located at the Faculty of Marine Engineering of the Gdynia Maritime University. A Confocal Laser Scanning Microscope is an optical device in which one of the light sources is a laser with a wavelength of 405 nm. During the surface topography measurements, a 20x magnification lens was selected. The surface of the test sample is scanned point by point with a confocal scanner. A photomultiplier that measures light intensity at each point is used to detect the signal. Placed in front of the photomultiplier the confocal shutter cuts off light reflected from the surface and coming from outside the focus plane. Three-dimensional information from subsequent surfaces is obtained by moving the lens in the Z-axis. Z-axis motion control is precise thanks to the 1 nm liner system. The intensity map created in this way is used to reconstruct the sample surface in a 3D image. Test results obtained from the profilometer were analysed by MapExpert 5 software, and from the Confocal Laser Scanning Microscope through a microscope integrated software.

4. Results and analysis of research

For each test, area of 1.5×1.5 mm the parameters and the 3D view of the surface were determined which accurately shows the topography of the examined surface the number of peaks and recesses and their frequency. Generated by the program, the 3D view allows observing surfaces from different perspectives (angles of rotation and tilt). It is possible to enlarge any part of the surface and cut off its parts with planes parallel to the median plane (simulating wear). The 3D view of the sample topography performed on the T-8000 profilometer is shown in Fig. 1.

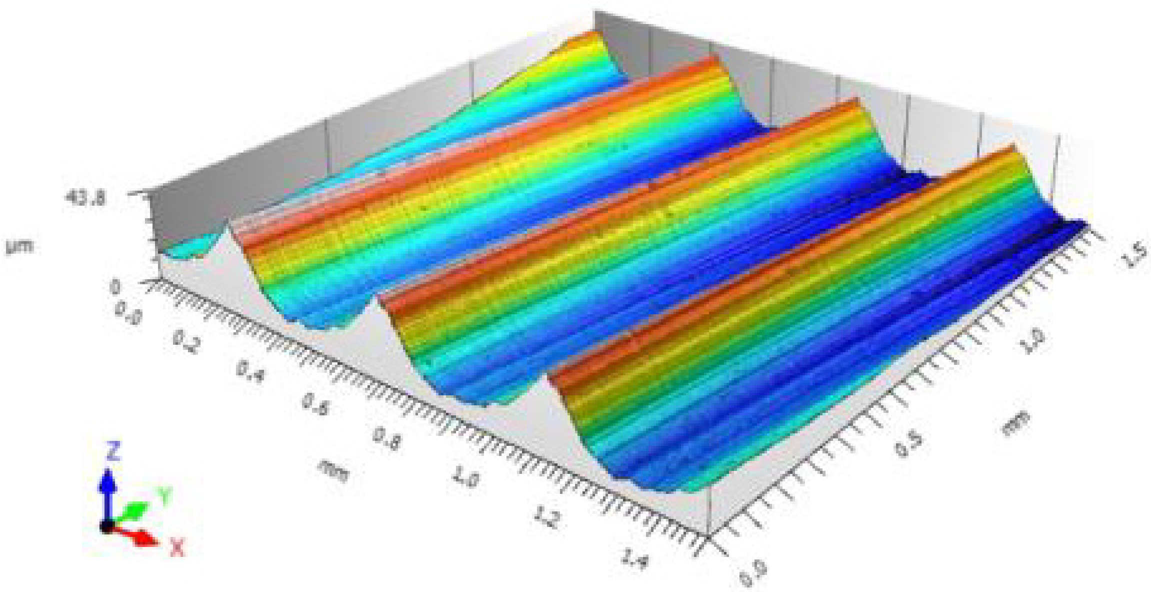

Fig. 1. 3D view of surface topography measurement done on T-8000 profilometer

A 3D view of the topography of the sample surface made on the Confocal Laser Scanning Microscope Lext OLS4100 is shown in Fig. 2.

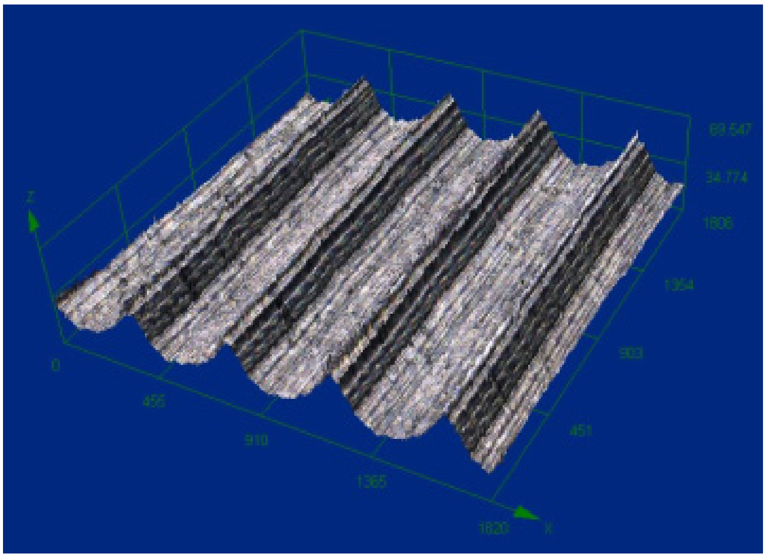

Fig. 2. 3D view of surface topography measurement done on Confocal Laser Scanning Microscope Lext OLS4100

For analysis of the measurement, results by contact and optical method five parameters describing the altitude features were used: Sg, Sp, Sv, Sz, Sa. In the presented results, it was noted that in every measurement the values of Sq, Sa are always higher when measured on a profilometer. Adequately, the parameters Sp, Sv, Sz have higher values, obtained by a confocal laser microscope. The parameter descriptive statistics are shown in Tab. 1. The Lext OLS4100 Confocal Laser Scanning Microscope surface histogram is shown in Fig. 3. The graph of surface topography measurements on the T-8000 profilometer is shown in Fig. 4.

Fig. 3. Graph of surface topography measurements on Confocal Laser Scanning Microscope Lext OLS4100

In order to determine the significance of differences in Surface topography results a non--parametric test was used to compare the distributions of the one-dimensional statistical features of Kolmogorov-Smirnov test and the equivalent of the classic t-student's test for unrelated U Mann-Whitney test. The U Mann-Whitney test for parameters Sa, Sz, Sq, Sp, Sv is presented in Tab. 2. The Kolmogorov-Smirnov test for parameters Sa, Sz, Sq, Sp, Sv is presented in Tab. 3.

The differences between these devices resulting from the physical phenomena they use do not only affect the duration of the test but may also affect the results of the measurements. Because the sample is, roughness pattern and research relate to topography, you cannot expect identical

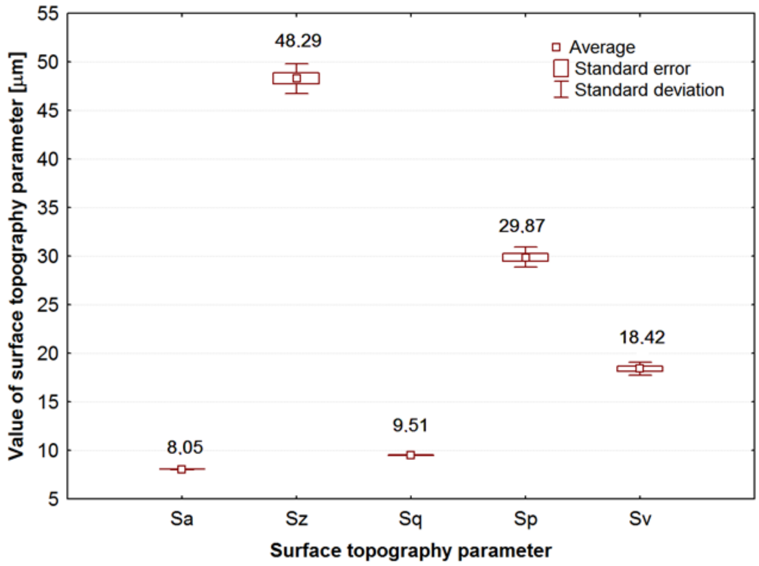

Fig. 4. Graph of surface topography measurements on T-8000 profilometer

Tab. 1. Descriptive statistics of the Sa, Sz, Sq, Sp, Sv parameters

Descriptive statistics of the Sa parameter							
Variable	Measuring instrument	N important	Average	Min.	Max.	Standard deviation	Standard error
Sa	Lext OLS4100	7	8.0497	8.039	8.06	0.01	0.0038
	T-8000	7	8.65	8.27	9	0.3	0.1139
Sz	Lext OLS4100	7	48.22657	45.607	49.786	1.6183	0.611667
	T-8000	7	44.3	43.8	44.6	0.3266	0.123443
Sq	Lext OLS4100	7	9.50557	9.494	9.521	0.010454	0.003951
	T-8000	7	10.15	9.85	10.4	0.219848	0.083095
Sp	Lext OLS4100	7	29.87014	28.152	30.769	1.031876	0.39
	T-8000	7	27.52857	26.5	28.3	0.67011	0.253278
Sv	Lext OLS4100	7	18.42271	17.455	19.095	0.669715	0.253128
	T-8000	7	16.77143	15.5	18	0.890158	0.336448

Tab. 2. Mann–Whitney U test for parameters Sa, Sz, Sq, Sp, Sv

U Mann–Whitney test (important results $p < 0.05$)				
Variable	Sum rang Lext OLS4100	Sum rang T-8000	Z	Level p
Sa [µm]	28	77	–3.1305	0.001745
Sz [µm]	77	28	3.13	0.001745
Sq [µm]	28	77	–3.1305	0.001745
Sp [µm]	76	29	3.00272	0.002676
Sv [µm]	73	32	2.619394	0.008809

measurement values but only approximations. After analysis, statistically significant differences in Surface topography between measurements on the T-8000 profilometer and Lext OLS4100 Confocal Laser Scanning Microscope were found. On this basis, it can be stated that the choice of the measurement method is important and affects the correct assessment of the topography of the surface. By choosing a method of Surface topography, it is important to remember that they have advantages and disadvantages that may affect the measurement results.

Tab. 3. Kolmogorov–Smirnov test for parameters Sa, Sz, Sq, Sp, Sv

Kolmogorov–Smirnov test (important results p <0.05)							
Variable	Max. negative difference	Max. positive difference	Level p	Average Lext OLS4100	Average T-8000	Standard deviation Lext OLS4100	Standard deviation T-8000
Sa [µm]	–1	0	$p < 0.005$	8.0497	8.65	0.01	0.3
Sz [µm]	0	1	$p < 0.005$	48.22657	44.3	1.618319	0.326599
Sq [µm]	–1	0	$p < 0.005$	9.50557	10.15	0.010454	0.219848
Sp [µm]	0	0.857143	$p < 0.025$	29.87014	27.52857	1.031876	0.67011
Sv [µm]	0	0.714286	$p < 0.10$	18.42271	16.77143	0.669715	0.890158

5. Conclusions

After analysis, statistically significant differences in surface topography between measurements on the T-8000 profilometer and Lext OLS4100 Confocal Laser Scanning Microscope were found. In the presented results it was noted that in every measurement the valves of the parameters Sq, Sa are always higher measured by a profilometer. Adequately, the parameters Sp, Sv, Sz have a higher value, measured by a Confocal Laser Scanning Microscope. On this basis, it can be stated that the choice of the measurement method is important and influence on the correct assessment of surface topography.

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