Tools for comparative analysis of a surface texture formed by turning

Narzędzia do analizy porównawczej stanu struktury geometrycznej powierzchni ukształtowanej toczeniem

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The paper presents methods of evaluating the surface texture machined by turning using individual groups of parameters and selected SGP functions. Surface parameters obtained using different feed rates were analyzed.
KEYWORDS: surface texture, 3D surface texture parameters

In recent years, development of new techniques for measuring the geometrical structure of surfaces belonging to the classification system presented in PN-EN ISO 25178-6:2011 [8], defining the class of linear profiling methods and methods of spatial topography, has enabled new parameters and functions that characterize surface topography.

In industrial practice, however, only contact-oriented roughness measurement methods using hand-held contact profilometers with slides or laboratory contact gauges without a slider are used to measure the primary profile, consisting of a form, waviness and roughness profile. The roughness parameter *Ra*, i.e. the arithmetic mean of the ordinates of the profile [1], is practically used only.

Measurements of the surface topography allow better describe the nature of the surface. Most of the surface interaction is three-dimensional, so its description cannot be restricted to profile analysis.

At the end of the twentieth century, as a result of work carried out at the University of Birmingham, the first 14 number of parameters describing the 3D surface irregularities were defined. These parameters are: amplitude (*Sq, Sz, Ssk, Sku*), spatial (*Sds, Std, Str, Sal*), hybrid (*Sdq, Ssc, Sdr*) and functional (*Sbi, Sci, Svi*). They were published in the famous "Blue Book" [5]. The surface geometry specification is contained in PN-EN ISO 25178-2:2012 Product geometry specifications (GPS) - Geometric structure of the surface: Spatial - Part 2: Terms, definitions and parameters of the surface geometry [7]. This norm defines parameters in the following groups: amplitude parameters, spatial parameters, hybrid parameters, functions and related parameters as well as other parameters.

Contemporary software packages for geometric surface analysis allow to calculate dozens of parameters. All parameters for a given surface type are unreasonable. Selection of the parameters specific to an application providing complete surface characteristics, requires knowledge and experience of performing such analysis. Correct selection of parameters is aimed at answering the question whether the examined geometrical structure of the surface will be able to provide the necessary structural and operational values.

Selection of parameters for the evaluation of the geometrical structure of the surface should be preceded by analysis of the structural design of the element and operating conditions. Type of contact of the test surface with other elements (rigid, resilient), type of load (static, dynamic) should be considered and whether it is a moving surface [2, 3, 6].

Research object

Measurements were made on cylindrical elements made of WCL steel with a diameter of 49 mm. Machining took place on the turning center DMG Alpha 500 with the following parameters:

- cutting speed v_c - 360 m/min,
- feedrate per revolution f_n - 5, 30, 60, 90, 120, 150 μm/rev,
- cutting edge radius r_n - 7.8 μm,
- corner radius r_ε - 0.8 mm,
- DCGT 11 T3 08 - UM 1125 plate.

The effect of the treatment was to obtain a directed, periodic surface area with unequalities of wavelength corresponding to feedrate per revolution and an amplitude not exceeding 2 mm [4].

Measuring instrument and software

Geometric measurements were performed using a Talysurf CCI optical instrument using the Coherent Correlation Coefficient method, a group of spatial topography methods with *Z* axis measurement range of 2.2 mm and a resolution of 10 pm, in which the image analysis is based on a 1024×1024 points. The measurements were made using a magnification of ×10 that allows the area of 1.66×1.66 mm to be scanned at a resolution of 1.66×1.66 μm. An analysis of larger areas allows the option of combining individual measurements. TalyMap Platinium software was used to analyze the measured area.

Analysis of results

The purpose of the considerations is to present the possibility of using the individual tools to analyze the geometrical structure in comparison with the simple

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measurement based on the determination of the *Ra* parameter.

The results of measurements of the mean values of *Ra* roughness parameters together with the standard deviation of six details produced with different feedrates are presented in Table I.

TABLE I. Measurements of *Ra* and *s*

Parameter	Feedrate, μm/rev					
	5	30	60	90	120	150
Ra, mm	0,166	0,176	0,234	0,405	0,416	0,415
s, mm	0,074	0,044	0,036	0,048	0,102	0,049

Those measurements allow to obtain minimal information on the measured surface.

Topography measurement enables preliminary analysis by interpretation of isometric surface images. Fig. 1 shows the isometric images obtained at the extreme feedrate values. The nature of these surfaces is different. The first surface is oriented by periodic low-level deterministic while the other is determined directed periodic surface.

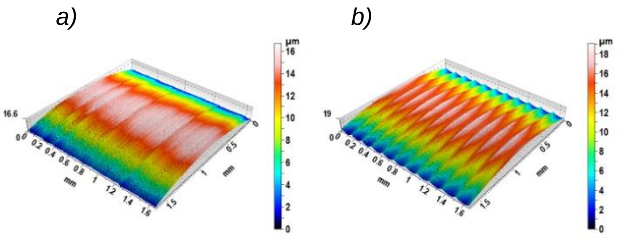

Fig. 1. The isometric surface for the feedrate: *a)* 5 μm/rev, *b)* 150 μm/rev

The isometric images of the individual surfaces after removal of the nominal form are shown in fig. 2. It can be observed how the feed value in a gradual manner influences the character of the surface obtained: from the periodically oriented surface with a low level of determination to a targeted periodic determination.

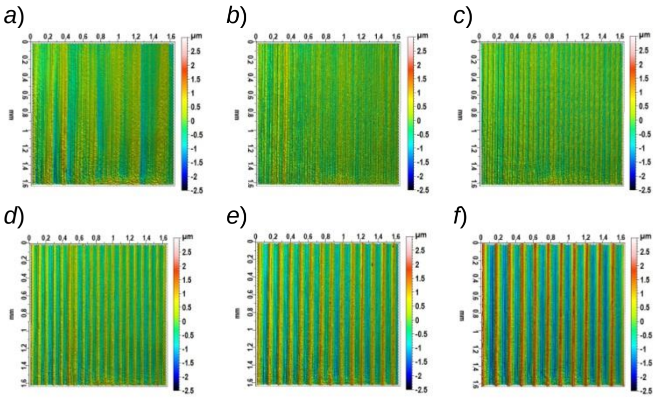

Fig. 2. Surface isometric image for feedrates: a) 5 μm/rev, b) 30 μm/rev, c) 60 μm/rev, d) 90 μm/rev, e) 120 μm/rev, f) 150 μm/rev

In the power spectral density distribution, there is only one component corresponding to the feedrate value for the higher feedrate values. As the feedrate value decreases, additional periodic components appear in addition to the determinant corresponding to the feedrate value associated with the distortion caused by the plastic deformation of the material. Fig. 3 shows the power spectral density distributions obtained for extreme feed values.

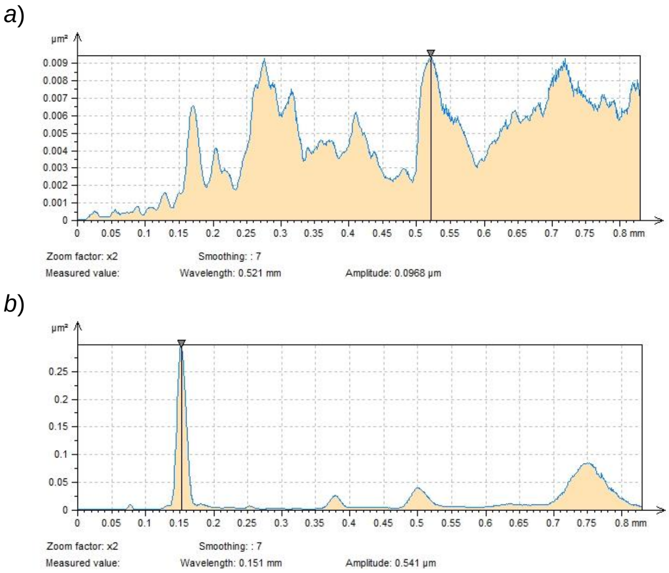

Fig. 3. Distribution of power spectral density for feedrates: *a)* 5 μm/rev, *b)* 150 μm/rev

The distribution of surface ordinates as a function of the feedrate varies: from the near normal to the smallest feed to the theoretical radial distribution characteristic for fine finishing.

Fig. 4 shows the depths histogram of surface elevations and Abbott-Firestone curve obtained using extreme values of feed rates. The Abbott-Firestone curve is confirmed by the values of *Ssk* - asymmetry and *Sku* - concentration coefficient (kurtosis) (Table II). As the feedrate increases, the slope coefficient increases: from small negative values to positive ones, indicating the right-angled slope.

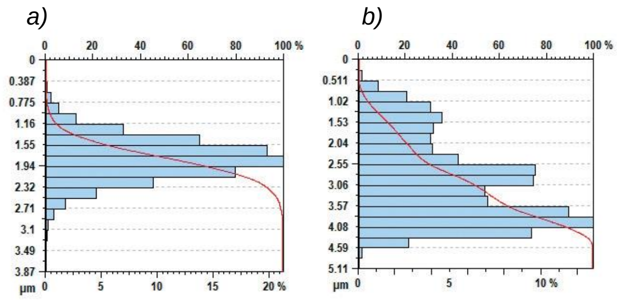

Fig. 4. Distribution of surface ordinates for feedrates: a) 5 μm/rev, b) 150 μm/rev

TABLE II. Results of Ssk and Sku parameters measurements

Parameter	Feedrate, μm/rev					
	5	30	60	90	120	150
Ssk	-0,038	0,178	0,105	0,383	0,338	0,541
Sku	3,555	3,452	2,547	2,250	2,146	2,285

Changes in amplitude values of surface parameters in the function of feed have a very similar character. Minimum parameter values were obtained for a feedrate of 30 μm/rev. The nature of these changes for selected amplitude parameters is shown in fig. 5.

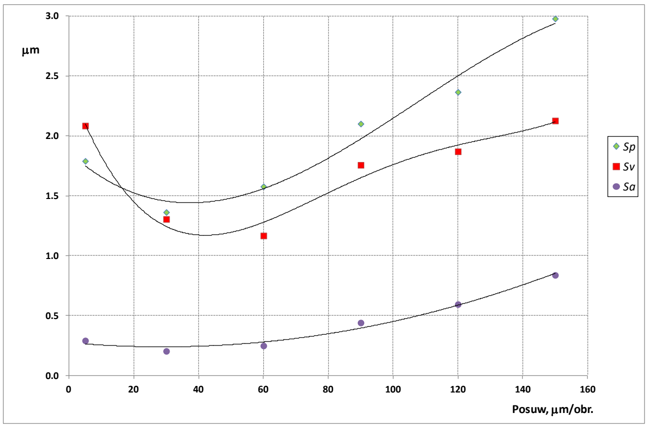

Fig. 5. Amplitude parameters: *Sp* - height of the highest elevation of the surface, *Sv* - depth of the lowest depression, *Sa* - arithmetic mean height of the surface

It is particularly noteworthy the way, in which the profiles of the original change depending on the applied feedrates. Decreasing the feed rate from 30 to 5 µm/rev produces a significant waveform component. Profile appears periodically determined from feed 90 µm/rev.

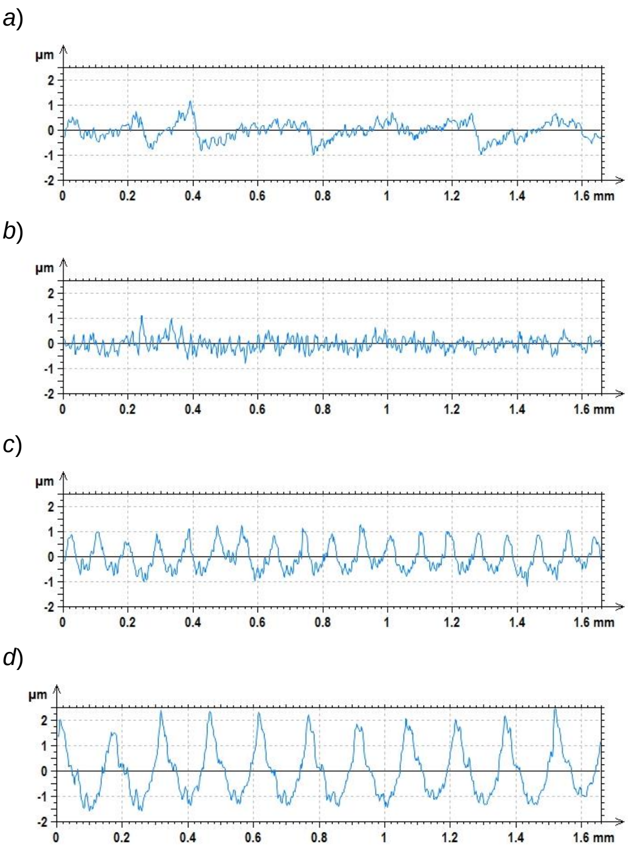

Fig. 6. Primary profiles for feedrates: a) 5 µm/rev, b) 30 µm/rev, c) 90 µm/rev, d) 150 µm/rev

Measurement results of hybrid parameters: *Sbi* carrier surface index, *Sci* index of liquid retention by core, and *Svi* index of liquid retention by cavity are shown in Table III.

TABLE III. Results of hybrid parameters *Sbi, Sci, Svi* measurements

Parameter	Feedrate, µm/rev					
	5	30	60	90	120	150
Sbi	0,314	0,274	0,285	0,438	0,619	0,914
Sci	1,522	1,574	1,605	1,677	1,771	1,841
Svi	0,119	0,103	0,098	0,067	0,058	0,046

All surfaces have similar liquid retention indexes across the core, while the largest liquid retention rates across the cavities are obtained at a feedrate of 30 µm/rev.

Conclusions

The surface roughness *Ra* values of elements produced with a feedrate ranging from 5 to 150 µm/rev are within a narrow range of 0.166 to 0.416 µm. However, it would be wrong to draw the conclusion that they have similar properties of the surface geometry. Only analysis with appropriate parameters, functions and tools allows to describe each of the obtained structures for the use of the measured surface.

The analysis showed that as the feed value increases, the nature of the surface changes drastically: from the periodic targeted low level of determinism to the random component and the significant component of the waveform to the targeted periodic surface.

As the feed rate increases, the nature of the ordinate distribution changes from the normal for the smallest applied feed to the theoretical radial distribution, and thus changes the shape of the load-bearing capacity and the associated parameters.

The parameter values reach the amplitude minima for the feed of 30 mm/rev.

Analysis of the distribution of power spectral density and specific profiles allows the identification of the component resulting from the applied feed and possible faults in the machine tool, and the object-holder tool.

Today's software for analyzing the surface geometry is equipped with a range of functions and tools for measuring data obtained during measurement. Their proper use, however, requires extensive knowledge in this field.

REFERENCES

1. Adamczak S. *„Pomiary geometryczne powierzchni. Zarysu kształtu, falistość i chropowatość”.* Warszawa: WNT, 2008.
2. Oczoś K., Liubimov V. *„Struktura geometryczna powierzchni. Podstawy klasyfikacji z atlasem charakterystycznych powierzchni kształtowanych”.* Rzeszów: Oficyna Wydawnicza Politechniki Rzeszowskiej, 2003.
3. Świderski J., Dobrowolski T. „Zasady dobrej praktyki dla pomiarów chropowatości powierzchni po bardzo dokładnym toczeniu”. *Mechanik.* 8–9 (2016): s. 1140–1141.
4. Skrzyniarz M., Nowakowski Ł., Miko E. „Opracowanie metody pomiarów przemieszczeń względnych narzędzia i przedmiotu obrabianego podczas toczenia”. *Mechanik.* 8–9 (2015): pages 577–585.
5. Stout K. et al. „The development of methods for the characterisation of roughness in three dimensions”. *European Report*. EUR 15178N,1993, ISBN 0704413132.
6. Blateyron F. „3D Parameters and New Filtration Techniques”. *Conference: JSPE*. Tokyo: 2006.
7. PN-EN ISO 25178-2:2012 Specyfikacje geometrii wyrobów (GPS) – Struktura geometryczna powierzchni: Przestrzenna – Część 2: Terminy, definicje i parametry struktury geometrycznej powierzchni.
8. PN-EN ISO 25178-6:2011 Specyfikacje geometrii wyrobów (GPS) – Struktura geometryczna powierzchni: Przestrzenna – Część 6: Klasyfikacja metod pomiaru struktury geometrycznej powierzchni.