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ANALYSIS OF SELECTED FUNCTION-DEFINING 2*D* SURFACE ROUGHNESS PARAMETERS IN TANGENTIAL TURNING

Abstract. *Among other, more frequently analysed surface topography parameters, the function-defining parameters must be analysed in different machining procedures to outline their application possibilities. These values are the core roughness, the reduced peak height, the reduced valley depth, the skewness, and the kurtosis of the roughness profiles. Tangential turning is a promising machining procedure, which can produce ground-like surfaces with twist-free properties by defined cutting edged tools. The achievable productivity is also very high. Therefore, in this paper, these roughness parameters were analysed from 2D roughness profiles measured on surfaces machined by tangential turning.*

Keywords: *functional parameters; kurtosis; skewness; tangential turning.*

1. Introduction

Machining with tangential turning [1] is analysed in this paper in the point of view of the functional parameters of the surface. Among others Molnár also proved [2,3], that between the frequently analysed surface topography parameters, the extent of the R_k parameters is equally significant. This cutting procedure has many advantageous properties. It can be an alternative to rotational turning in machining of outer cylindrical surfaces [4,5] because twist-free surfaces are achievable [6]. Leichner et al. proved in their study that oil leakage, wear of the tool and machining costs can be reduced, when tangential turning is applied on sealing surfaces [7]. The combined procedure, where turning and grinding is done in one clamping, can be a good alternative [8], however MQL technique can be applied in tangential turning. Better tool life can be achieved than in traditional turning due to the different insert and feed motion [9]. The application of tangential turning is widely developed by machine tool manufacturers as well (e. g. EMAG [10]).

In this paper, the function defining parameters of the roughness profile are studied in tangential turning by changing the cutting speed, feed, and depth of cut. The core roughness, the reduced peak height, the reduced valley depth, the skewness, and the kurtosis of the roughness profiles were measured and analysed. During the measurement, the recommended adjustment values are set [11,12].

2. Experimental conditions and methods

The aim of this study was the analysis of the function defining surface parameters in tangential turning. Cutting experiments were carried out to achieve this goal. The tools used during the experiments was the following. A tangential tool with 45° inclination angle was used. The indexable turning tool is made by HORN Cutting Tools Ltd. and consisted of two parts S117.0032.00 insert and H117.2530.4132 holder. The working part of the tool was an uncoated carbide insert (MG12 grade). In the experiments, a cylindrical workpiece is machined, which outer diameter was 70 mm. The chosen material was 42CrMo4 grade alloyed steel, which processed by hardening heat treatment to 60 HRC hardness before the experiments. The tangentially turned surfaces was prepared before the experiments by turning with a standard CNMG 12 04 12-PM 4314 cutting insert made by SANDVIK Coromant, which was put into a PCLNR 25 25 M12 tool holder. An EMAG VSC 400 DS hard machining centre was applied for the study.

I aimed to analyse the alteration effect of the setup parameters of tangential turning, therefore the cutting speed (v_c), the feed per workpiece revolutions (f) and the depth of cut (a) were changed during the experiments. A lower and an upper limit value were chosen for each studied parameter. The lower value range of the parameters are aimed in this study in the initial research of the topic. Therefore, the cutting speed was chosen to be 100 m/min and 200 m/min, the feed was set to 0.3 mm and 0.6 mm. Two kinds of depth of cut were also chosen: 0.1 mm and 0.2 mm. This limit values resulted in 8 different setups, which can be seen in Table 1.

Table 1 – Experimental setups

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

The necessary measurements were carried out after the experiments with an AltiSurf 520 three-dimensional topography measuring instrument using a confocal chromatic probe. The measurement variables were chosen according to ISO 4288:1996 standard. In this paper, the 2*D* roughness parameters describing the functional properties of the surfaces were evaluated.

The analysed parameters were (ISO 13565-2:1996 and ISO 4287:1997):

- R_k – Core Roughness, is a measure of the core (peak to valley) roughness of the surface [μm]
- R_{pk} – Reduced Peak Height, is a measure of the peak height above the core roughness [μm]
- R_{vk} – Reduced Valley Depths, is found from a measure of the valley depths below the core roughness [μm]

- R_{sk} – Skewness of the assessed profile [-]
- R_{ku} – Kurtosis of the assessed profile [-]

3. Experimental results

The experiments were carried out with the planned setups. Figure 1 shows an example of the measured roughness profile and the assessment of the R_k parameters in case of Setup 8. The Bearing Area Curve based on the ISO 13565-2:1996 standard, and the core roughness, reduced peak height and valley depths are calculated for each measurement. The skewness and kurtosis parameters are calculated from the profiles according to ISO 4287:1997. Each machined workpiece was measured three times and the average values of the registered values were calculated. These results are shown in Table 2.

Table 2 – Measurement results

Setup	1	2	3	4	5	6	7	8
R_k [μm]	7.00	4.48	4.07	9.75	1.09	0.91	1.29	1.26
R_{pk} [μm]	1.33	0.98	0.89	1.83	0.60	0.36	0.69	0.55
R_{vk} [μm]	3.75	2.16	1.58	2.63	1.12	0.40	0.36	0.35
R_{sk} [-]	-0.45	-0.50	-0.38	-0.18	-0.23	-0.99	0.49	0.26
R_{ku} [-]	2.98	2.66	2.90	2.40	2.33	5.82	2.81	2.90

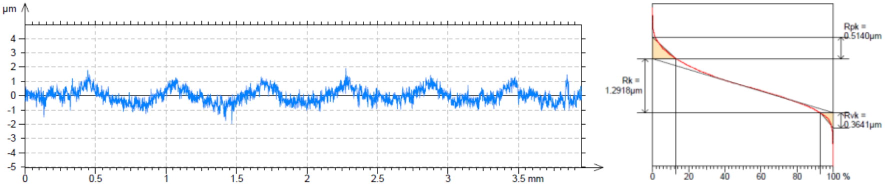

Figure 1 – Example of the measured 2*D* profile and the evaluation of the R_k parameters

4. Discussion

The three R_k parameters were analysed based on the graphs shown in Figure 2. Here the green points represent the 100 m/min cutting speeds while the red points show the values measured after the machining with 200 m/min. The four directions represent four different parameter combination. The feed increases in the bottom left direction while the depth of cut increases in the bottom right direction. Based on these graphs, a complex analysis can be done on these parameters.

Increasing the cutting speed results in lower values of these three parameters. This conclusion shows, that in the viewpoint of the R_k parameters, the material removal is better in 200 m/min cutting speed. This is caused by the increased rate of plastic strain, which results a more favourable plastic deformation.

As the analysis of the other two setup parameters, it can be seen, that the increase of the depth of cut results in lower values of the studied roughness parameters. Higher depth of cut means higher chip width, which also improves the material removal in the chip root. The increase of the feed resulted in a more different effect. The reduced valley depth decreases while the core roughness and the reduced peak height increases, if we increase the feed from 0.3 mm to 0.6 mm.

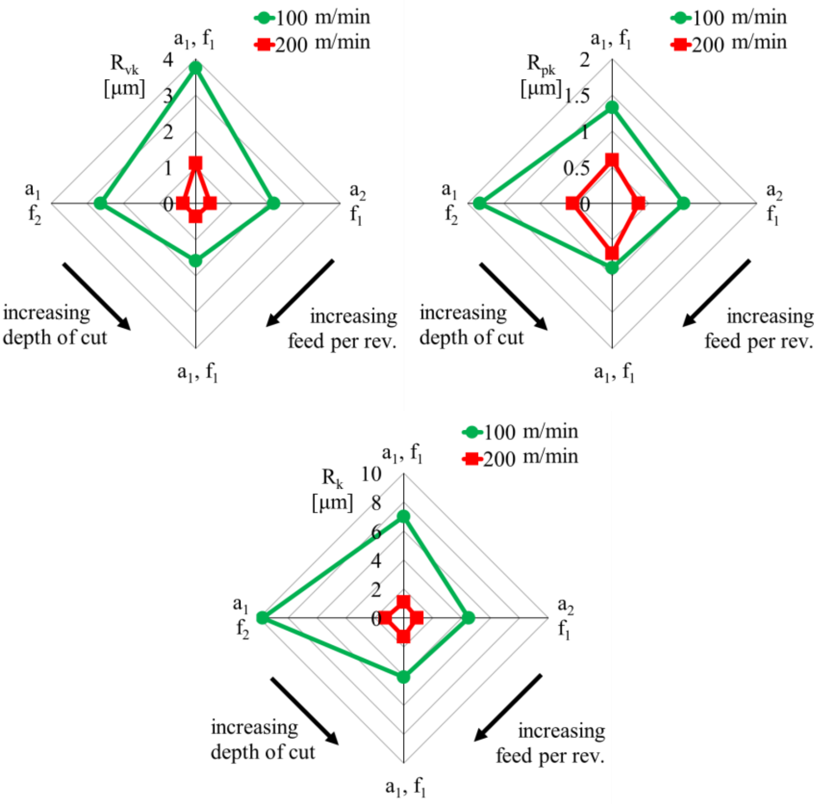

Figure 2 – Alteration of the R_{sk}, R_{vk}, R_k parameters

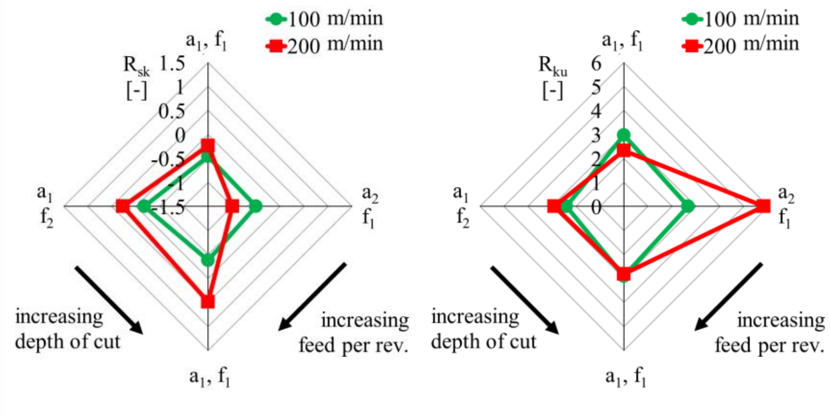

Figure 3 – Alteration of the skewness and kurtosis of the roughness profile

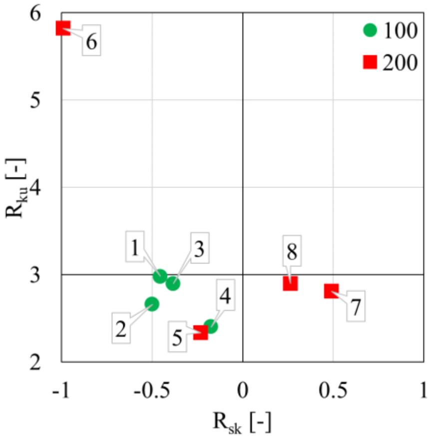

Figure 4 – Topological map of the studied setups

The skewness and the kurtosis of the roughness profiles are shown in Figure 3. Machining with lower cutting speed resulted in a lower value of the skewness, which means a flatter surface with some small valleys. As the cutting speed increased, this attribute of the surface is reversed. Increasing the feed per rev. decreases the flatness of the surface, while increasing the depth of cut had almost no effect. These mean that to achieve a machined surface with a better bearing capability, the cutting speed must be decreased while the feed should be increased in tangential turning. The reason for this phenomenon is the higher than usual contact length of the cutting tool, which helps to achieve a smoother surface. The kurtosis of the roughness is in the region of 2.3 – 3.0 in 7 cases and showed no clear correlation with the setup parameters in the studied region. This represents that the tangentially turned surfaces has a higher periodicity, and the peaks and valleys on the surface are wider, which means better functional attributes and longer life-time of the machined parts.

The topological map (R_{sk}–R_{ku} graph) is presented in Figure 4 based on the measured results. In the viewpoint of the functionality of the machined surface, the lower left quadrant of the map is preferred to be achieved, because these surfaces show the better bearing capability and life-time. The lower cutting speed has a clear advantage over the higher cutting speed because all the results with 100 m/min cutting speed remained in the desired quadrant. Increasing the feed and depth of cut resulted in worse skewness or kurtosis, which should be avoided.

5. Conclusions

Cutting experiments were carried out to study the functional attributes of tangentially turned outer cylindrical surfaces. In this work the cutting speed, the feed and depth of cut were adjusted to analyse the alteration effect of these parameters. After the cutting experiments the core roughness, the reduced peak height, the reduced valley depth, the skewness, and the kurtosis of the roughness profiles were measured. In the evaluation of the resulted data the following conclusions were drawn:

- Higher cutting speed is favourable to achieve better R_k parameters.
- The skewness of the profile is better on lower cutting speed.
- The kurtosis showed no clear correlation with the studied technological parameters.
- Surfaces with good functional attributes can be achieved with tangential turning.

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АНАЛІЗ ВИБРАНИХ ФУНКЦІЙНО-ВИЗНАЧАЛЬНИХ 2*D* ПАРАМЕТРІВ ШОРСТОСТІ ПОВЕРХНІ ПРИ ТАНГЕНЦІАЛЬНОМУ ТОЧІННІ

Анотація. *Серед інших, часто аналізованих параметрів топографії поверхні, параметри, що визначають функції, повинні бути проаналізовані в різних процедурах обробки, щоб окреслити можливості їх застосування. Це такі значення як: основна шорсткість, зменшена висота піку, зменшена глибина западини, асимметрія і ексцес профілів шорсткості. Тангенціальне точіння є багатообіцяючою процедурою обробки, за допомогою якої можуть вироблятися поверхні аналогічні шліфованим з безскручувальними властивостями за допомогою інструментів із певними ріжучими крайками. Досяжна продуктивність також дуже висока. Тому в цій статті ці параметри шорсткості були проаналізовані на основі 2D профілів шорсткості, виміряних на поверхнях, оброблених тангенціальним точінням. У роботі досліджено функції, що визначають параметри профілю шорсткості при тангенціальному точінні шляхом зміни швидкості різання, подачі та глибини різання. Було виміряно та проаналізовано шорсткість серцевини, зменшену висоту піку, зменшену глибину западини, перекос і ексцес профілів шорсткості. Експерименти з різанням проводилися для вивчення функціональних властивостей тангенціально обточених зовнішніх циліндричних поверхонь. Швидкість різання, подача та глибина різання були скориговані для аналізу ефекту зміни цих параметрів. Після експериментів з різанням були виміряні шорсткість серцевини, зменшена висота піку, зменшена глибина западини, перекос і ексцес профілів шорсткості. В результаті оцінки отриманих даних було зроблено наступні висновки: вища швидкість різання сприятлива для досягнення кращих параметрів* R_k*, асиметрія профілю краща при меншій швидкості різання, ексцес не показав чіткої кореляції з досліджуваними технологічними параметрами, поверхні з хорошими функціональними характеристиками можна отримати за допомогою тангенціального точіння.*

Ключові слова: *функціональні параметри, ексцес, перекос, тангенціальний поворот*