The topographic characteristics of contact zones in the surface contact formed in the grinding process

Charakterystyka topografii stref kontaktu w połączeniach stykowych powierzchni kształtowanych w procesie szlifowania

WOJCIECH KACALAK
FILIP SZAFRANIEC *

DOI: https://doi.org/10.17814/mechanik.2017.10.148

In the publication a topographic characteristics of the contact zones in the contact joints for the surfaces formed in the grinding process was presented.
KEYWORDS: stereometric structure of the surface, grinding, contact joints

Analysis of topography of technical surfaces and their stereometric properties is an increasingly important task in assessing the quality of machining processes, as well as in assessing the quality of products and predicting their performance [1, 3, 12, 14]. The increase in the requirements for accuracy and properties of the components, the desire to reduce their weight and size (to minimize material consumption) and also to increase their load capacity and durability, as well as the development of production technology resulted in the development of many new methods of measurement and measuring equipment and a substantial larger number of parameters used in assessing the characteristics of stereometric surface.

The selection of such stereometric evaluation parameters of the technical surfaces that would constitute a complementary set would provide a high classification efficiency and be easy to interpret, still a difficult task. It requires solving many problems, developing and disseminating systems for computation and analysis, and supporting decision-making in line with design, technology, and operational decisions [2-8].

The surfaces used are usually designed to interact with other surfaces, so the placement, size and statistical characteristics of the potential contact fields are important [10, 11, 13, 15, 16]. Many well-known surface topography parameters of assessment stems from the perception of the area as a geometrical object. Taking into account the characteristics typical of the material object gives grounds for important studies [2, 13]. These were the basis for the development and application of new sets of parameters to evaluate stereometric features of surfaces [3-9, 15, 16] dependent on:

- values and characteristics of the distribution of the first derivative of the outline (including the statistical characteristics of values close to zero);
- decomposition of ordinate vertices of surfaces and outlines;
- distribution of hills and recesses in a particular direction;
- the size, location and distance of probable contact with a coordinated surface or with a statistically equivalent surface for specific surface conditions;
- distribution of tilt angles of lines connecting adjacent vertices of the surface;
- decomposition of the height-to-element ratio from the elevation field;
- distribution of the value of the ratio of the circumference to the element from the field of elevation of the surface over a certain level;
- features describing the shape of vertices of unequalities and their intersection at a given level.

Methodology of research

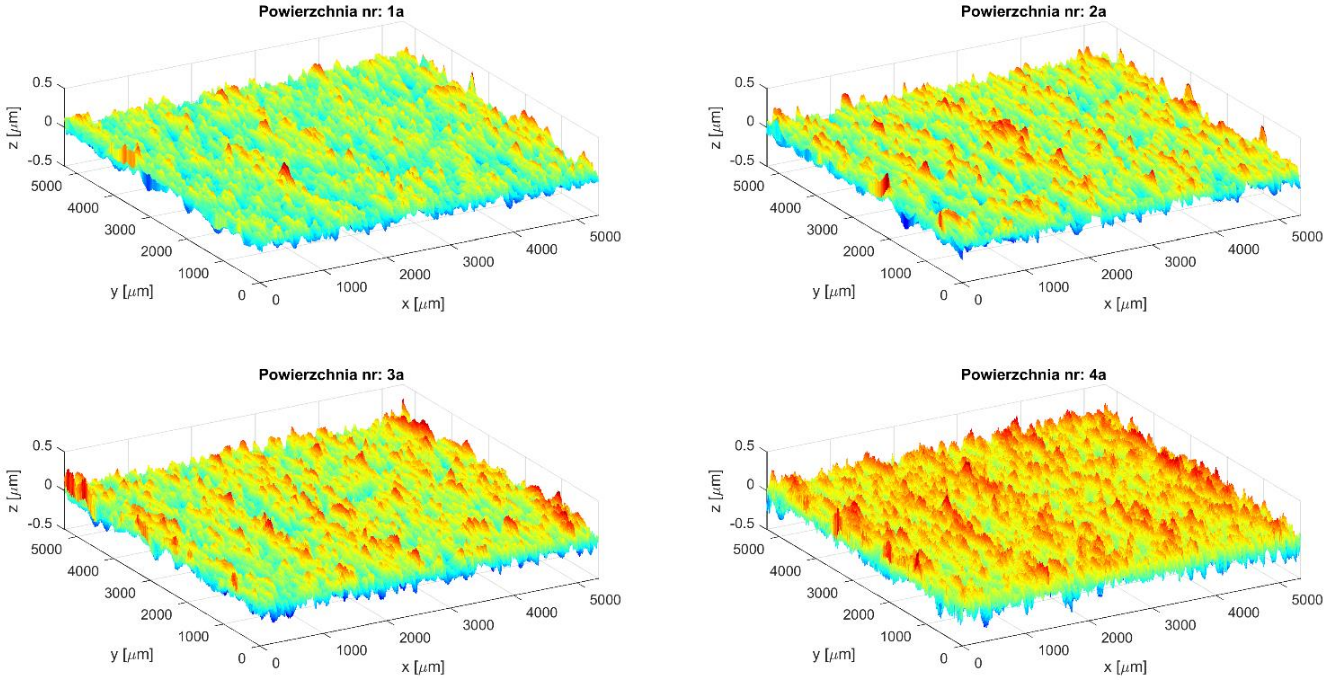
In order to determine the characteristics of the topography of the contact zones, four different surfaces were tested after the grinding process using the measuring system Talysurf CCI 6000 Taylor Hobson. For each of these surfaces made in the two data acquisition locations. Four pairs of surface fragments of 5.33 mm × 5.33 mm were obtained for which the amplitude parameters *Sa, Sq, Sp, Sv* and *St* were determined, and - additionally - the average volume of material on the *Smmr* unit surface and the mean volume of the *Smvr* recesses the measurements are shown in Table I). The 3D views the analyzed surface (No. 1a, 2a, 3a and 4a) are shown in fig. 1.

TABLE I. Surface 3D parameters after grinding, marked with symbols 1a-4b

	Sa	Sq	Sp	Sv	St	Smmr	Smvr
Nr	[μm]	[μm]	[μm]	[μm]	[μm]	[μm]	[μm]
1a	0.0602	0.0752	0.4101	0.2987	0.7088	0.2987	0.4101
1b	0.0704	0.0881	0.4782	0.3286	0.8068	0.3286	0.4782
2a	0.0613	0.0767	0.3572	0.3048	0.6620	0.3048	0.3572
2b	0.0715	0.0896	0.4564	0.3352	0.7916	0.3352	0.4564
3a	0.0637	0.0806	0.3625	0.3222	0.6847	0.3222	0.3625
3b	0.0747	0.0942	0.4138	0.3679	0.7792	0.3679	0.4138
4a	0.0738	0.0927	0.3960	0.4650	0.8610	0.4650	0.3960
4b	0.0880	0.1107	0.4636	0.5053	1.0282	0.5053	0.4636

* Prof. dr hab. inż. Wojciech Kacalak (wk5@tu.koszalin.pl), mgr inż. Filip Szafraniec (filip.szafraniec@tu.koszalin.pl) – Politechnika Koszalińska, Wydział Mechaniczny.

Fig. 1. 3D views of surfaces formed in the grinding process



An analysis of the features of the contact areas of these pairs of surfaces (the designation: *a* - for the first surface, *b* - for the second surface as the cooperating surface). For this purpose, MATLAB has developed applications that include procedures for determining the features of contact areas in surface proximity. The approximation values were taken from the lower limit range:

$$(\mathrm{St(a)} + \mathrm{St(b)}) - (\mathrm{Sa(a)} + \mathrm{Sa(b)})$$

where: *St(a)* and *St(b)* - values of *St* for *a* and *b* surfaces; *Sa(a)* and *Sa(b)* - values of *Sa* for *a* and *b* surfaces.

The tests were performed in the range of 5÷40% of the value (*St(a)* + *St(b)*). The surfaces were brought together with the parallelism (|) and the perpendicular (┴) directions of the machining traces. By combining all the areas of the *PS* contact area (fig. 2) at 40% (*St(a)* + *St(b)*), the total contact areas (Table II) were determined, which are considerably higher for contact joints with parallel machining positions.

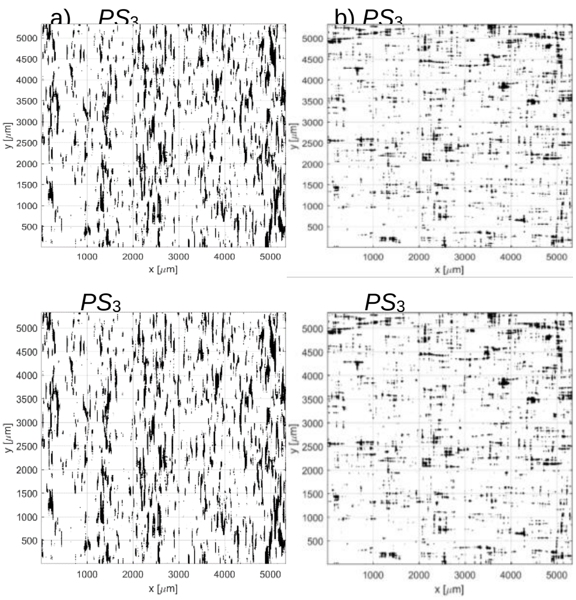


Fig.2 The contact areas of *PS* at 40% (*St(a)* + *St(b)*) for surfaces 3 and 4 (top view): a) contact joint for parallel processing (||), b) contact for perpendicular traces of processing (┴)

TABLE II. Total surface area of contact at 40% (St(a) + St(b))

	(┴)	(| |)
Total contact surface of analyzed area,mm^2	0.2032	1.2370
	0.7636	2.3304
	1.8495	3.8399
	5.8952	7.3838

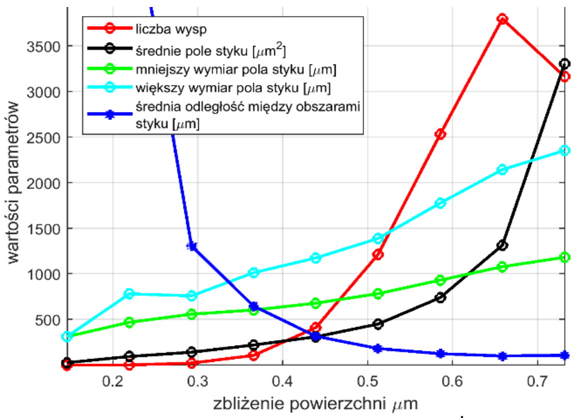


Fig. 3. Parameters of contact areas for surface 3 (┴)

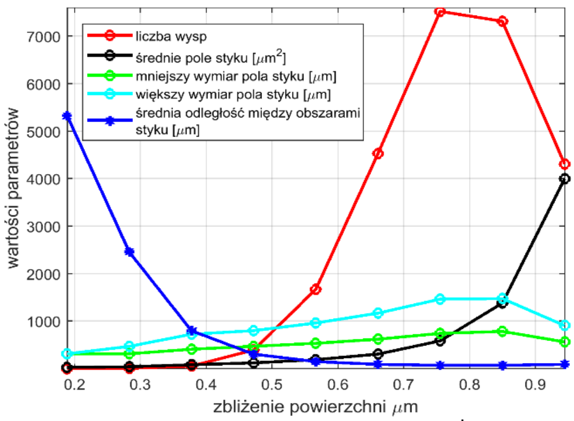


Fig. 4. Parameters of contact areas for surface 4 (┴)

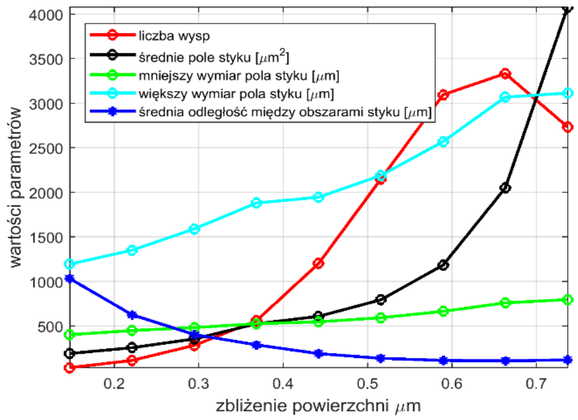


Fig. 5. Parameters of contact areas for surface 3 (||)

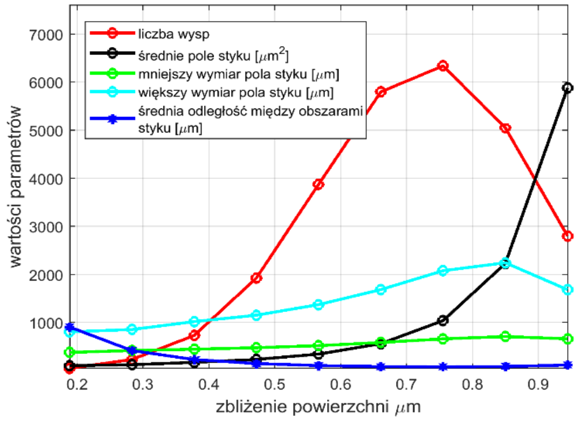


Fig. 6. Parameters of contact area for surface 4 (||)

For each level of proximity, the number of contact areas (islands), mean contact area, smaller area, and larger contact area, average distance between contact areas, were determined. The values of the contact area parameters for selected surfaces are shown in figs. 3-6.

Interpretation of results and conclusions

Parameters describing the contact areas of the cooperating surfaces, associated with the preservation of the parallelism of the machining traces and their perpendicularity, have the following features:

- Number of contact boxes for perpendicular traces of traces is small at slight close-ups and increases significantly for larger close-ups. The ratio of the number of contact areas for the approximation of 0.4 μm and the maximum number of fields is: for the area 3 - about 15, and for the area 4 - about 50.
- Number of contact areas for parallel traces of traces is quite large for small surface close-ups and gradually increases for larger close-ups. The ratio of the number of contact areas for the approximation of 0.4 μm and the maximum number of fields is: for surface no. 3 - about 4, and for surface 4 - over 6.
- Maximum number of contact areas for perpendicular traces is 140 to 285 mm^{-2}, and for parallel traces of traces - 115 to 220 mm^{-2}.
- Ratio of the area to the volume of material under the surface, describing the surface expansion, is correlated with the number of contact fields. The higher the average absolute value of the surface gradient, the greater the number of contact areas (fig. 7).

Described relationships give recommendations for maximizing the contact rigidity of the connections. Smoothing of the surface with small deviations of shape, resulting in a reduction in the amplitude of high frequency components (large gradient), reduces the number of contact fields, but significantly increases the contact area. The perpendicular traces of the traces can then be advantageous. Smoothing introduces new machining traces, which means that many contact features depend on topography - determined by grinding traces and subsequent smoothing.

Parameters often used in various analysis and set in Table I, have similar values, while parameters describing the features of potential contact areas allow for a distinct differentiation of the operating characteristics of the surface. This results in a classification ability and technical suitability of the parameters.

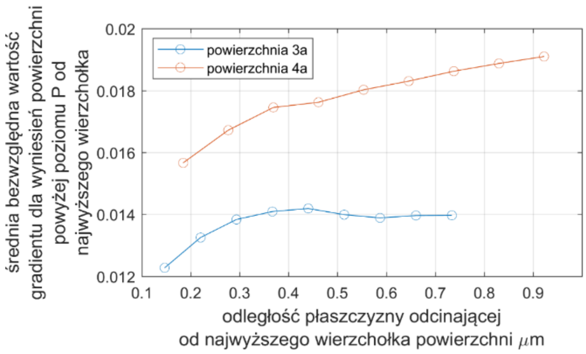


Fig. 7. Average absolute gradient value for surface elevations above *P* level determined from the highest vertex

REFERENCES

1. Grzesik W. „Wpływ topografii powierzchni na właściwości eksploatacyjne części maszyn". *Mechanik*. 88, 8–9 (2015): pages 587–893.
2. McCool J.I. "Comparison of models for the contact of rough surfaces". *Wear*. 107 (1986): s. 37–60.
3. Kacalak W. i in. „*System do analizy i oceny topografii powierzchni technicznych*". Projekt R03 040 03, 2010.
4. Kacalak W., Tandecka K. „Metrologiczne aspekty oceny topografii diamentowych folii ściernych do precyzyjnego mikrowygładzania". *Pomiary Automatyka Kontrola*. 5 (2011).
5. Kacalak W., Szafraniec F., Tomkowski R., Lipiński D., Łukianowicz Cz. „Metodyka oceny zdolności klasyfikacyjnej parametrów charakteryzujących cechy stereometryczne nierówności powierzchni". *Pomiary Automatyka Kontrola*. 57 (2011): pages 542–546.
6. Kacalak W., Tomkowski R., Lipiński D., Szafraniec F. „System oceny struktury geometrycznej powierzchni po obróbce ściernej". *Mechanik.* 8–9 (2014): pages 219–226.
7. Kacalak W., Szafraniec F., Ściegienka R. „Topografia powierzchni elementów ceramicznych szlifowanych z zastosowaniem ściernic o hiperboloidalnej powierzchni czynnej". *Mechanik*. 8–9 (2016): pages 1180–1182. DOI: 10.17814/mechanik.2016.8-9.307.
8. Kacalak W., Tandecka K., Mathia T.G. "A method and new parameters for assessing the active surface topography of diamond abrasive films". *Journal of Machine Engineering*. 16, 4 (2016): pages 95–108.
9. Kacalak W., Różański R., Lipiński D. "Evaluation of classification ability of the parameters characterizing stereometric properties of technical surfaces". *Journal of Machine Engineering*. 16, 2 (2016): pages 86–94.
10. Lipiński D., Kacalak W. "Metrological aspects of abrasive tool active surface topography evaluation". *Metrology and Measurements Systems*. 23, 4 (2016): pages 567–578. DOI: 10.1515/mms-2016-0043.
11. Lipiński D., Kacalak W. „Zastosowanie metod analizy obrazu do oceny powierzchni czynnej narzędzia ściernego". *Mechanik.* 8–9 (2016): pages 1152–1153. DOI: 10.17814 /mechanik. 2016.8-9.293.
12. Lubimow W., Oczoś K.E., Łabudzki R.K. „Klasyfikacja struktur geometrycznych powierzchni (SGP)". *Obróbka ścierna, podstawy i technika. Zbiór prac XIII Naukowej Szkoły Obróbki Ściernej*, 2000.
13. Majumdar A., Bhushan B. "Fractal model elastic-plastic contact between rough surfaces". *Journal of Tribology*. 113 (1991): pages 1–11.

14. Pawlus P. „*Topografia powierzchni – pomiar, analiza, oddziaływanie*". Rzeszów: Oficyna Wydawnicza Politechniki Rzeszowskiej, 2005, pages 165–168.
15. Tomkowski R., Kacalak W., Lipiński D. "Evaluation of the surface topography after precision machining". *Journal of Machine Engineering*. 12, 4 (2012): pages 71–80.
16. Tomkowski R., Kacalak W., Lipiński D. "Methodology of evaluation of extra smooth surfaces with the use of new evaluation parameters". *Proceedings of the International Conference on Surface Metrology*, 2012, France, pages 64–71.