© Universiti Tun Hussein Onn Malaysia Publisher's Office

IJIE

http://penerbit.uthm.edu.my/ojs/index.php/ijie
ISSN : 2229-838X e-ISSN : 2600-7916

The International Journal of Integrated Engineering

Preliminary Study on the Function-Defining 3D Surface Roughness Parameters in Tangential Turning

István Sztankovics[1*]

[1]Institute of Manufacturing Science Egyetemváros,
University of Miskolc, Miskolc, H-3515, HUNGARY

*Corresponding Author

DOI: https://doi.org/10.30880/ijie.2023.15.07.007
Received 15 June 2023; Accepted 3 October 2023; Available online 5 December 2023

Abstract: The function-defining three-dimensional (3D) surface roughness parameters (which describe an aspect of the surface quality based on areal topography measurements) are studied on tangentially turned surfaces with different technological parameters in this paper. The 2^3 factorial design is applied in the planning of experiments. Two levels of depth of cut, cutting speed and feed were chosen for the comprehensive analysis of the tangential turning process. The values of Core Roughness, Reduced Peak Height, Reduced Valley Depth, Skewness and Kurtosis are measured by the application of a 3D areal roughness measurement machine. Equations were determined for the calculation of the studied parameters according to the factorial design method. The results were evaluated in two steps: first the functional parameters derived from the Areal Material Ratio curve were analyzed, then the Skewness and Kurtosis of the assessed area were studied. It is found that a two-fold increase in the cutting speed decreases the Core Roughness Depth, Reduced Peak Height, and Reduced Valley Depth 2-4-fold. The increasing feed rate lowers the presence of inordinately extremes, resulting in a smoother surface. In the point of view of Skewness and Kurtosis, lower cutting speeds and higher feeds are more favorable.

Keywords: Core roughness, factorial design, kurtosis, finish machining, skewness, tangential turning

1. Introduction

There are many goals which can be achieved during the development of machining procedures in the automotive industry. The main targets are the achievement of high productivity, the generation of the acceptable surface quality and doing this with better energy efficiency [1,2]. These attributes vary with the changing of machining procedures and/or technological parameters. A generally accepted procedure in manufacturing of hardened cylindrical parts is hard turning. By the application of this procedure, a higher material removal rate can be achieved than with grinding [3]. Pathapalli et al. showed [4] that to achieve high material removal rate, low surface roughness and low tool wear rate simultaneously the order of impact of the control parameters is built up to be depth of cut, cutting speed, and feed rate. Depth of cut is usually given by the allowance between the blank and the finished part, therefore the alteration of the other two technological parameters is studied more often. Tamang and Chandrasekaran. showed in their work [5], that better surface roughness can be obtained at high cutting speed and lower feed rate. However, higher heat is produced in hard machining, which causes premature tool wear on the cutting tool [6]. This phenomenon - as pointed out by Kundrák and Pálmai [7] is caused by the occurrence of a different tool wear mechanism (thermally activated process). Thus, increasing the cutting speed leads to an exponential decrease in tool-life. In addition, Felhő and Varga showed, that increasing the feed rate leads to a more orderly generated surface, which is easier to predict and approximate with the defined roughness values [8].

A solution to the increased tool wear in hard turning is the change of its kinematics. When machining outer cylindrical surfaces, we usually apply longitudinal feed direction. Another approach can be the tangential movement of the tool [9], as shown in Figure 1. As it can be seen, longer cutting edge will machine the surface, and the points of this

*Corresponding author: istvan.sztankovics@uni-miskolc.hu

edge come into contact continuously during the cutting. This leads to a more evenly distributed tool wear along the cutting edge, furthermore cooler parts of the cutting edge can reach the chip removal zone. This leads to a better tool life with the same technological parameters [10]. The machining accuracy mainly depends on the extent of the inclination angle, tangential feed, and depth of cut [11]

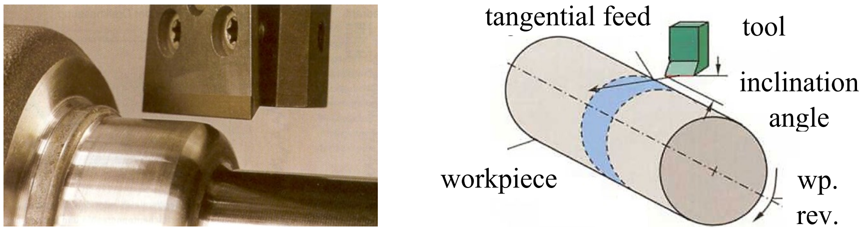


Fig. 1 - Tangential turning and its kinematic scheme [10]

The most used parameters in the quantification of surface quality are the Arithmetic Mean Deviation (R_a) and the Maximum peak to valley height of the profile (R_z). However, it is indicated [12] that these parameters are not always good in the characterization of the machined surface. The results of Yue et al. indicated [13] that the original parameters are unsuitable to characterize the textured surfaces, however the Abbot-Firestone curve parameters are more effective for tribological applications. It is also crucial to adjust the proper parameters during the measuring [14]. Figure 2 presents three of the parameters, which can be read from this curve: Core Roughness (S_k), Reduced Peak Height (S_{pk}), Reduced Valley Depth (S_{vk}). These parameters are better in describing the amount of material, which will be removed from the machined surface during the initial contact in the assembly (S_{pk}); the area, which will take the most amount of load during the working conditions (S_k); and the valleys, which will hold the most amount of lubricant and/or debris (S_{vk}).

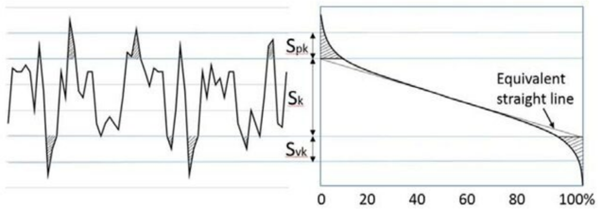
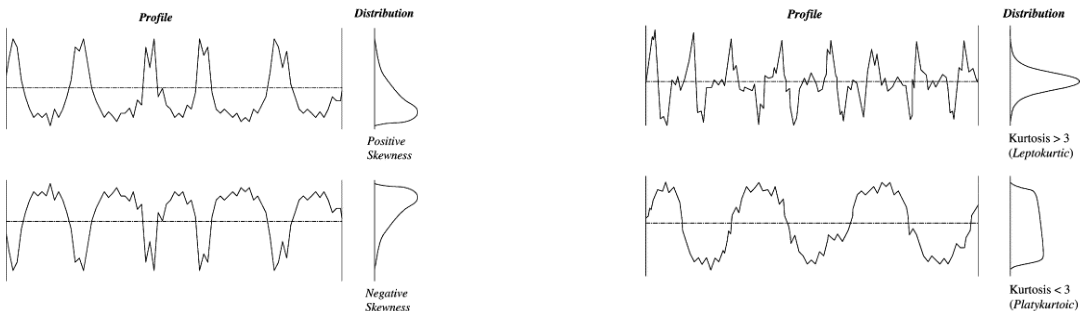


Fig. 2 - Explanation of the bearing area curve (Abbot-Firestone curve) [15]



(a) meaning of Skewness (b) meaning of Kurtosis

Fig. 3 - Meaning of the Skewness and Kurtosis roughness parameters [16]

Other two parameters, which can characterize the functionality of the machined surface are the Skewness and the Kurtosis [16]. The meaning of these parameters and their values can be easily understood using Figure 3. The Skewness describes the uneven distribution of the measured points around the mean line. Positive Skewness indicates high peaks with wide valleys, while negative Skewness means smooth surfaces with deep and narrow valleys. The determining value of Kurtosis is three: if this value is higher, then a frequently changing surface is present; while if it is below 3, a more even surface can be expected.

Therefore, these two parameters tell a lot about the functional behavior of the machined surface. The characteristic of Skewness and Kurtosis can be manipulated by the alteration of machining procedures [17] In hard turning, a negative Skewness was obtained only when the machining was carried out at relatively low feed rate [18], however it is usually not influenced by the depth-of-cut and the cutting speed. The Skewness and Kurtosis can be analyzed together on a so-called topological map [19], where the different machining procedures can be distinguished [20].

In this paper, a preliminary study is carried out to analyse the effect of the technological parameters on the function-defining areal surface roughness parameters. The 2^k full factorial experimental design methos was applied to select the analyzed values of the cutting speed, feed and depth of cut. The values of Core Roughness, Reduced Peak Height, Reduced Valley Depth, Skewness and Kurtosis are measured and studied according to the expected functional behavior of the machined surface.

2. Methods and Conditions

In this paper, tangentially turned surfaces were analyzed by the application of cutting experiments and theoretical equation determination. The latter is done using the 2^k factorial design method. The cutting experiments were carried out on an EMAG VSC 400 DS hard machining center, which is capable of moving the tool in tangential direction to the cylindrical part. The machined workpieces were 42CrMo4 grade alloyed steels which were hardened to 60 HRC. This kind of material grade is frequently used in the automotive industry due to its good characteristics, hence it is chosen for the study. The machined diameter was 70 mm. The tangential turning tool (which was made by HORN Cutting Tools Ltd.) had an inclination angle of 45° (holder code: H117.2530.4132), which results in a better chip removal characteristic. A S117.0032.00 coded MG12 type uncoated carbide insert was fixed into the holder, which is suitable in machining of the workpiece material.

The tangential turning process was analyzed by the alteration of the cutting speed (v_c), the feed per workpiece revolutions (f) and the depth of cut (a). Two settings were chosen for these technological parameters according to the 2^k factorial design method, resulting in 8 experimental setups. The cutting experiments were carried out two times for each setup. The intention of this study was to make a preliminary analysis of the tangentially turned surfaces with different machining conditions. According to the cutting tool manufacturer recommendations, the cutting speed was set to 100 m/min and 200 m/min values, the feed was chosen to 0.3 mm/rev and 0.6 mm/rev, and the depth of cut was adjusted to 0.1 mm and 0.2 mm. Table 1 summarizes the experimental setups: the values of the selected factors and the design matrix.

Table 1 - Experimental setup

Setup	Selected factors			Design matrix		
	v_c [m/min]	f [mm]	a [mm]	v_c [-]	f [-]	a [-]
1	100	0.3	0.1	-1	-1	-1
2	200	0.3	0.1	1	-1	-1
3	100	0.6	0.1	-1	1	-1
4	200	0.6	0.1	1	1	-1
5	100	0.3	0.2	-1	-1	1
6	200	0.3	0.2	1	-1	1
7	100	0.6	0.2	-1	1	1
8	200	0.6	0.2	1	1	1

An AltiSurf 520 three-dimensional topography measuring instrument was applied for the measurements, which were carried out after the experiments using a confocal chromatic probe. The setup parameters for the measurements were chosen according to ISO 4288:1996 standard. In this paper, the 3D roughness parameters describing the functional properties of the surfaces were evaluated. These parameters were chosen by the recommendations of the technical literature. Other roughness parameters describing other aspect of the surface (for example the Arithmetic mean roughness or Maximum height of the profile) will be analysed in other studies.

The analyzed parameters of the 3D (Areal) surface texture were (ISO 13565-2:1996 and ISO 4287:1997):

- S_k - Core Roughness, is a measure of the core (peak to valley) roughness of the surface [μm]
- S_{pk} - Reduced Peak Height, is a measure of the peak height above the core roughness [μm]
- S_{vk} - Reduced Valley Depths, is a measure of the valley depth below the core roughness [μm]
- S_{sk} - Skewness of the 3D surface texture [-]
- S_{ku} - Kurtosis of the 3D surface texture [-]

The results were used to determine equations for the better understanding of the cutting process. These were worked out using the form in Equation 1 according to the 2^3 factorial design method. The y is the dependent value and k_i are the coefficients describing the effect of the different factors on the dependent value. The independent variables are the cutting speed (v_c), feed (f) and depth of cut (a)

$$y(v_c, f, a) = k_0 + k_1 v_c + k_2 f + k_3 a + k_{12} v_c f + k_{13} v_c a + k_{23} f a + k_{123} v_c f a \quad (1)$$

3. Experimental Results

Figure 4 presents one obtained surface topographies for each setup. 4 mm x 4 mm areas were evaluated on each measured surface, where the filter and other instrumental variables were adjusted according to the standard.

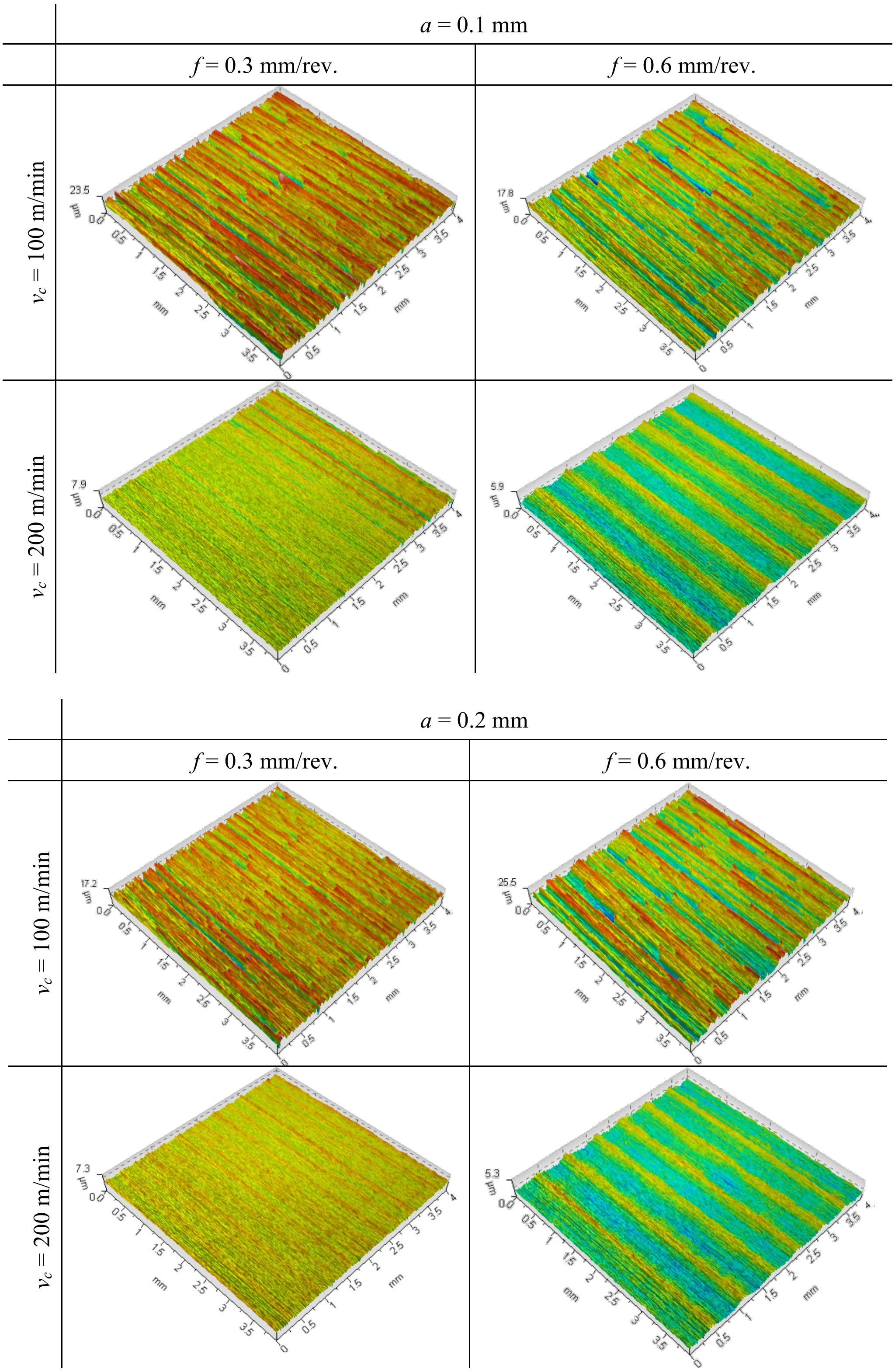


Fig. 4 -The measured areal topographies for each setup

Among the many quantitative describing parameters of the surface, the Core Roughness, Reduced Peak Height, Reduced Valley Depth, Skewness and Kurtosis values were collected. The results of the measurements of the 3D surface measurements are presented in Table 2. The table contains the measurements for the 2 experiments for each setup and shows the calculated average of the measured values. Table 3 presents the calculated ratios of the Reduced Peak Height to Core Roughness (S_{pk} / S_k), which helps in studying the functional behavior of the machined surfaces.

The calculated averages were used to determine equations, which are capable of calculating and further analyzing the studied 3D roughness parameters. The 2^3 full factorial design methods were applied to work out these. For each studied parameter the required coefficients are calculated. Equation 2-8 presents the results of the evaluation of Equation 1 for each studied characteristic roughness parameter. These equations are deducted by the application of Maple mathematical software, and the error in the studied point is statistically neglectable. The goodness of the presented function in other points should be analyzed further and it will be a target of a future study.

$$S_{sk}(v_c, f, a) = 1.320 - 0.0116v_c - 4.562f - 8.936a + 0.0329v_cf + 0.0256v_ca + 18.62fa - 0.0458v_cfa \quad (2)$$

$$S_{ku}(v_c, f, a) = 1.104 + 0.0131v_c + 4.941f + 8.136a - 0.0388v_cf + 0.0194v_ca - 36.72fa + 0.1505v_cfa \quad (3)$$

$$S_k(v_c, f, a) = 31.680 - 0.1283v_c - 53.960f - 165.401a + 0.2278v_cf + 0.7146v_ca + 418.60fa - 1.9040v_cfa \quad (4)$$

$$S_{pk}(v_c, f, a) = 7.079 - 0.0320v_c - 11.441f - 34.840a + 0.0575v_cf + 0.1705v_ca + 82.95fa - 0.4186v_cfa \quad (5)$$

$$S_{vk}(v_c, f, a) = 10.930 - 0.0443v_c - 16.101f - 50.090a + 0.0661v_cf + 0.2431v_ca + 127.70fa - 0.6292v_cfa \quad (6)$$

$$S_{pk} / S_k\ (v_c, f, a) = 0.7882 - 0.0065v_c - 1.492f - 2.741a + 0.01781v_cf + 0.03466v_ca + 5.01fa - 0.07036v_cfa \quad (7)$$

$$S_{vk} / S_k\ (v_c, f, a) = 0.2854 - 0.0019v_c + 0.814f - 1.267a - 0.00025v_cf + 0.04294v_ca - 0.103fa - 0.06360v_cfa \quad (8)$$

Table 2 - Experimental results

Setup	Data set	S_k [μm]	S_{pk} [μm]	S_{vk} [μm]	S_{sk} [-]	S_{ku} [-]
1	1	7.24	1.55	3.19	-0.51	3.06
	2	6.64	1.70	2.86	-0.36	3.13
	Average	6.94	1.62	3.02	-0.44	3.09
2	1	0.96	0.60	1.07	-0.77	5.40
	2	3.80	0.59	1.18	-0.20	2.38
	Average	2.38	0.60	1.12	-0.49	3.89
3	1	2.87	0.73	1.69	-0.43	2.63
	2	6.00	1.57	2.55	-0.37	2.90
	Average	4.43	1.15	2.12	-0.40	2.76
4	1	1.01	0.61	0.29	0.52	3.02
	2	0.98	0.58	0.33	0.29	2.67
	Average	0.99	0.60	0.31	0.40	2.85
5	1	4.38	1.10	1.98	-0.53	3.17
	2	4.39	1.05	2.80	-0.77	3.73
	Average	4.39	1.08	2.39	-0.65	3.45
6	1	0.81	0.29	0.33	-0.08	3.28
	2	1.71	0.71	1.73	-1.09	6.51
	Average	1.26	0.50	1.03	-0.59	4.89
7	1	8.22	1.71	3.51	-0.21	2.54
	2	9.23	1.97	3.36	-0.17	2.40
	Average	8.72	1.84	3.43	-0.19	2.47
8	1	0.99	0.47	0.29	0.33	2.92
	2	1.01	0.48	0.26	0.85	4.38
	Average	1.00	0.48	0.28	0.59	3.65

Table 3 - Calculation of the ratio parameters

Setup	1	2	3	4	5	6	7	8
S_{pk} / S_k [-]	0.23	0.25	0.26	0.60	0.25	0.40	0.21	0.48
S_{vk} / S_k [-]	0.44	0.47	0.48	0.32	0.54	0.82	0.39	0.28

4. Discussion

The presentation of the applied methods, equipment and the measured results and calculated equations description are followed by the evaluation of the collected data. The analysis is done in two steps by processing the measured data and worked out equations. Firstly, the functional parameters derived from the Areal Material Ratio curve - based on the ISO 13565-2:1996 standard - were analyzed. Secondly, the symmetry and deviation of the measured points from an ideal Normal - bell curve - distribution is studied.

4.1 Functional Parameters Derived from The Areal Material Ratio Curve

In this study, three of the functional parameters describing the material ratio of the measured area are analyzed. These are the Core Roughness Depth, Reduced Peak Height, and Reduced Valley Depth. S_k represents the height of the core surface over which a load may be distributed after the surface has been run in. The nominal roughness can be characterized with this value, and it can replace other height parameters such as Average Roughness or Maximum Height of Surface. S_{pk} characterizes the peak height of the assessed area, which will be the initial contact area between the fitting surfaces, therefore high contact pressure will appear. This leads to the fast removal of this material from the surface during the initial run-in of the machine containing these parts. Finally, S_{vk} is a measure of the valley depths below the core roughness. The higher this value is the deeper and thinner the valley will become on the surface thus leading to better lubrication effect in good cases or debris entrapment in bad case. Figure 5 shows the measured S_k, S_{pk}, S_{vk} values, while Figure 6 shows the previously determined functions of these parameters.

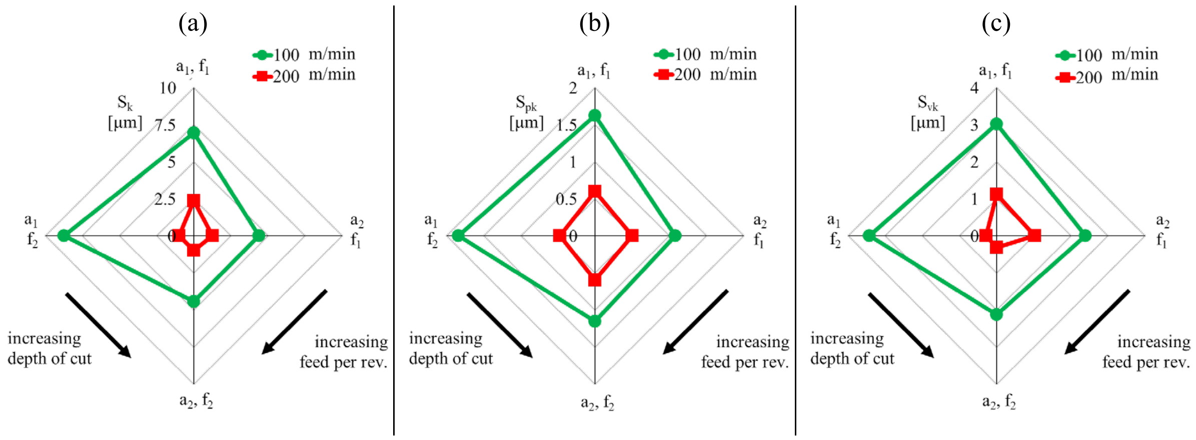
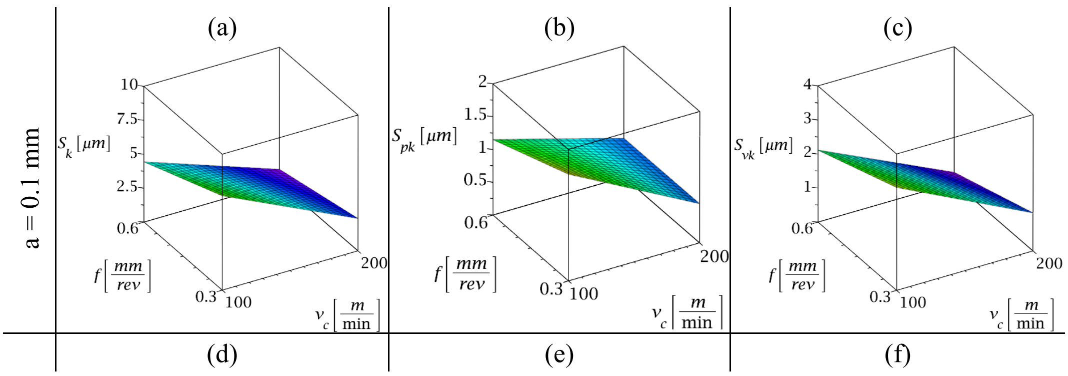


Fig. 5 - The measured core roughness depths, reduced Peak heights, and reduced valley depths



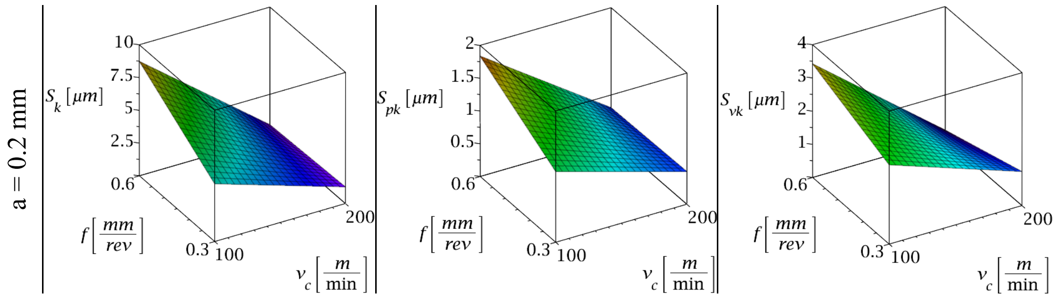


Fig. 6 - The graphs of core roughness depths, reduced peak heights, and reduced valley depths

Based on Fig. 5-6 it can be stated that increasing the cutting speed from 100 m/min to 200 m/min decreases the extent of these values 2-4-fold. This phenomenon is related to the increased rate of plastic deformation in the surface layer of the machined surface, which results lower surface roughness in the studied range. The increase in the depth of cut has also a lowering effect on these parameters: by adjusting 0.2 mm depth of cut instead of 0.1 mm, the S_k, S_{pk}, S_{vk} values are halved. The increase of the depth of cut increases the to be removed chip height which lowers the specific cutting force but also increases the acting cutting force. This means an increased burnishing effect on the machined surface; however, this observation needs further analysis. The feed rate has different effects on different cutting speeds and depth of cuts. If the cutting speed was 100 m/min, the increase of the feed had almost no or rather increasing effect on the examined parameters. However, with 200 m/min cutting speed, increasing the feed lowered the values by a significant amount. Figure 6 shows that Equation 2-4 describes well the characteristics of above written change.

A further analysis of these values is carried out by the so-called ratio parameters. These are introduced, because the commonly used roughness parameters are not always capable in differentiating between surfaces with deep valleys, high peaks, or variable heights. The ratio of the Reduced Peak Height to Core Roughness (S_{pk} / S_k) shows the relationship between the peak material and core material. The higher the value of this ratio the increased the peak height will be. Reduced Valley Depth to Core Roughness (S_{vk} / S_k) can provide information about how well the surface will maintain lubricant and/or hold unwanted material particles. Figure 7 shows the graphical visualization of Equation 7-8.

From Figure 7 the following conclusions can be drawn. It can be seen in Fig. 7.a-b, that the Reduced Peak Height to Core Roughness ratio will be the highest at high cutting speed and feed rate on both depths of cuts. In the other hand (Fig. 7.c-d), the Reduced Valley Depth to Core Roughness ratio will be the lowest in the cases described previously. This is caused by the better machined surface generation due to the high deformation speed and contact length. Fig. 4 also shows that the effect of the cutting tool geometry on the surface roughness is the highest in 0.6 mm/rev feed and 200 m/min cutting speed. This results in a more orderly, periodical surface topography, which results in a higher peak height, but a lower valley depth related to the core roughness. In low cutting speed (100 m/min) the feed and depth of cut shows little effect on the analyzed ratios. In high cutting speed (200 m/min), with the increase of the feed the peaks are becoming more dominant than the valleys. Figure 7 shows that the depth of cut has a low effect on the studied S_{pk} / S_k and S_{vk} / S_k ratios.

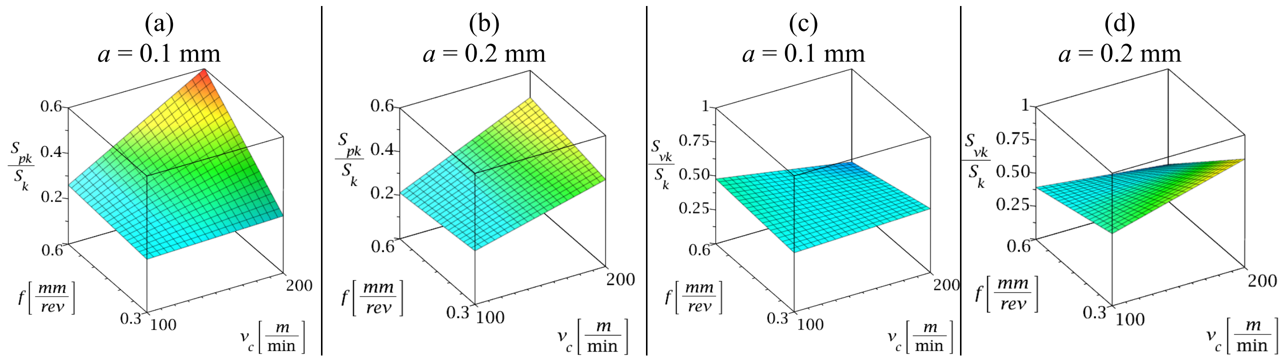


Fig. 7 - Change of the S_{pk} / S_k and S_{vk} / S_k ratios on different depth of cuts

4.2 Skewness and Kurtosis of the Assessed Area

The other two studied parameters were the Skewness and Kurtosis of the assessed area. The former describes the symmetricity of the distribution of the peaks and valleys about the mean plane. S_{sk} = 0.0 and S_{ku} = 3.0 means that the surface heights are Normally distributed. If S_{sk} is positive, the peaks are more dominant on the surface, however if its value is negative, the valleys are more influential. Kurtosis expresses the presence of inordinately high peaks/ deep valleys, where the separator value is 3. If S_{ku} is higher than 3, more extreme extent peaks and valleys can be found on the surface, while if it is lower than 3, lower extremes are present. Fitted functioning surfaces should have $S_{sk} < 0.0$ and $S_{ku} < 3.0$. The two values are analyzed separately at first. Figure 8 shows the measured values of the Skewness (a) and Kurtosis (b).

Based on Fig. 8 it can be concluded that the cutting speed increases these values in most cases. It can be seen in Fig. 8.a that higher feed means higher Skewness when the cutting speed is 200 m/min: a two-fold increase in the feed affects not just the extent but the sign as well. The Skewness is negative on lower feed, which means the valleys are more dominant on the surface; while the Skewness is positive on 0.6 mm/rev, which means the peaks are more impactful. This is caused by the changing periodic characteristic of the surface, which is shown in Figure 4. The depth of cut shows little effect on the S_{sk} in either cutting speeds. Fig. 8.b presents the change of Kurtosis. The increasing feed rate lowers the presence of inordinate extremes, resulting in a smoother surface. This is caused by the better chip removal due to the increased chip height. However, the increase in the depth of cut increases the Kurtosis, because the former also increases the chip width, which results in a longer contact between the cutting edge and the workpiece.

Figure 9 shows the graphical visualization of Equation 2 and 3. Fig. 9.a-b shows that on both depth of cuts, the high cutting speed and high feed combinations resulted in the highest and only positive values of S_{sk}. Lowering either of these results in a negative Skewness, which values varies only a little. Fig. 9.c-d presents that the highest two Kurtosis values are achieved with 200 m/min cutting speed and 0.3 mm/rev. feed on both depth of cuts. To decrease the S_{ku} we need to either lower the cutting speed or increase the feed rate.

In the end of this section, the combination plots of the Skewness and Kurtosis are analyzed. These kinds of graphs are studied frequently, because they talk more about the functional characteristics of the machined surfaces. Figure 10 presents the same plot; however, the meaning of the colors is changing according to the analyzed technological parameter.

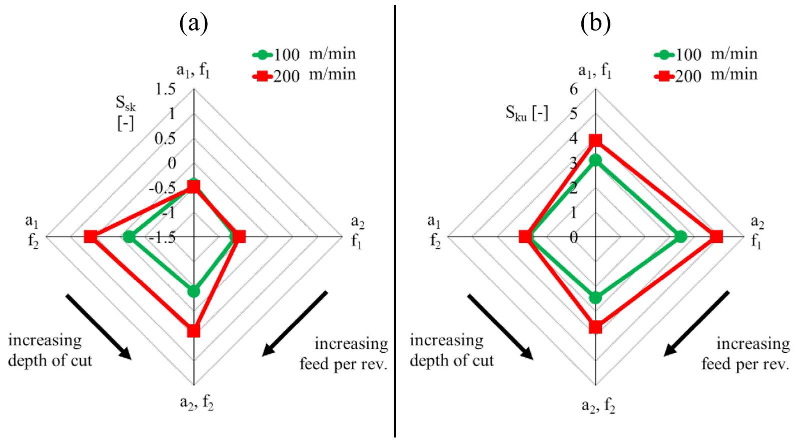


Fig. 8 - The Measured Skewness and Kurtosis

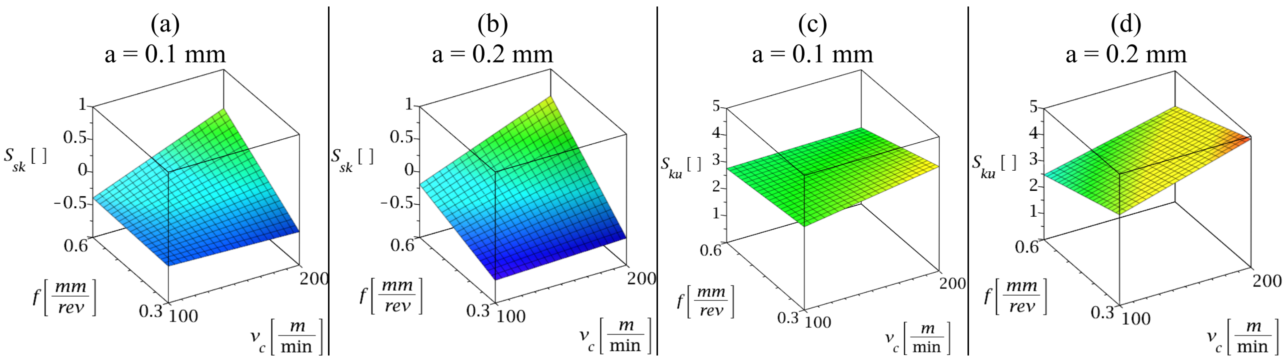


Fig. 9 - Alteration of the S_{sk} and S_{ku} values on different depth of cuts

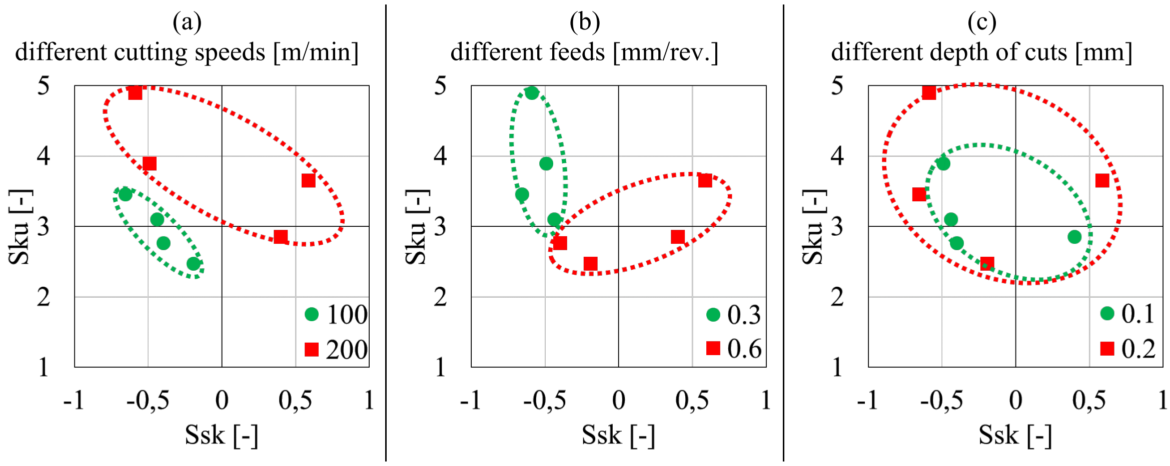


Fig. 10 - Combination plot of the S_{sk} and S_{ku} values on different setups

Fig. 10.a shows the combined effect of the cutting speed change. It can be seen that on 100 m/min cutting speed the results are less spread than on 200 m/min. Also increasing the cutting speed moves the set of result from the lower left quartile to the upper right. This means that lower cutting speeds are more favorable. Fig. 10.b presents the effect of feed alteration. In this case increasing the feed from 0.3 to 0.6 mm/rev. transfers the values from the upper left quartile to the lower right quartile, however higher feeds lead to results in the most favorable section. Here the measurements are less spread. Finally, Fig 10.c shows the effect of the changing depth of cut. Here we can see that the increasing depth of cut results in a more stretched values, which is caused by the increasing cutting force and chip width. The outcome can be more controlled if the depth of cut is lower.

5. Summary

The development and application of machine procedures require many kinds of studies. The aim of these developments is to improve the functionality of the machined surfaces. There are various parameters which can characterize this requirement. In this paper the roughness parameters from the Abbot-Firestone curve, the Skewness and the Kurtosis are analyzed. The studied machining procedure is tangential turning, where we use a wide cutting edge with tangential feed in order to produce the machined surface. By the application of this procedure the productivity can be increased while the surface roughness can be lowered. However, it is also important to study the functional roughness parameters in case of this procedure as well. Experiments were carried out with 2 kinds of cutting speed, feed and depth of cut (8 setup). After the necessary measurements were done, equations were determined using the 2^3 factorial design method. The effects of the technological parameter alterations were analyzed using the measured results and the given equations. The following findings can be highlighted:

- Setting the cutting speed from 100 m/min to 200 m/min decreases the Core Roughness Depth, Reduced Peak Height, and Reduced Valley Depth 2-4-fold.
- The increase in the depth of cut has also a lowering effect on the S_k, S_{pk}, S_{vk} values.
- The Reduced Peak Height to Core Roughness ratio will be the highest, while the Reduced Valley Depth to Core Roughness ratio will be the lowest at high cutting speed and feed rate.
- The increasing feed rate lowers the presence of inordinately extremes, resulting in a smoother surface
- The high cutting speed and high feed combinations resulted in the highest and only positive values of S_{sk}.
- In the point of view of Skewness and Kurtosis, lower cutting speeds and higher feeds are more favorable.

Acknowledgment

The authors fully acknowledged the University of Miskolc for supporting this work.

References

[1] Byrne, G., Dornfeld, D., & Denkena, B. J. C. A. (2003). Advancing cutting technology. CIRP Annals, 52(2), 483-507. doi: https://doi.org/10.1016/S0007-8506(07)60200-5

[2] Bruzzone, A. A., Costa, H. L., Lonardo, P. M., & Lucca, D. A. (2008). Advances in engineered surfaces for functional performance. CIRP annals, 57(2), 750-769. doi: https://doi.org/10.1016/j.cirp.2008.09.003

[3] Kundrák, J., Mamalis, A. G., & Molnár, V. (2019). The efficiency of hard machining processes. Nanotechnol. Percept, 15, 131-142. doi: https://doi.org/10.4024/N05KU19A.ntp.15.02

[4] Pathapalli, V. R., P, S. R., Basam, V. R., & Doni, M. K. (2019). Multi Response Optimization of Turning Process by Considering its Cutting Parameters Implementing Grey Relational Analysis. International Journal of Integrated Engineering, 11(8), 110-118. DOI: https://doi.org/10.30880/ijie.2019.11.08.011
[5] Tamang, S., & Chandrasekaran, M. (2021). Multi-objective Optimization of Turning Performance Characteristics using GA Coupled with AHP based Approach. International Journal of Integrated Engineering, 13(6), 126-136. DOI https://doi.org/10.30880/ijie.2021.13.06.012
[6] Panda, A., Bag, R. ., Sahoo, A. K. ., & Kumar, R. . (2020). A Comprehensive Review on AISI 4340 Hardened Steel: Emphasis on Industry Implemented Machining Settings, Implications, and Statistical Analysis. International Journal of Integrated Engineering, 12(8), 61-82. doi: https://doi.org/10.30880/ijie.2020.12.08.007
[7] Kundrák, J., & Pálmai, Z. (2019). The Change of Tool Life in a Wide Range of Cutting Speeds in Hard Turning. Manufacturing Technology, 19(2), 254-260. doi: 10.21062/ujep/279.2019/a/1213-2489/MT/19/2/254
[8] Felho, C., & Varga, G. (2022). Theoretical roughness modeling of hard turned surfaces considering tool wear. Machines, 10(3), 188. doi: https://doi.org/10.3390/machines10030188
[9] Schreiber, L., & Trott, K. (1999). Verfahren zur drallfreien spanenden Bearbeitung von rotationssymmetrischen Flächen. Patent DE19963897A1.
[10] Schneider, J., & Schreiber, L. (2002). MASCHINEN UND ANLAGEN-Mit dem Tangentialdrehen zu drallfreien Oberflachen. Werkstatt und Betrieb, 135(6), 40-45.
[11] Nee, A. Y. C., & Venkatesh, V. C. (1985). Form accuracy of tangentially skived workpieces. CIRP Annals, 34(1), 121-124. doi: https://doi.org/10.1016/S0007-8506(07)61738-7
[12] Mgherony, A., Mikó, B., & Farkas, G. (2021). Comparison of Surface Roughness When Turning and Milling. Periodica Polytechnica Mechanical Engineering, 65(4), 337-344.
[13] Yue, H., Deng, J., Zhang, Y., Meng, Y., & Zou, X. (2020). Characterization of the textured surfaces under boundary lubrication. Tribology International, 151, 106359. doi: https://doi.org/10.1016/j.triboint.2020.106359
[14] Nagy, A. (2021). Investigation of the effect of areal roughness measurement length on face milled surface topographies. Cutting & Tools in Technological System, (94), 60-69. doi: https://doi.org/10.20998/2078-7405.2021.94.07
[15] Heidari, M., & Yan, J. (2017). Fundamental characteristics of material removal and surface formation in diamond turning of porous carbon. International Journal of Additive and Subtractive Materials Manufacturing, 1(1), 23-41. doi: 10.1504/IJASMM.2017.10003952
[16] Gadelmawla, E. S., Koura, M. M., Maksoud, T. M., Elewa, I. M., & Soliman, H. H. (2002). Roughness parameters. Journal of materials processing Technology, 123(1), 133-145. doi: https://doi.org/10.1016/S0924-0136(02)00060-2.
[17] Ferencsik, V., & Varga, G. (2022). The effect of burnishing process on skewness and kurtosis of the scale limited surface. Cutting & Tools in Technological System, (97), 83-90. doi: https://doi.org/10.20998/2078-7405.2022.97.07
[18] Molnar, V. (2022). Asymmetric Height Distribution of Surfaces Machined by Hard Turning and Grinding. Symmetry, 14(8), 1591. doi: https://doi.org/10.3390/sym14081591
[19] Whitehouse, D. J. (1994). Handbook of surface metrology. CRC Press.
[20] Kovacs, Z. F., Viharos, Z. J., & Kodácsy, J. (2022). Improvements of surface tribological properties by magnetic assisted ball burnishing. Surface and Coatings Technology, 437, 128317. doi: https://doi.org/10.1016/j.surfcoat.2022.128317