



“Fiatalok a Tudományért 2024”

tudománynapi rendezvény

Válogatott publikációk

Miskolc
2024

**“FIATALOK A TUDOMÁNYÉRT 2024” CÍMŰ
TUDOMÁNYNAPI RENDEZVÉNY
2024. NOVEMBER 07.**

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ISBN 978-963-358-352-4

Elérhetőségek:

Miskolci Egyetem Gépészmérnöki és Informatikai Kar Gyártástudományi Intézet

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Kiadó: Miskolci Egyetem Gyártástudományi Intézet, 2024.

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ELŐSZÓ

1825. november 3-a mérföldkő a magyar tudományos élet történetében. Ezen a napon Széchenyi István, a 'legnagyobb magyar', példátlan nagylelkűségről tett tanúbizonyságot: birtokainak egyéves jövedelmét ajánlotta fel a Magyar Tudós Társaság megalapítására. Ez a kezdeményezés megalapozta a Magyar Tudományos Akadémia létrejöttét, amely azóta is a magyar tudományos kutatás és kultúra egyik legmeghatározóbb intézménye.

2003 óta november 3-át hivatalosan is a Magyar Tudomány Ünnepeként tartjuk számon. Ez az alkalom nem csupán Széchenyi áldozatkészségének és előrelátásának állít emléket, hanem arra is emlékeztet, hogy a tudomány fejlődése a társadalom minden tagjának közös felelőssége. A Magyar Tudomány Ünnepe lehetőséget teremt arra, hogy méltassuk a tudományos eredményeket, előmozdítsuk a kutatás és innováció ügyét, valamint megerősítsük a tudomány és a társadalom közötti párbeszédet.

2024. november 7-én "Fiatalok a tudományért 2024" című tudomány napi rendezvény került megtartásra a Magyar Tudományos Akadémia Miskolci Területi Bizottság Gépészeti és Informatikai Szakbizottság Anyag- és Gyártástechnológiai Munkabizottsága szervezésében, melyen a Miskolci Egyetem Anyagszerkezet-tani és Anyagtechnológiai Intézet, valamint a Gyártástudományi Intézet fiatal kutatói mutatták be kutatási tevékenységüket, eredményeiket. A mai tudományos élet egyik kiemelkedő jellemzője a nemzetköziség és az együttműködés, amely a Miskolci Egyetem kutatói közösségében is egyre hangsúlyosabb szerepet kap. Az intézményben számos külföldi kutató és oktató dolgozik együtt magyar kollégáikkal, ami hozzájárul a tudományos munka sokszínűségéhez és a globális szemlélet erősödéséhez. Ennek jegyében a rendezvény keretében magyar és angol nyelvű előadások is elhangzottak. Ez az esemény jól példázza, hogy az Egyetem elkötelezett a tudomány nemzetközi dimenzióinak erősítése és a tudástranszfer előmozdítása iránt.

A rendezvényen elhangzott előadások közül válogatott, magyar és angol nyelvű publikációkat jelentet meg a Gyártástudományi Intézet kollektívája ebben a kiadványban, melyek betekintést nyújtanak a Miskolci Egyetemen folyó változatos témájú gyártástudományi kutatásokba. A kiadványban szereplő publikációk az alábbi témák szerint lettek csoportosítva:

- A) Megmunkált felületek érdessége
- B) Anyagok megmunkálhatósága
- C) Gyártórendszerek, Ipar 4.0
- D) Kompozit anyagok
- E) Felületek vasaló megmunkálása

Bízunk benne, hogy a megjelent publikációkat az Olvasó érdekesnek találja! Köszönjük a szerzők munkáját és cikkeikkel való hozzájárulásukat a Magyar Tudomány Ünnepehez!

Dr. Sztankovics István
egyetemi docens
szerkesztő



ROUGHNESS PROFILE ELEMENT WIDTH AND GRADIENT ANALYSIS ON A PLANE SURFACE FACE-MILLED WITH AN OCTAGONAL INSERT

Antal Nagy

ABSTRACT

On a face-milled surface, due to the motion conditions, such a topography is created that, when its 2D roughness is examined at different points of the surface, the periodicity of the profile elements is the same, but their shape and therefore their slope also changes. In the article, the extent and nature of the deviations of spacing and hybrid parameter values measured at several locations on the plane surface are studied.

Keywords: face milling, surface roughness, hybrid roughness parameter, topography inhomogeneity

1. INTRODUCTION

The quality of the surfaces of machine parts that perform various functions must be given in order to guarantee that they can operate as planned during their lifetime. For this, the values of the amplitude parameters are most often specified [1]. The values of these indices, such as R_a and R_z , are suitable for monitoring the cutting process. However, those are not suitable (they have no strong correlation) in all cases for characterizing the topography of the surface regarding functional properties of the component, the optimization of which is increasingly being in the center of attention [2, 3]. Therefore, it is recommended to expand the surface quality specification, e.g. with other types of parameters [4]. The hybrid type has both height and spacing information incorporated [2], the most frequently analyzed parameter among them is Rdq root-mean-square gradient. It characterizes how steep the peaks and valleys of the surface are, thus allowing to define whether how sharp surface asperities are [5]. In tribology analysis, Rdq is considered to be an important factor which influences the tribological properties of the surfaces, like it reflects the friction behavior regardless of the surface topography. Many mechanical properties such as friction, elastic contact, reflectance, fatigue crack initiation, hydrodynamic lubrication, strength of adhesive joints and optical behavior affect this parameter [6-8]. For example, in several studies of sliding of polished surfaces a close correlation was found between the tribological behavior – friction and wear – and the mean slope. R_a parameter has a limited capability in this respect. The authors could evaluate the wear behavior considering the mean absolute profile slope and the number of sliding cycles [8]. In the case of molds produced by milling, where the surface gloss is also an important aspect, the Sdq or Rdq values measured on the surfaces showed a good correlation with the surface gloss, where the smaller gradient (slope) value referred to lower scattered light angle. However, S_a and S_q height parameters had a correlation with the surface reflectance only to a certain extent [9].

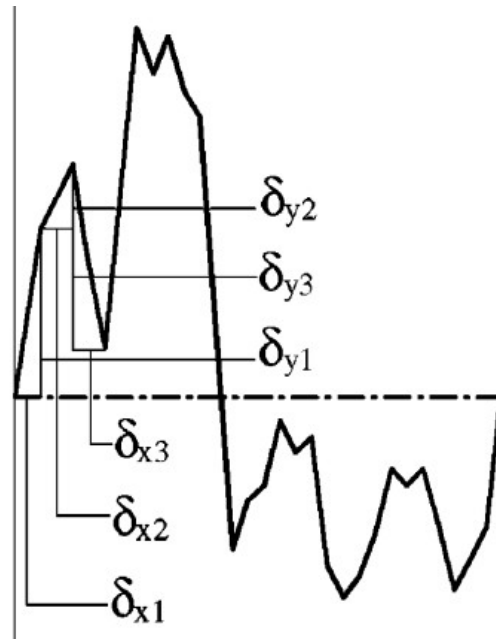


Fig. 1. Illustration for the calculation of Rdq on the profile [6]

In cutting, tool edge geometry, movement conditions, technological data, etc. determine the characteristics of the machined topography (including its Rdq value), which can be used to influence its functional properties. In a study [10], where previously hard turned surfaces were superfinished or burnished, the slope (and spacing) of the topography irregularities was changed. Typical values of $Rdq \approx 3^\circ$ for initial surfaces were consequently reduced to $Rdq \leq 1^\circ$ after abrasion or plastic deformation (multi-pass burnishing). If Wiper inserts were used in hard turning, these modifications did not cause significant change in Rdq value because the topographies did not contain such sharp peaks as those on surfaces turned with conventional inserts. On face-milled aluminum surfaces the measured Rdq value greatly decreased (from 14.2° to one-third) for increasing feed only in case of small set values between 0.02 and 0.1 mm/tooth. A further increase in feed per tooth did not cause any remarkable differences in the mean slope value. Similarly, an increase in the cutting speed changed Rdq value; in the lowest tested range (from 200 to 240 m/min) it significantly reduced from 15.5° to approx. one third, and it remained small regardless of further rise of speed value [11]. Since profiles with elements having different heights and widths have similar Rdq values (e.g. on surfaces turned with different feeds or cutting speeds [12]), this single parameter may not show a change in some functional characteristics. Therefore, in order to better identify the characteristics of the topography, it is useful to examine the values of the parameter RSm mean width of profile elements. It gives the average distance between crossings of the mean line [2] and it is used to measure the horizontal characteristics of the surface deviations [6]. Among the roughness parameters measured on turned surfaces, a better correlation was shown for the change of feed by the values of RSm , than those of Rdq , since the slope of the cutting marks remain approx. the same but the spacing parameter value changes linearly with it [12].

So far, the Rdq or RSm values of topographies have not or rarely been investigated on face-milled surfaces. Also, we have no knowledge of how or what extent the values of these parameters deviate at different points of the machined surface. In this article, the aim of the investigation is to examine the magnitude and nature of the changes in values of spacing and hybrid parameters measured at various points of a face-milled plane surface, and thus to specify what kind of change in certain functional characteristics can be expected in different parts of the topography.

2. EXPERIMENTAL CONDITIONS

To analyze the roughness of the face-milled surface, I performed a cutting experiment on a PerfectJet MCV-M8 vertical milling machine. For that, I used an ATORN 10612120 milling head with a diameter of $D_s = 80$ mm, on which an octagonal OCKX 0606-AD-TR, HC4640 grade coated carbide insert ($\kappa_r = 43^\circ$; $\gamma_o = 25^\circ$; $\alpha_o = 7^\circ$, $r_e = 0.5$ mm) was installed (Fig. 2). For cutting, 0.3 mm/tooth feed per tooth, 0.8 mm depth and 58 mm width of cut and 200 m/min cutting speed values were set. On a C45 grade unalloyed steel specimen I machined a 58×50 mm² plane surface with a perpendicular tool axis and with a symmetrical positioning. Due to the full length feed movement of the workpiece, the topography consists of double milling marks (Fig. 1). In face milling it is worth noting that the relative directions of the cutting and the feed movements varies, i.e. up-milling from the start of cutting until the plane of symmetry (**SZIM**) per revolution (where **BE-1** and **BE-2** planes are placed), and then down-milling (where **KI-1** and **KI-2** planes are defined) takes place alternately (Fig. 1).

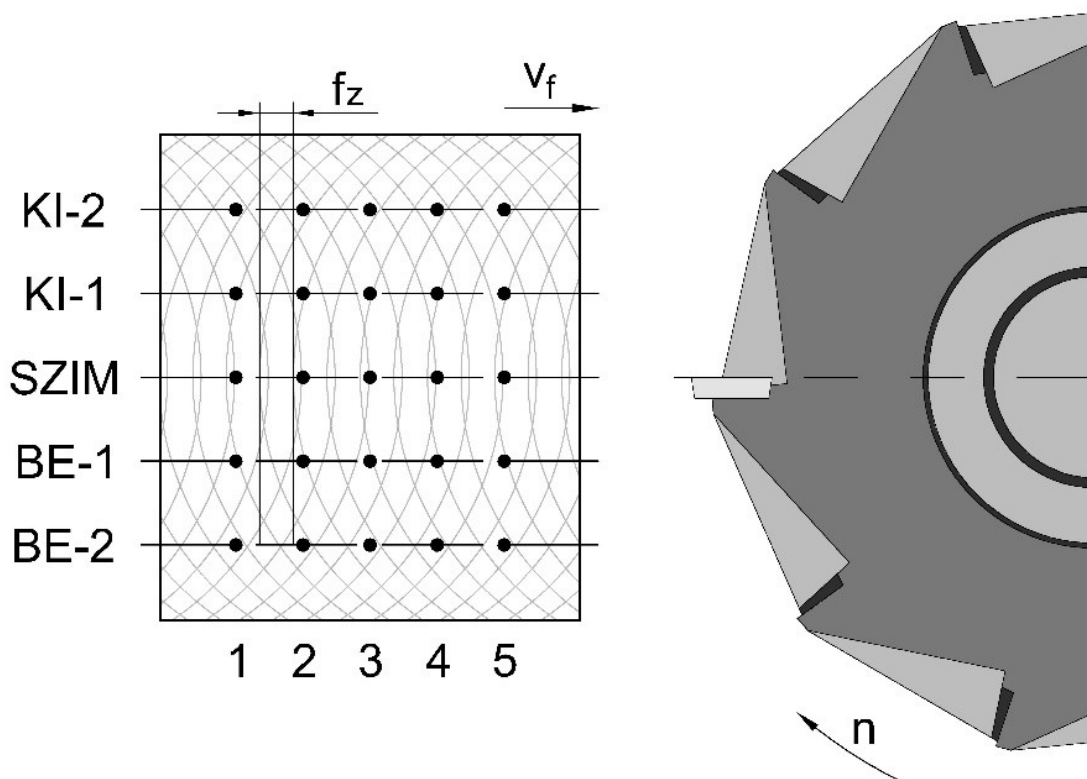


Fig. 2. Motions and relative positions of the tool and workpiece, locations of measurement planes and points on the machined surface

After the machining the roughness measurement was carried out on an AltiSurf 520 topography measuring device with a CL2 confocal chromatic gauge. To evaluate the roughness differences, I took 25 measurement points on the surface, 5 of which are located in each measurement plane oriented in the feed direction, designated as **BE**, **SZIM** and **KI**. The planes have a 10 mm distance between each other, on which the measurement points (showing the center of the profiles in Fig. 1) are shifted by 8 mm each (Fig. 1). Among these, the symmetry plane is the **SZIM** plane, the **BE-1** and **BE-2** planes are located on the up-milled, and the **KI-1** and **KI-2** planes are on the down-milled part of the surface. At the measurement points, I measured the profiles in the feed direction, at the length of 4 mm specified in the relevant ISO 21920 standard, and evaluated them with a 0.8 mm set value of section length.

3. RESULTS AND DISCUSSION

After the experiments, I evaluated the results of the roughness measurement. I report the values of the mean spacing of the profile elements RSm , which characterize the periodicity, and the values of the root-mean-square gradient Rdq , which describe the slope of the roughness profiles taken at the measurement points (Table 1).

In the table I give the arithmetic mean $\bar{R}$ of the values in each measurement plane, the size of deviation ΔR and the quotient of these ($\Delta R/\bar{R}$). I illustrate the distribution of roughness values on map diagrams in Fig. 3 (corresponding to the position of measurement points shown in Fig. 2). Roughness profiles measured at several points are given in Fig. 4.

Table 1. Roughness values of profiles measured on the surface

Measurement plane		1	2	3	4	5	$\bar{R}$	ΔR	$\Delta R/\bar{R}$
RSm [mm]	BE-2	0.06	0.06	0.12	0.07	0.06	0.07	0.06	78.6%
	BE-1	0.10	0.10	0.07	0.07	0.09	0.08	0.03	38.0%
	SZIM	0.17	0.17	0.15	0.15	0.18	0.16	0.04	21.3%
	KI-1	0.19	0.22	0.17	0.18	0.14	0.18	0.08	42.5%
	KI-2	0.09	0.21	0.22	0.20	0.20	0.18	0.14	74.0%
	ΔR	0.13	0.16	0.15	0.13	0.14	Total diff.:	0.16 mm 119 %	
Rdq [°]	BE-2	13.66	12.00	14.77	10.23	9.50	12.03	5.27	43.8%
	BE-1	9.57	10.32	9.55	14.09	11.79	11.06	4.54	41.0%
	SZIM	8.11	7.11	7.00	8.47	6.67	7.47	1.80	24.1%
	KI-1	6.43	5.73	6.60	6.00	6.45	6.24	0.87	14.0%
	KI-2	9.43	6.38	6.43	6.25	6.65	7.03	3.18	45.2%
	ΔR	7.23	6.27	8.34	8.09	5.34	Total diff.:	9.04 ° 103 %	

The parameter RSm specifies the average distance of the periodic features. In face milling, the repetition of the tool edge imprints is determined by the feed per tooth in the feed direction; RSm value is theoretically the same as f_z (on a topography with single cutting marks). On a surface with double tool edge marks (the type of the studied surface), as a result of the secondary material separation by the back-cutting after the front-cutting, the milling grooves intersect each other on several parts of the surface. Thus, on a profile measured in the feed direction, the traces of the front- and back-cutting can appear within a length of f_z .

The illustration of the double cutting marks and the length of f_z is shown in Fig. 2. In this case, the theoretical value of RSm is between $f_z / 2$ and f_z . On the investigated surface, the value of the spacing parameter is lower than the value of the feed per tooth at all measurement points. On the part of the surface marked by the **SZIM** and **KI** planes, these are half to two-thirds of f_z , mostly higher than the theoretical minimum value (0.15 mm). In the **BE** planes, they are very low; a quarter to a seventh of f_z . The RSm value is minimum on the down-milled surface part (at three points in the **BE-2** plane) and maximum in the **KI** planes (also at points **KI-1-2** and **KI-2-3**).

Looking at the distribution of the values, the most significant change is in the perpendicular direction to the feed: there is an increase from the **BE-2** plane towards the **KI-2** plane.

The value of Rdq , which expresses the average slope of the profile elements (a neighbouring valley and a peak), shows opposite change characteristics to those described above. Where the value of RSm is minimal, Rdq is maximal (in the **BE-2** plane) and vice versa in the **KI-1** plane

(at point 2). Also, the change in values also follows a contrary trend when viewed perpendicular to the feed direction compared to those of RSm ; it mostly decreases from the **BE-2** plane towards the **KI-2** plane. It varies randomly in the measurement planes (in the feed direction).

The differences and reverse trends can be explained by analyzing the profiles. Most of the curves shown in Fig. 4 are smooth, regular and very similar in the **SZIM** and **KI** planes. However, in the **BE** planes, the tool edge traces are distorted, often difficult to identify, and their elements are apparently noisy (Fig. 4). As a result, compared to regular ones, the curve intersects the center line much more times of profiles measured in the **BE** planes, thereby reducing the value of RSm . Also, the profile elements are steeper (more roughness peaks and valleys appear at the evaluation length), which cause an increase in the Rdq value.

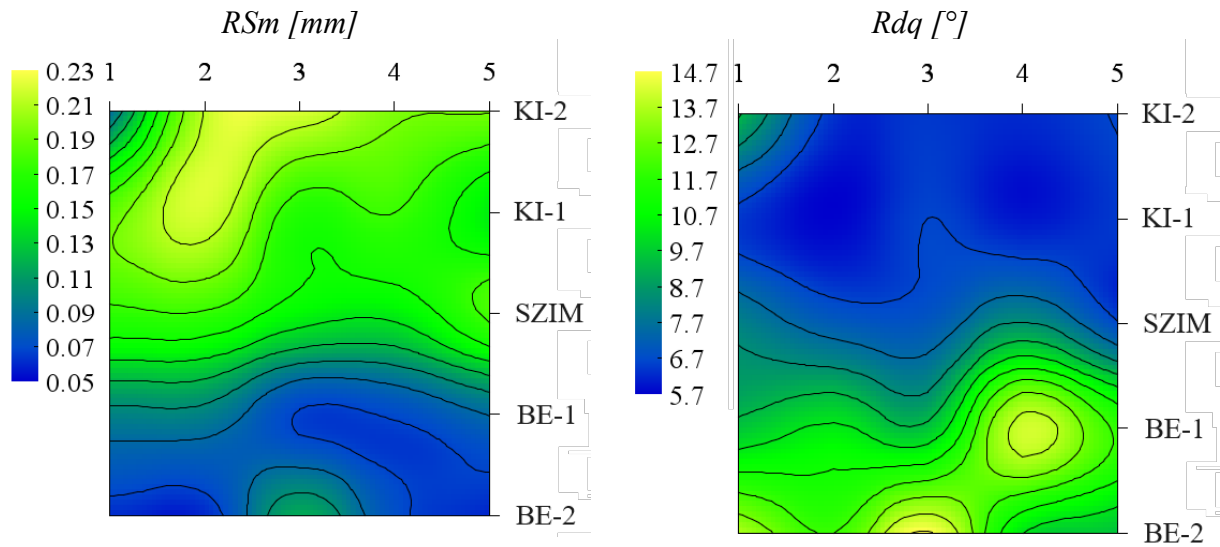


Fig. 3. Distribution of RSm and Rdq parameter values on the surface

The value of RSm or Rdq of some measurement points is outlying, which is noticeably different from the values of the other points of the measurement plane (Fig. 3).

- The previously described findings are also true at point **KI-2-1**, where RSm is smaller and Rdq is larger than the other values in plane **KI-2**.
- At point **BE-2-3**, the characteristics of two parts of the profile differ. In the range between 0-3 mm, the profile elements are noisy, but the edge marks are recognizable. Thus, the values of Rdq and RSm would not be outliers. On the other hand, in the interval between 3-4 mm, the height and slope of the profile elements are significantly higher, but their periodicity distance remained similar. As a result, the value of Rdq is higher compared to the values of the neighboring points, but the reduction of RSm is not significant.
- In point **BE-1-4**, in addition to the noise that appears on the profile curve (which increases the value of Rdq and decreases the value of RSm), a distortion can also be seen; a deep and wide valley is formed which does not intersect the center line. The latter does not significantly change the value of Rdq but increases the value of RSm . As a combination of these effects, Rdq became larger, RSm remained at a similar value as in other points of the **BE-1** plane.

The deviation of the roughness values is small in the **SZIM** plane, but in the other planes it differs for the two parameters. In the case of RSm , it is similarly small in the **BE** planes and significant in the **KI** planes and the largest in the **KI-2** plane. For Rdq , it is minimal in the **KI-1** plane, but large in the other planes, and maximal in the **BE-2** plane. Large differences are due to outliers. So, the topography is typically the most inhomogeneous around the side planes **KI-2** and **BE-2**. Regularity can be observed in the distribution of deviation values in the planes, but differently for the two indices. The difference values are minimal in **BE-1** in the case of Rdq , minimal in the **KI-1** plane for RSm , and they increase in both directions the further away from these planes.

The deviation of values measured on the surface has a large degree for RSm , most of which are accounted for the values measured in the **KI-2** plane. There are also large differences between the values of Rdq , which were not concentrated in one plane. Not for RSm , but for Rdq the measured outliers contribute significantly to the deviation.

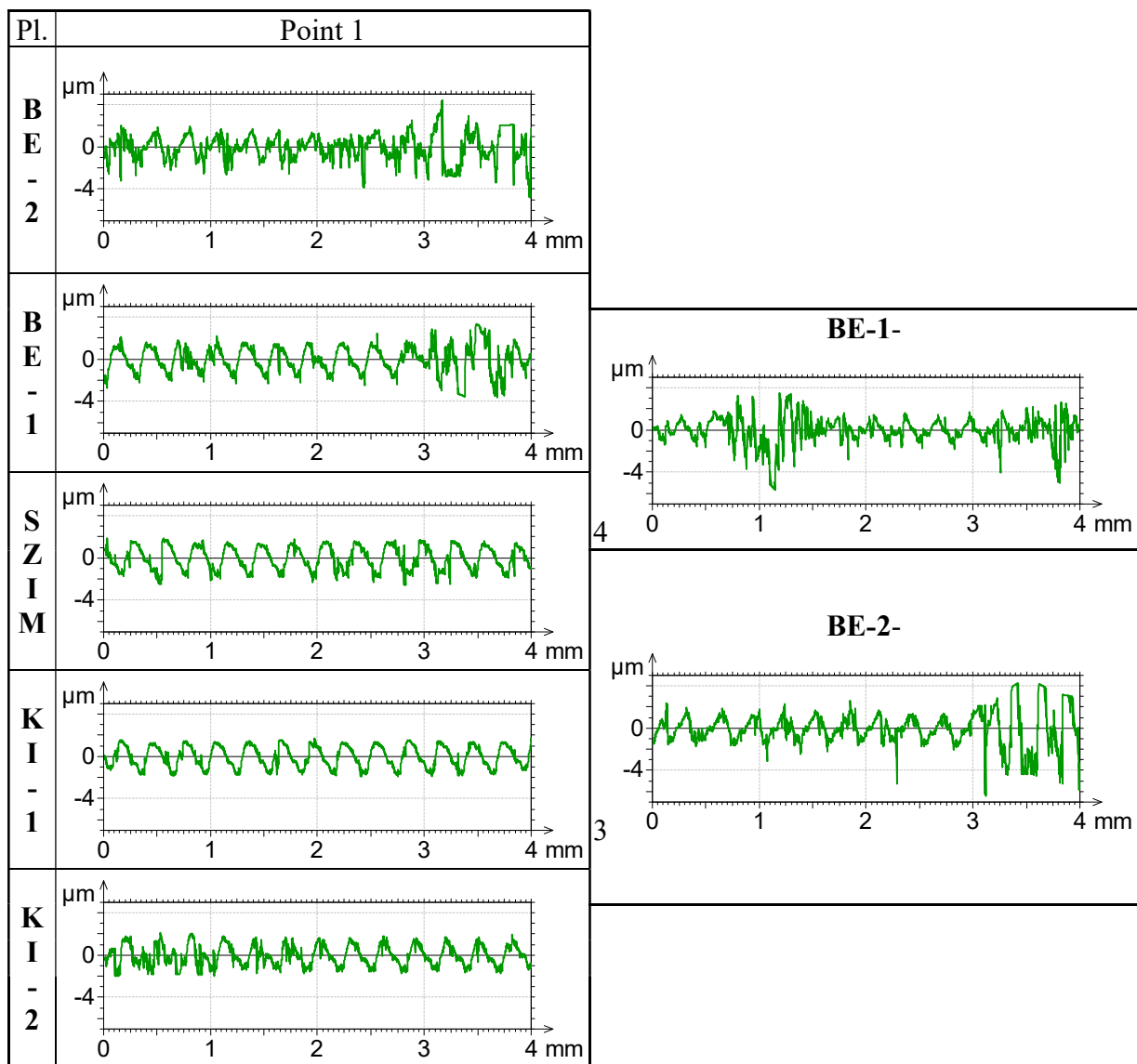


Fig. 4. Roughness profile curves measured in several points on the surface

4. SUMMARY

In the article, I investigated the periodicity and slope characteristics of the topography of a face-milled plane surface using a symmetrical tool setting based on 5×5 measured roughness profiles. I briefly summarize the results.

The value of the parameter RSm , which characterizes the periodicity of the surface texture, was approximately the expected (half the feed per tooth) in the plane of symmetry and on the down-milled surface part, and it was significantly smaller (half to a third of f_z) on the surface part where up-milling occurred. The values on the surface increased along the front-cutting movement of the tool edge. The value of Rdq , which characterizes the slope of profile elements, did not change symmetrically to the middle plane as expected, but decreased following the front-cutting movement path of the tool edge. So, an opposite change in the values of the two parameters was observed between the measurement points. The reason for this is that while the measured profiles were regular in the plane of symmetry and on the down-milled surface part, they were distorted (the profile elements crossed the center line several times more and an increase in their slope could be observed) on the up-milled side of the topography, and the measured parameter values changed accordingly.

The values measured in the symmetry plane had slight deviations. Typically, the differences are significant on the down-milled surface part, and large on the side where up-milling occurred. In the latter part, there were profiles showing outliers, contributing to large deviations in the measurement planes as well as on the examined area of the surface. So, it can be concluded that the inhomogeneity of the surface characterized by the two examined parameters was the lowest in the plane of symmetry and the maximum near the surface edge on the up-milled part.

Based on the distribution of the values, it is expected that the friction coefficient will decrease, the surface load capacity, wear resistance and fatigue strength will increase, along the path of the tool edge on the surface.

Among the two examined roughness parameters, the values of Rdq changed with greater sensitivity to the distortions and errors of the profiles. In addition, the change in the value of RSm only reflects distortions around the center line (regardless of its extent), it cannot indicate other types of surface defects (e.g. a wider and deeper valley or a higher peak). For this reason, to characterize the roughness and inhomogeneity of the face-milled topography, the Rdq parameter is recommended to examine.

5. REFERENCES

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