

The Mysteries of the Surface

First Part: The Characteristic Features of the Microgeometry of the Machined Surface

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Abstract: In these days, the key elements for the reliability and the safe operation of technical devices are the following: surface of the tools, the surface quality and the roughness of the connecting elements. The present work is going to introduce the idea that different machining methods that create microgeometries that are very much different from each other and of diverse roughness parameter proportions. It will be shown that the wear and the change of the tool edge(s) – resulting from the deterioration process of the tools, used during production – cause significant arithmetical, average and form deviations. The uncertainties of the roughness measuring technique, arising during the evaluation of the real and filtered surface profiles, will be shown via samples.

Keywords: machined surface; microgeometry; roughness; wear process

1 Introduction

Production, quality and operations — terms, being inseparable, depending on each other and mutually determinant of each other. Each specification and problem, arising during the production process of connecting components, may have a significant influence on the operation.

This research work has been oriented to examine surface microgeometry by a skidless stylus method, to the modernization and extension of the evaluation possibilities of the surface profiles and topographies, gained from measurements at Bánki Donát Faculty of Óbuda University, for more than three decades [1-4].

The research and development works started in 1975, with a surface roughness measuring device, type “Kalibr 201”; the first evaluation programs in FOKAL programming language run on TPA computers. The set of devices of the research work has now been significantly updated. We have workshop machines, works

manager “pocket” devices (Perthen, Taylor-Hobson), surface roughness measuring instruments to carry out quality works of higher level (Perthen, Mitutoyo); furthermore, to the execution of up-to-date examinations there is research equipment (type: Perthometer Concept): its outgoing digital signals can be directly processed by a computer. The education and research works are supported by the wide range of ancillaries and a whole assortment of styluses. Measurements, carried out on outer or inner arcs or on holes, having a diameter of 1.5 mm or measurements of edge roughness and edge rounding off, performed on cutting tools (Figure 1) are just few from the measuring applications yet to be mentioned.

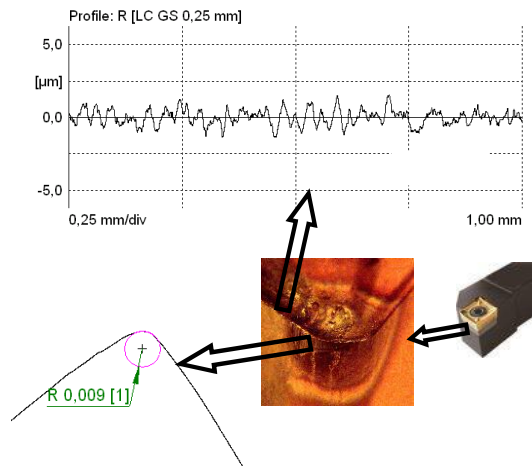


Figure 1

Edge roughness and rounding off in case of cutting insert

2 Roughness of Surfaces as Machined with Different Methods

In the 21st Century it is needed to have technical specialists to meet the quality requirements of the manufacturing technology industry, at a high level, to identify surface roughness, not only with roughness parameters R_a or R_z , but to identify the possibilities for improvement for the products using more sensitive quality characterizations on the connecting surfaces. Parallel with the dynamic development of the machining technology and surface finishing processes, the machines currently are characterized by new technical surfaces, being different in their character and quality and having been consciously planned and produced, when techniques that were well-proven earlier, are losing in their importance or they require more careful consideration. In industrial practice, the change in this way of thinking has evolved very slowly (Figure 2) [5].

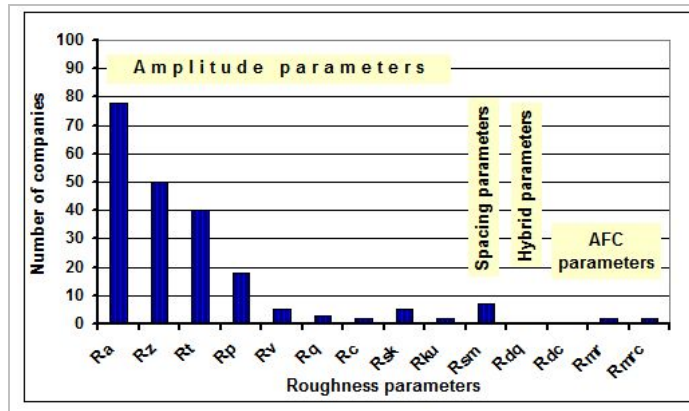


Figure 2

The roughness parameters, measured/applied in the industrial practice [5]

In the manufacturing technology of our globalized world, we can notice that the arithmetic parameters (Ra, Rz, Rt, Rp) are dominant and other attributes, describing the working behavior in a better way, are still pushed into the background. The drawings, prepared for components, usually contain only one parameter, therefore, the following questions arise: Can we reconvert one parameter into another with certainty? Is there a correlation, for example, between Ra and Rz that may be used for machining and described by a formula?

The formulas “ $Rz=4 \times Ra$ ” or “ $Rz=4.5 \times Ra$ ” have been used in professional training and in the practice of manufacturing technology for at least 6 or 7 decades. Occasionally, there are publications, revising and trying to modify this way of thinking [6, 7, 8], but until now, they were not able to achieve a real breakthrough in this question. If we analyze the roughness of surfaces, machined with different methods, the values, shown in Table 1, are gained. It can be seen that there are significant differences in the ratio of Rz/Ra as the measured values scatter in the range of 5.36 and 9.2.

Table 1

Roughness of surfaces, formed with different machining methods

Milled groove surface			Ground milling cutter shaft			Super finished shaft		
Ra	Rz	Rz/Ra	Ra	Rz	Rz/Ra	Ra	Rz	Rz/Ra
0.39	2.09	5.36	0.15	1.3	8.67	0.05	0.46	9.2
0.31	1.72	5.55	0.15	1.29	8.6	0.07	0.53	7.57
0.29	1.69	5.83	0.15	1.25	8.33	0.07	0.53	7.57

Having analyzed the values, it can be noticed that the tool edges, the cutting data, the machining system and its surroundings may 'produce' surfaces that have very different micro-geometric characteristics. The micro-geometric profiles of surfaces, have nearly the same average surface roughness Ra and are machined by

different processes such as milling, spark erosion machining, grinding and super finishing operations. These are shown in Figure 3. Every profile has well determined characteristics, and this means that there are surfaces with significantly different formal features with obviously different R_z/R_a ratios and they have different behavior during the operation as well.

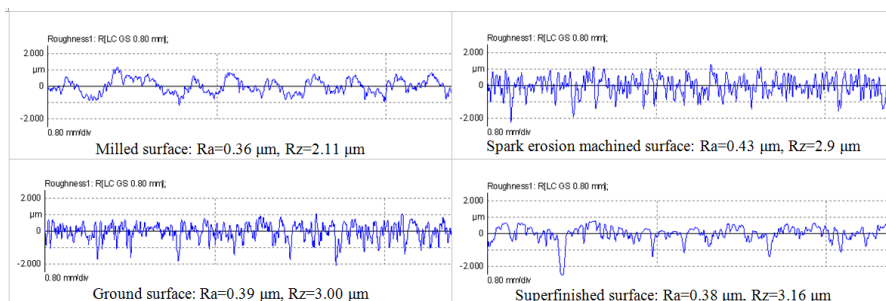


Figure 3

Surface roughness profiles in case of different machining methods

($R_a=0.36\ldots0.43\ \mu\text{m}$; $R_z/R_a=5.8\ldots9.5$)

Several cutting processes (turning, planing, drilling, peripheral milling, grinding, super finishing, spark-machining, etc.) were examined in order to discover the micro-geometric characteristics, the relationships among the roughness parameters of each machining method and to observe the variance of the features on the surfaces [9].

The measurements were carried out on a roughness measuring device, type Mahr-Perthometer and the values were evaluated by MarSurf XCR-20 software. On each workpiece, formed with the same machining operation, 25 standardized profile measurements were carried out on different places on the material. The roughness (R) and unfiltered (P) parameters of measurements, performed in the earlier described way, were evaluated; and the data, such as maximum and minimum values of the range, variance of the values, average values and range/minimum values and were collected in a form of a table. Only part of the test results are presented in this paper. The roughness parameters of a steel surface, machined with a coated carbide tool, are shown in Table 2.

Although the surface is supposed to have the same roughness parameters, from the measured data it can be seen that there are significant differences in the parameter values and their ratios, as well as, in different moments of the machining operation (it depends on the contact between the tool and the workpiece). According to the data, indicated in Table 2, the deviation is 27% in case of R_a , average roughness, being generally known and the most often used parameter on the machine drawing, 46% in case R_z (height of unevenness) and it is nearly 200% in the case of R_t parameter [10]. A significant variance was observed in case of skewness index number R_{sk} as well.

Table 2
Turning operation with sharp tool, $v_c = 250$ m/min; $a = 1.5$ mm, $f = 0.05$ mm

Roughness	Max.	Min.	Range, R	Dispersion, s	Average	R/Min.
Filtered R-profile						
Ra	0.254	0.201	0.054	0.018	0.229	27%
Rz	1.983	1.358	0.625	0.150	1.577	46%
Rt	4.794	1.621	3.173	0.651	2.229	196%
RSm	65.458	31.730	33.728	8.337	42.299	106%
Rsk	4.412	-0.698	5.110	0.966	-0.089	
Rdq	0.091	0.059	0.032	0.008	0.077	54%
Unfiltered P-profile						
Pa	0.425	0.229	0.197	0.048	0.342	86%
Pz	2.697	2.024	0.672	0.191	2.353	33%
Pt	5.015	2.229	2.786	0.574	2.905	125%
PSm	197.729	45.856	151.873	42.587	109.784	331%
Psk	3.197	-0.271	3.468	0.652	0.211	
Pdq	0.091	0.058	0.033	0.008	0.077	57%

The component surfaces, having (fitting, moving away or frictional) connection with each other, are in touch with each other not along the filtered R-profile, but along the unfiltered P-profile. The evaluation is made even more difficult, if the parameters of P profile is examined as well and they are compared to the values of the filtered profile. The deviations are significantly greater, compared to the R profile: for example, in case of Pa parameter it is 86%, while the difference between the Pt parameters is greater than 100%. It can be seen as well that the change in the increase of the arithmetical parameters of the P profile is significantly greater, compared to the R profile, as it is nearly 50% (in case of Pa and Pz). Parallel with roughness parameters, the earlier described changes are extremely well demonstrated by the surface profiles, taken in the same magnification (Figure 4).

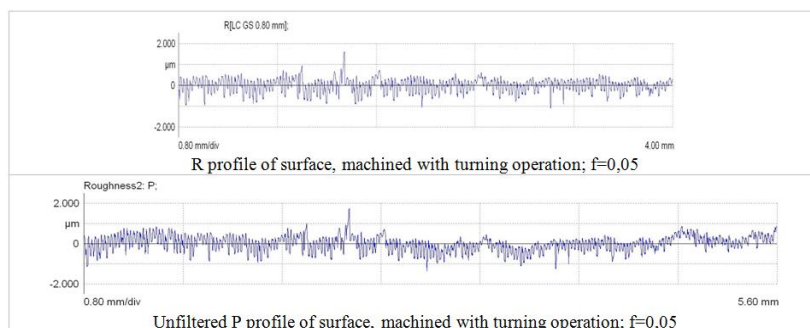


Figure 4

R and P surface profiles during turning operation in case of new and worn out tool

The same can be observed in case of machining operations carried out with an irregular edge geometry, or with grains, having a geometrically nondescribable shape, i.e. in the case of grinding. For this machining type, a typical stochastic surface structure develops (see Figure 5), being significantly different from the periodicity of the surface development, arising during machining with tools of regular edge geometry (turning, milling operation etc.). The surface, machined with grinding operations contains numerous cutting scratches of irregular shape and different depth size and results in a great diversity of surface profiles.

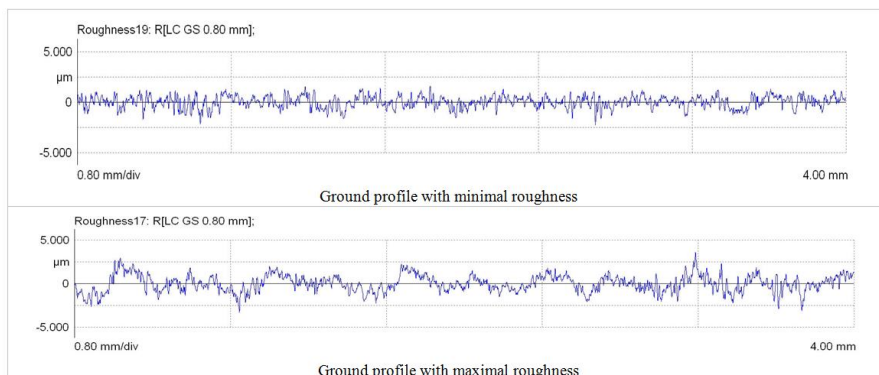


Figure 5

Minimal and maximal roughness values of R profile of surfaces, gained with grinding operation

As it can be seen well in Table 3, there is a variance of 63% in the average roughness value R_a and height of unevenness R_z , while in case of R_{max} and R_t values the difference is 70-80%. The negative value of R_{sk} refers to a good load bearing capacity of the surface. The coefficient of formula, used in practice to convert the values R_z and R_a , has an increasing tendency in this type of machining and it achieves a value of $R_z \approx 7R_a$ on average.

Table 3

Parameters of steel surface, machined with grinding operations, cooling and spark-out; $v_c = 50$ m/s

Roughness	Maximum	Minimum	Range, R	Dispersion, s	Average	R/min.
R profile						
R_a	0.76	0.47	0.29	0.077	0.574	63%
R_z	5.14	3.16	1.98	0.469	3.994	63%
R_t	6.90	3.77	3.13	0.804	5.030	83%
R_{Sm}	106.00	41.95	64.05	15.693	61.694	153%
R_{sk}	0.02	-0.63	0.65	0.173	-0.335	
R_{dq}	0.20	0.17	0.04	0.011	0.181	123%
P profile						
P_a	1.15	0.55	0.59	0.166	0.762	107%
P_z	7.91	4.08	3.83	1.007	5.415	94%

Pt	9.08	4.26	4.83	1.170	6.246	113%
PSm	216.20	54.61	161.59	49.746	110.257	296%
Psk	-0.04	-0.84	0.80	0.203	-0.337	
Pdq	0.21	0.17	0.04	0.010	0.181	124%

The variance between the maximal and minimal values of unfiltered P-parameters, indicated in Table 3 is above 100%. The parameter values of Pa, Pt and Pdq oscillate in the range of 105-125% and they can cause serious work in production in order to keep the prescribed surface roughness values in the prescribed range [11].

3 The Change in the Characteristics of a Turned Surface during Machining

When analyzing a turned surface, at an appropriate magnification, the geometric marks developed during machining can be observed. These are peaks, tool marks, outstanding peaks (built-up edges) and cavities (extracts), their sizes, shapes and distance from each other are quite different (Figure 6). The micro-geometric shape, developed on the surface, is determined by the kinematics of the machining process, the direct and indirect effects of the chip detachment, the geometric features of tool and by the physical-mechanical characteristics of the workpiece, to be machined. To these elements amounts the effect of further several important factors, such as cutting speed, the condition of the cutting edge of tool, the presence of cooling and lubricating, the dynamic behavior of machine - device - workpiece - tool system, the features of the surroundings and process, they mainly determine the irregularity of the part microgeometry, to be developed on the surface, and the waviness. Significant differences may be caused by the change of these factors in the surface microgeometry during the machining process [1, 7, 9, 11, 12]. In the case of serial production it means a serious challenge to continuously maintain the prescribed surface roughness measures.

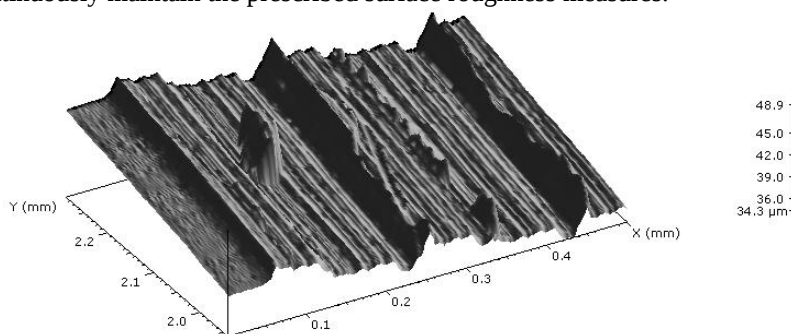


Figure 6

The micro-geometric features of surface, machined with turning operation

As it can be seen, from the above-mentioned examples, the connection between microgeometry, developed on the surface and the machining operation is quite versatile and complicated. The effect of some factors are described by theoretical formulas, these are Bauer-formula (1) and Brammertz-formula (2):

$$Rz \approx R_e = 125 \cdot \frac{f^2}{r_e} \quad [\mu m] \quad (1),$$

and

$$Rz \approx R_{eBr} = 125 \cdot \frac{f^2}{r_e} + h_{min} \cdot \left(0.5 + \frac{r_e \cdot h_{min}}{2000 \cdot f^2} \right) \quad [\mu m] \quad (2),$$

Whereas:

- f Applied feed, mm
- r_e Nose radius of the tool, mm
- h_{min} Minimum detachable chip thickness, i.e. $h_{min} = f (v_c, r_n, \text{etc.}) = 3\text{-}8 \mu m$
- r_n Rounding off radius of the tool edge (on average approx. $25 \mu m$)

Although formulas (1) and (2) do not include several factors, their application is widespread in technology planning practice, for example, when determining the feed limits.

There is a great uncertainty in the common effect of all influencing factors and among them, the temporal change may have a significant role as well. Based on publications [13-15], prepared on turning examinations, the general conclusion can be drawn that a cutting operation, lasting for 15-20 minutes, results in an increase of Ra value by $1 \mu m$. Only the trend and size of the change may be predicted by this information, and the changes in the micro-geometric shape on the surface, developing as a result of the tool deterioration process, may not be seen. The research carried out in this topic, focused on the analysis connected with the generally considered trend and on the on deeper changes that develop during the deterioration process.

Several cutting tests were carried out on C50 (constructional) and Ko36 (corrosion-resistant) steel, using CNMG120408 type, PVD-coated cutting inserts and applying the same machining data ($a=1.5 \text{ mm}$; $f= 0.2 \text{ mm}$). In order to determine the deterioration behavior of the tool, not only the wear and force values were measured (depicted on the time, spent in machining), but Ra and Rz surface roughness values as well. Parallel with the temporal increases of the wear values and in certain cases, serious changes were observed in the roughness parameters, while a general increasing tendency was registered in the majority of cases (Figure 7).

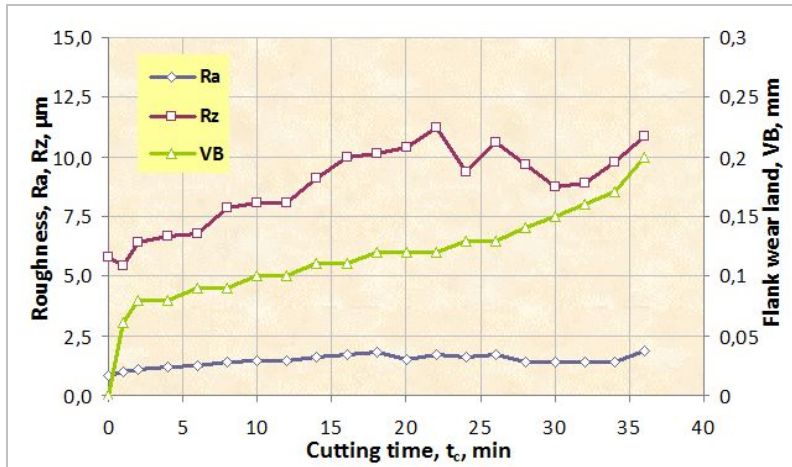


Figure 7

The connection between flank wear-land and roughness in case of turning operation in C50 steel ($v_c=315$ m/min; coating: nACoX3)

In case of turning operation with another PVD-coated tool, change in surface roughness, resulting from the wear process, was 100%, the degree of irregularity scattered in the range of 25-30%. As a result of it, there was obviously an oscillation in the ratio of R_z/R_a in the range of 5.3-7.2 (Figure 8).

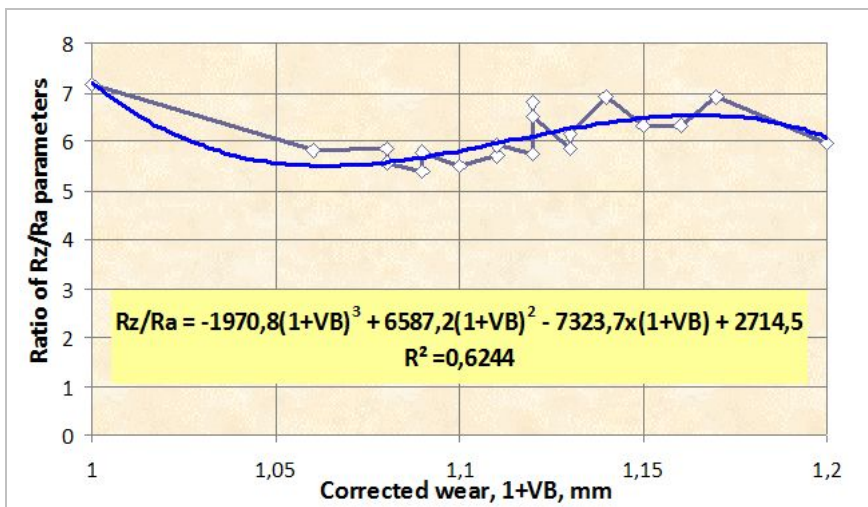


Figure 8

The connection between roughness and corrected wear in case of turning operation in C50 steel ($v_c=315$ m/min; coating: nACo3)

The same changes in the surface roughness were observed during the turning operation in the Ko36 material, tested in the second phase, but they occurred much faster than expected, due to the greater abrasive effect and adhering character effect of the corrosion-resistant material.

Based on our experiences, it can be noticed that the diversity of the surface shapes is the consequence of the wear changes, developing on the flank wear-land area of the tool, when the sectional profile of the wear mark on the flank wear-land area, changing continuously and being determining, is “copied” onto the surface of the workpiece (Figure 9).

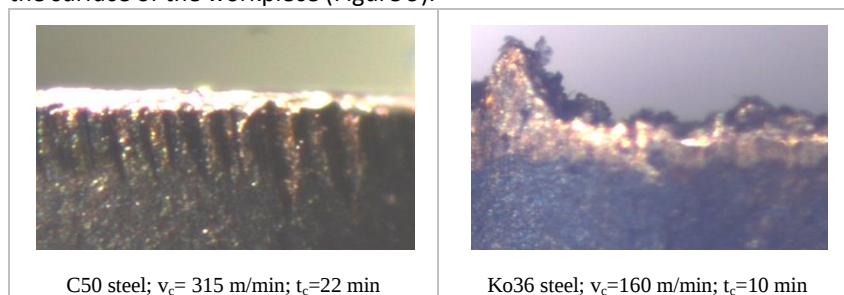


Figure 9

Photo about flank-land wear, taken by stereomicroscope (magnification: 45x)

4 Connection between the Tool Edge and the Machined Surface

An extra research series was carried out in material qualities, mentioned earlier, in order to examine the micro-geometric connection between the tool edge and the surface machined by it, in a deeper way. The dry turning operation was performed with DNMG150608R-K GC4025 (made by Sandvik) insert, the depth of cut was 1 mm, the applied cutting speed values were in case of constructional steel $v_c=300$ m/min and 160 m/min in case of more difficult to machine corrosion-resistant steel, respectively. A feed value of $f=0.1$ was determined by us as in order to better observe the change in the wear marks on the micro-geometric profile diagrams. Every minute, stereomicroscopic pictures were taken of the flank wear-land of the tool edge section, forming the surface microgeometry. At the same time, filtered (R profile) and unfiltered (P profile) profiles, together with the surface profile pictures were registered by MarSurf XCR-20 evaluation software on Mahr-Perthen surface roughness measuring instrument (in every minute). After having finished the tests, the surface forming insert and cutting tool were examined in details: 3D optical microscopic and electron microscopic pictures were taken, additionally, topographic measurements were performed with the help of surface roughness measuring instrument.

In Figure 10, the values of Ra and Rz parameters are shown as a function of the cutting time (t_c) in the case of tests, carried out in C50 material. In regards to the Rz parameter, the degree of differences, resulting from the tool wear, is more than 3X. It is typical for the change that it has a slightly increasing (cca. $0.3 \mu\text{m}/\text{min}$) tendency in the first 20 minutes. During this period of time, the regular edge shape disappears and a typical transcriptional mechanisms develops [1]; after that a definite decrease can be observed (parallel with further deterioration of the edge shape, the formation of a “ironing” edge section can be observed). The temporal changes can be described by a three-degree polynomial, drawn on the change of the values, with adequate accuracy. Although the coefficient of determination (R^2) values scattered in a range between 0.65 and 0.75, the correlation (R) had a value above 0.8. In technical practice, the variance of wear processes of cutting operations can be properly characterized by this last-mentioned value.

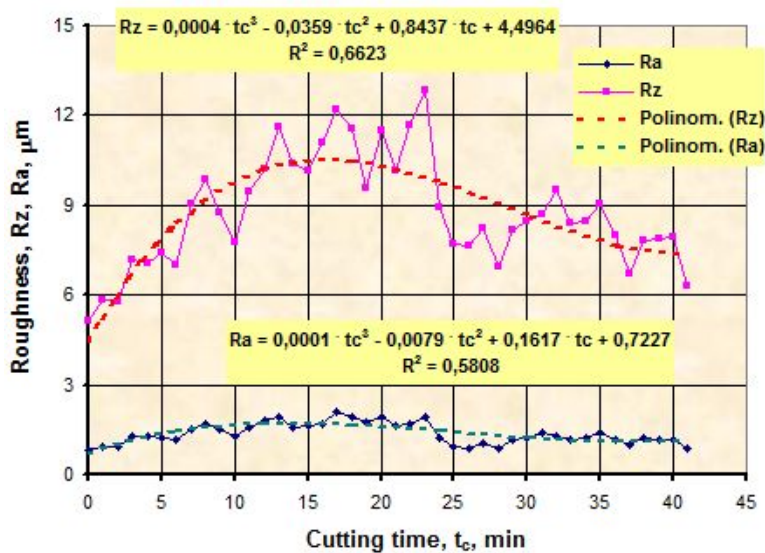


Figure 10

The development of Ra and Rz value in function of cutting time in case of turning operation in C50 steel ($v_c=300 \text{ m/min}$; coating: CVD, type 4025)

The development of surface microgeometry is well demonstrated by the roughness profile diagrams, shown on Figure 11; on these the interactions between the edge shape and the machined surface, described earlier, can be well seen.

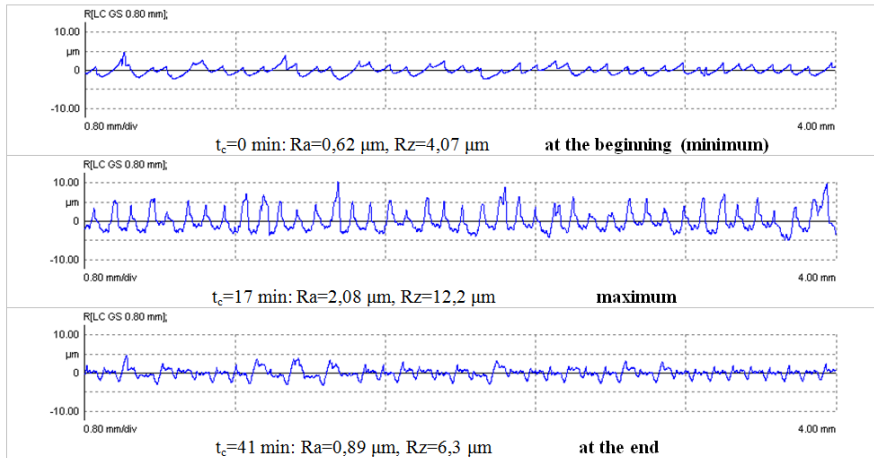


Figure 11

The development of roughness profile diagrams in function of cutting time in case of turning operation in C50 steel

In Table 4 the development of the main surface micro-geometric parameters, observed during the time of examination, is summarized. A greater value than 100% was achieved in differences among the measured minimum and maximum values in case of R_a average roughness, R_z height of unevenness, R_t maximum unevenness and R_{dq} mean square of average profile slopes. The greatest change was observed in the values of R_{sk} : the strong transformation of microgeometry, resulting from the tool wear, is demonstrated the best by it. The unfiltered parameters of the R profile were exceeded by the similar values of the P profile, the degree of differences is similar as earlier described.

Table 4

Surface, machined with turning operation, material: C50; $v_c=300$ m/min; $a=1$ mm; $f=0.1$ mm; $r_e=0.8$ mm

Roughness	maximum	minimum	Range, R	Dispersion, s	Average	R/min
R profile						
R_a	2.08	0.83	1.25	0.35	1.36	151%
R_z	12.2	5.13	7.07	1.84	8.76	138%
R_t	16.8	7.12	9.68	3.25	10.71	136%
R_{Sm}	149.3	98	51.3	11.27	112.70	52%
R_{sk}	1.09	-0.13	1.22	0.35	0.64	-938%
R_{dq}	0.279	0.106	0.173	0.04	0.20	163%
P profile						
P_a	2.3	0.91	1.39	0.37	1.46	153%
P_z	15.2	6.68	8.52	2.32	10.31	128%
P_t	23.8	7.41	16.39	4.05	12.65	221%

P _{Sm}	216.5	101.7	114.8	20.76	121.86	113%
P _{sk}	1.97	-0.07	2.04	0.49	0.74	-2914%
P _{dq}	0.28	0.115	0.165	0.04	0.20	143%

In Figure 12, the values of the Ra, Rz parameters, as a function of cutting time, are shown from tests carried out with corrosion-resistant steel. The character and the generating reasons of the change are the same, the wear process takes place in a much more intensive way in case of more difficult to machine and inclined to burr formation steel assortments. In the first 6 minutes of machining, the surface roughness has an increasing tendency (approx. 1 µm/min), after that a definitive decrease can be observed. The differences, resulting from the tool wear, achieved treble value in case of Rz parameter treble value of differences. The temporal changes (especially in case of average roughness values) were described by a three-degree polynomial, drawn on the change of the values, with adequate accuracy.

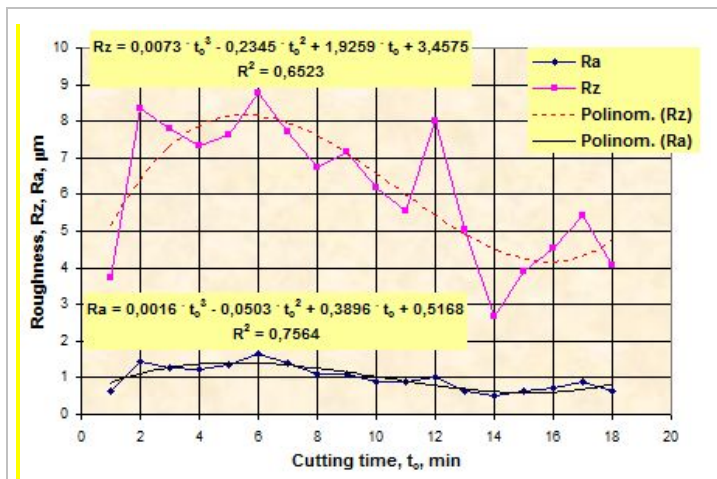


Figure 12

The development of Ra and Rz values in function of cutting time in case of turning operation in Ko36 steel ($v_c=160$ m/min; coating: CVD, type 4025)

In the roughness profile diagrams of Figure 13, presenting the changes in the surface microgeometry, the phenomena, described earlier in connection with Figure 11, can be recognized. As a result of “wandering” of the momentary cutting edge, the arithmetic parameters of surface roughness may achieve lower values, than those gained with a sharp tool.

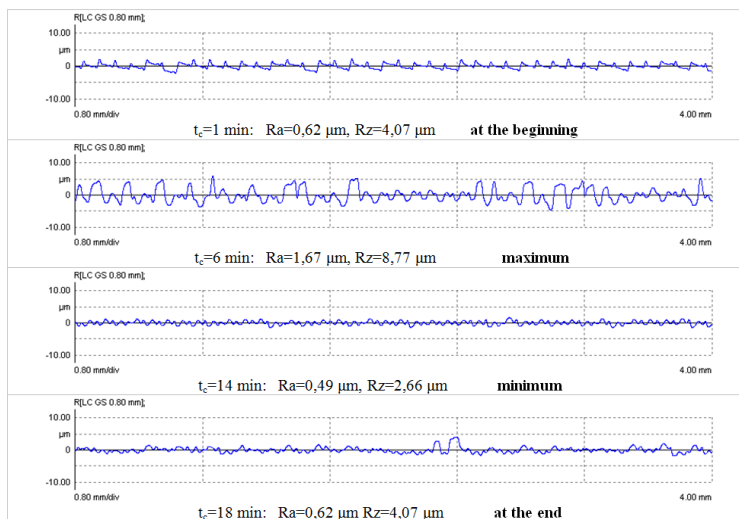


Figure 13

The development of roughness profile diagrams in function of cutting time in case of turning operation in Ko36 steel

The change in the parameters that occurred during the examination time is shown in Table 5, for the case of a turned surface. Analyzing the data, it is clear that the change, resulting from the tool wear, is greater than 200% – due to the bad machinability features of the corrosion-resistant material – in case of Ra average roughness, Rz height of unevenness and Rt maximal unevenness; while in case of Rdq values, the change is greater than 100%. In regard to the Rsk values, the change is greater: the drastic transformation of microgeometry, resulting from the tool deterioration, is confirmed. The parameter values of R profile is obviously exceeded by the P profile parameter values, but the degree of change is smaller (lower than 200%).

Table 5

Surface, machined with turning operation, material: Ko36; $v_c = 160$ m/min; $a = 1$ mm; $f = 0.1$ mm; $r_e = 0.8$ mm

Roughness	maximum	minimum	Range, R	Dispersion, s	Average	R/min
R profile						
Ra	1.67	0.49	1.18	0.34	1.00	241%
Rz	8.77	2.66	6.11	1.84	6.15	230%
Rt	12.98	3.12	9.86	2.37	8.25	316%
RSm	211.4	58.6	152.8	33.23	123.78	261%
Rsk	1.72	-0.07	1.79	0.51	0.93	-2557%
Rdq	0.143	0.063	0.08	0.03	0.10	127%

P profile						
Pa	1.67	0.6	1.07	0.34	1.07	178%
Pz	9.58	4.43	5.15	1.85	7.39	116%
Pt	13.23	5.9	7.33	1.95	9.23	124%
PSm	195.2	75.5	119.7	31.25	138.21	159%
Psk	2.61	0.5	2.11	0.52	1.25	422%
Pdq	0.133	0.06	0.073	0.02	0.10	122%

The wear marks, registered in the case of certain feed values, are shown in the stereomicroscopic pictures taken of the surface forming tool edge section and its flank wear-land using a 45X magnification (Figure 14).

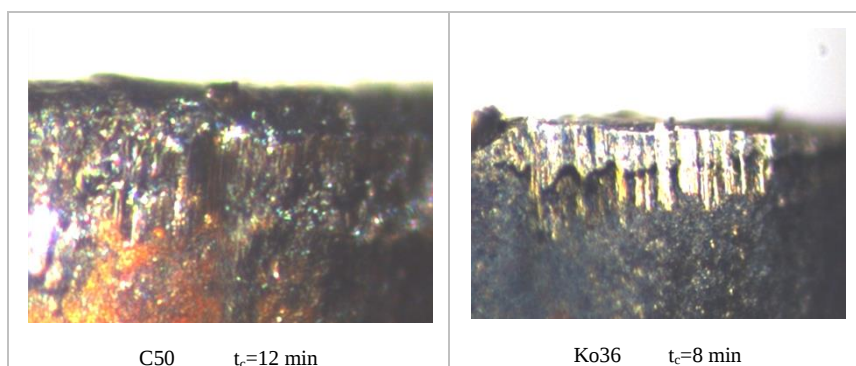


Figure 14

Stereomicroscopic pictures, taken about the flank wear-land wear in case of the machined materials

On these, the form and shape of the edge wear is well recognizable, but they are not able to carry out detailed analyses or even more to compare it with the microgeometry of the machined surface based on these pictures.

In case of a turning operation in C50 constructional steel, devices, enabling greater resolution and registrations (2D roughness measurements, 3D topography and electron microscope) were invoked in order to compare the tool edge section and the microgeoemetry.

The flank wear-land of the tool edge was scanned with stylus method, starting from the tool edge section in 10 μm steps, similar as in case of machined surface. The best correspondence between the edge shape and the machined surface was registered in the section, when the wear on the tool edge point achieved approx. 0.12 mm (Figure 15), i.e. the momentary cutting edge stayed in this position after having machined 22 minutes. This statement can be made if the tool edge point is “traversed” by 180° (this is valid for further examination and analysis methods as well).

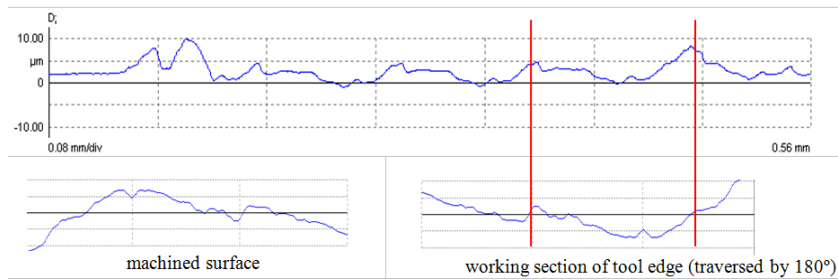
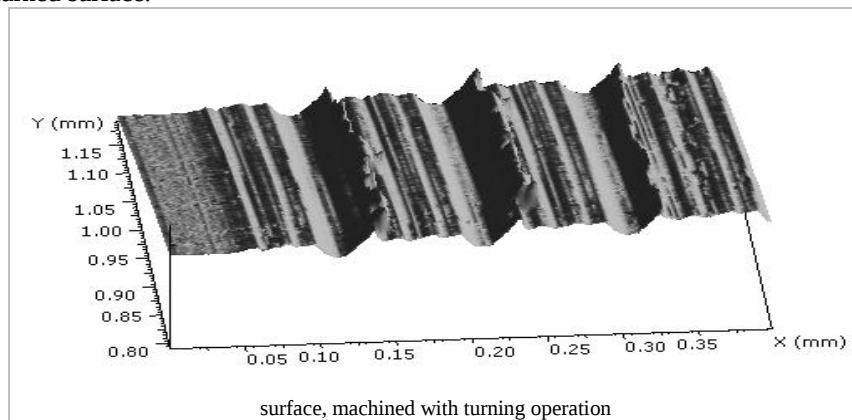


Figure 15

The flank wear-land wear on the tool edge ($VB_c \approx 0,12 \text{ mm}$) and the micro-geometric section of the machined surface in case of turning operation in C50 material ($t_c = 22 \text{ min}$)

After having finished the cutting tests, there were further solutions to examine the inserts instrumentally. 3D topography was performed for the last section of the machined surface and for the flank wear-land of the tool edge on the Mahr-Perthen measuring instrument (Figure 16). The wear marks, indicated by a dart on the flank wear-land, can be compared easily with the shape of micro-profile of turned surface.



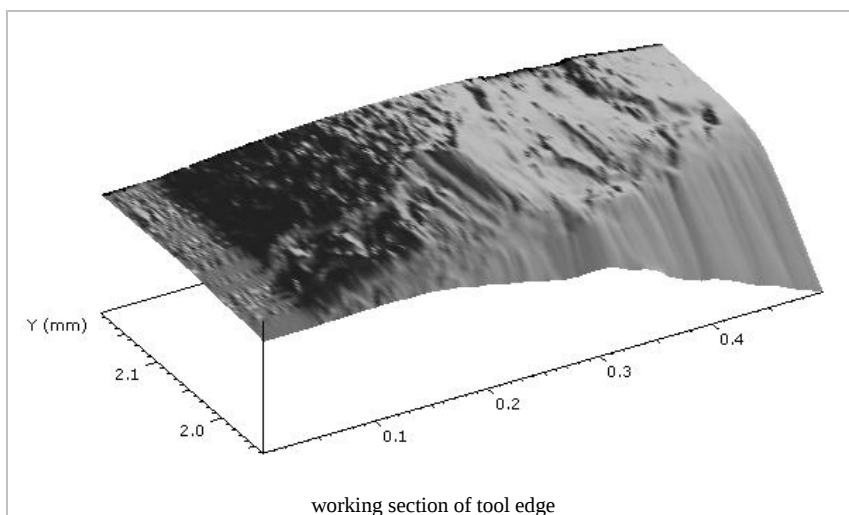


Figure 16

The machined surface and the topographic picture of tool flank wear-land in case of turning operation in C50 material ($t_c=41$ min)

Further and more detailed comparisons were carried out on 3D optical microscope with high resolution, type: Alicona InfiniteFocus and on Hitachi 3400 scanning electron microscope, located in the laboratory for material analysis at Széchenyi István University. The pictures, taken for these examinations, are shown in Figures 17-18.

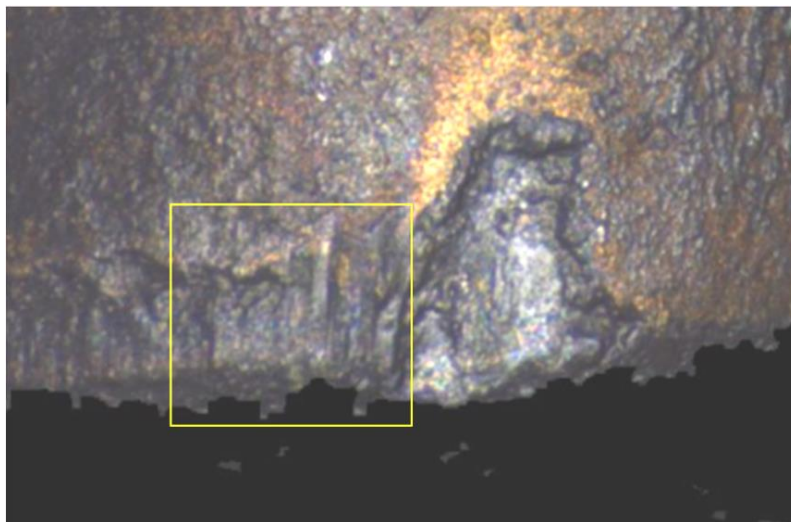


Figure 17

3D visualization of the flank wear-land of the tool edge

The picture, taken on Alicona, can be very well compared with the topographic pictures, made on Mahr-Perthen. On Figure 17 every typical wear mark can be well observed: the coating peel off, developed on the flank wear-land of the minor cutting edge and not influencing the tool in surface forming even as wear marks on the edges, forming the microgeometry of machined surface (for better visibility marked with a frame in the picture).

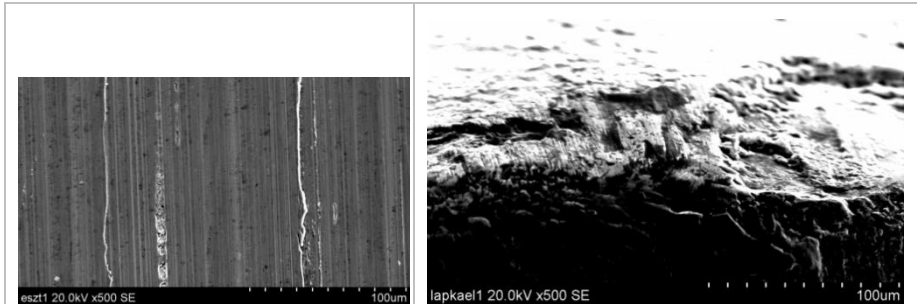


Figure 18

The machined surface and the picture, taken with electron microscope about the flank wear-land of the tool edge

Figure 18 was taken with an electron microscope, it shows the flank wear-land of the tool edge, compared to the statements, made until now, as the details of the worn-out flank wear-land are well illustrated: the adhesion splits [16] and the wear marks of abrasive character are changing continuously.

Summary and Conclusions

A surface, machined by any method, cannot be considered homogeneous; no matter in regard to measurement technique, production or especially the operation. A significant difference may be shown, in the micro-geometric parameters that characterize the surface, in extreme cases it may achieve a value of 70-100%.

During production and quality control of a surface, consideration that surface formation takes place in the course of the deterioration process of the tool always needs to be noted. It means that the wear process of the tool and its temporal development interacts with the surface as machined. This process can be traced back to the wear features of the flank wear-land of the tool edge: there is a change in the character of the micro-geometric profile, the generally known Ra and Rz roughness parameter values may even show a difference of 200-300%.

The R parameters of surface roughness do not characterize the microgeometry of the working, connected surfaces, quite reliably in and of itself, since – as a result of the filtering – there may be significantly differences in the existing surface. Therefore, the parameters of P profile, were always registered during the tests. Based on the comparison of the R and P parameters it is worth consideration to use features of the unfiltered P profile as they express the contact, friction and contact relations between the contact surfaces in a better way.

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