# CAN THE INCREASED FEED BE BENEFICIAL ON THE SURFACE QUALITY IN TANGENTIAL TURNING?

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***Abstract***

*The increase of the productivity in machining of mechanical parts is often achieved by the application of higher feed values. However, this usually leads to the generation of rougher surface topography. Therefore, the achievable surface roughness usually limits the maximum value of the feed in machining, hence the realisable productivity is highly limited. In this study, the tangential turning procedure is being analysed in the point of view of the generated surface topography. Experiments were carried out on 42 CrMo4 cylindrical workpieces to measure the roughness after machining. The evaluation of the results showed that the small increase of the feed has an advantageous effect on the surface roughness in tangential turning, because the chip removal becomes more stable thus decreasing the generated deflects on the surface.*

**Keywords:** *high feed, surface roughness, tangential turning*

## 1. Introduction

In the development of machining procedures, the optimization criteria vary according to the actual application task. A standard job in the every-day work of the industrial technologists is the decrease of the cycle time of the manufactured parts (Kovács, 2020). An easy looking solution to achieve this is the increase of speed of the secondary feeding movement. However, it is important to know the tribological aspects of the generated surface (Tóth et al., 2021), which characteristics are changing by the alteration of this parameter. In the point of view of surface quality, feed is an important data. As Kittali et al. evaluated as others, feed rate is a highly influential parameter on surface roughness (Kittali et al., 2022). However, its exact effect can have a different characteristic in different machining procedures. Kundrák et al. showed in their works on face milling, that the effect of the feed rate appears as a trend (Kundrák et al., 2020): increasing the feed rate causes the increase of the values of the roughness parameters (Kundrák et al., 2022). Ferencsik and Varga showed that the increase of the feed can be beneficial in the practice of surface burnishing (Ferencsik et al., 2022). Kun-Bodnár and Maros proved in their experiences of abrasive waterjet turning, that the total height parameter decreases at radial turning in function of feed speed, while at tangential turning characteristic tendency cannot be established (Kun-Bodnár et al., 2022). It is also important to note, that the effect of the feed is not so straightforward in each procedure. Satheesh Kumar et al. highlighted in their study, that low feed rates have low impact in the roughness (Kumar et al., 2012).

Furthermore, the selection of the studied roughness parameters is also essential. In turning procedures, the study of surface roughness parameters such as Arithmetical Mean Height, Skewness, and Kurtosis is critical for ensuring the quality and functionality of machined parts (Gadelmawla et al., 2002; Khorasani et al., 2012; Abellán-Nebot et al., 2024; M'Saoubi et al., 2008). The Arithmetical Mean Height is the average deviation of the surface profile from the mean line, providing a general measure of surface roughness. It is widely used to assess the overall smoothness, which directly impacts factors like friction, wear resistance, and the ability to form seals with other components. The analysis of skewness and kurtosis of the measured profile is less widespread *(Figure 1)*. Skewness measures the asymmetry of the surface profile. A negative skewness indicates a surface with more valleys than peaks, which can improve lubrication retention and reduce friction, while a positive skewness suggests a peak-dominated surface, potentially leading to increased wear. Understanding skewness helps in predicting the functional performance of the turned part, particularly in applications requiring specific tribological properties. Kurtosis indicates the sharpness of the surface profile. High kurtosis values signify surfaces with sharp, narrow peaks, which can lead to increased wear and stress concentrations. Low kurtosis indicates a flatter surface, which may better distribute stress and reduce wear. Analysing kurtosis ensures that the surface texture meets the operational demands, optimizing durability and performance in the final product.

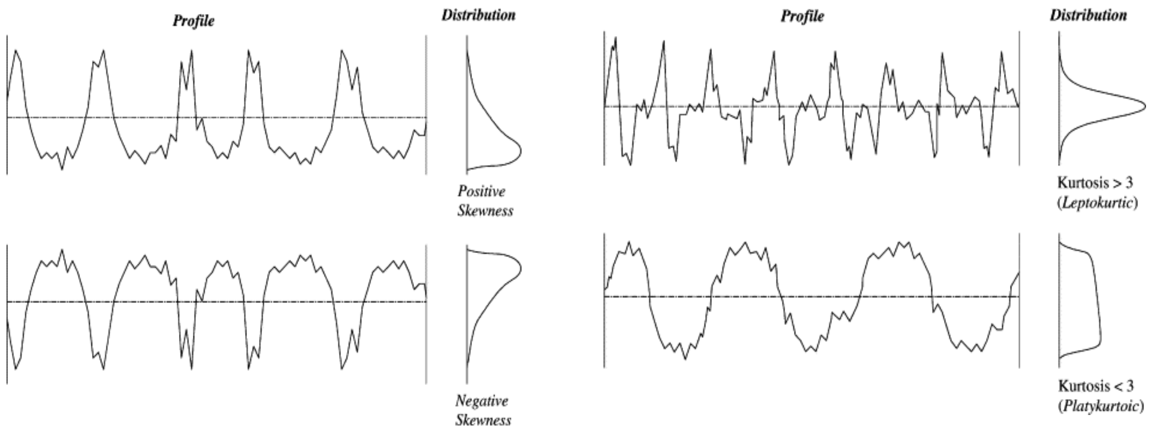


***Figure 1.*** *Explanation of Skewness and Kurtosis of the analysed profile* (Gadelmawla et al., 2002) *(schematic figures, the abscissa is the measured length, and the ordinate is the profile height)*

Therefore, it is necessary to study the surface roughness in tangential turning of outer cylindrical surfaces as well. In this paper, an interesting characteristic of the alteration effect of the feed is showed in this finishing procedure. The aim of this paper is to analyse various surface roughness parameters in function of the feed. To achieve this, cutting experiments are carried out, and roughness measurement are done. Among the gathered data, the Arithmetical Mean Height of the evaluated area, Skewness of the evaluated area, Kurtosis of the evaluated area are evaluated in this paper. The study complemented with the analysis of the acting main cutting force as well.

## 2. Experimental conditions and methods

To study the effect of the feed increase in tangential turning, experiments were carried out with varied values of the selected process parameters (feed, depth of cut).

The cutting experiments were carried out on an EMAG VSC 400 DS hard machining centre, which is capable to apply the required tangential feed of the tool. The machined workpieces were 42CrMo4 grade alloyed steel shafts which were hardened to 60 HRC. The machined outer diameter was 70 mm. The tangential turning tool was made by HORN Cutting Tools Ltd. and had an inclination angle of 45°

(holder code: H117.2530.4132). A S117.0032.00 coded MG12 type uncoated carbide insert was fixed into the holder.

The main aim of the study was the analysis of the effect of the feed alteration. Therefore 4 types of feeds (*f*) were chosen for the experiments. Due to the planned force measurements, 2 types of depth of cuts ($a_p$) were also set. The cutting speed ($v_c$) was constant during the experiments. Therefore 8 experimental setups have resulted from the design plan. The exact values of the different technological parameters are presented in Table 1.

***Table 1.*** *Experimental setups*

| Setup | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Selected factors | | | | | | | | | |
| $v_c$ | [m/min] | 200 | 200 | 200 | 200 | 200 | 200 | 200 | 200 |
| $f$ | [mm/rev] | 0.3 | 0.6 | 0.8 | 1 | 0.3 | 0.6 | 0.8 | 1 |
| $a_p$ | [mm] | 0.1 | 0.1 | 0.1 | 0.1 | 0.2 | 0.2 | 0.2 | 0.2 |

Measurements were carried out on the workpieces after the cutting experiments with a Mitutoyo SJ-301 Surftest roughness measurement device. The roughness profiles were registered on three generatrix of each bore. The measured profiles were evaluated with the AltiMap Premium 6.2.7487 surface analysis software. The analysed parameters of the 3D (areal) surface were the following (ISO 21920:2021):

- $S_a$ – Arithmetical Mean Height of the evaluated area [µm]
- $S_{sk}$ – Skewness of the evaluated area [–]
- $S_{ku}$ – Kurtosis of the evaluated area [–]

The cutting forces were measured during the experiments with a Kistler 9257A three component dynamometer to further evaluate the feed increase effect. The measurement setup also contained three Kistler 5011 charge amplifier, a NI-9215 data acquisition unit withcDAQ-9171 chasing and NI Labview software. The forces measured by the dynamometer are equivalent to the forces to be analysed, therefore no further calculations were needed. In this paper, the results for the major cutting force and its specific value are shown:

- *Fc* – major cutting force [–]
- *kc* – specific value of the major cutting force

## 3. Experimental results

On every machined workpiece, a 4 mm × 4 mm area was measured in the middle of the produced surface. *Figure 2* presents the 8 measured surface for each experimental setup. The data was analysed and evaluated by the roughness measurement software, and the values of $S_a$, $S_{sk}$ and $S_{ku}$ are gathered.

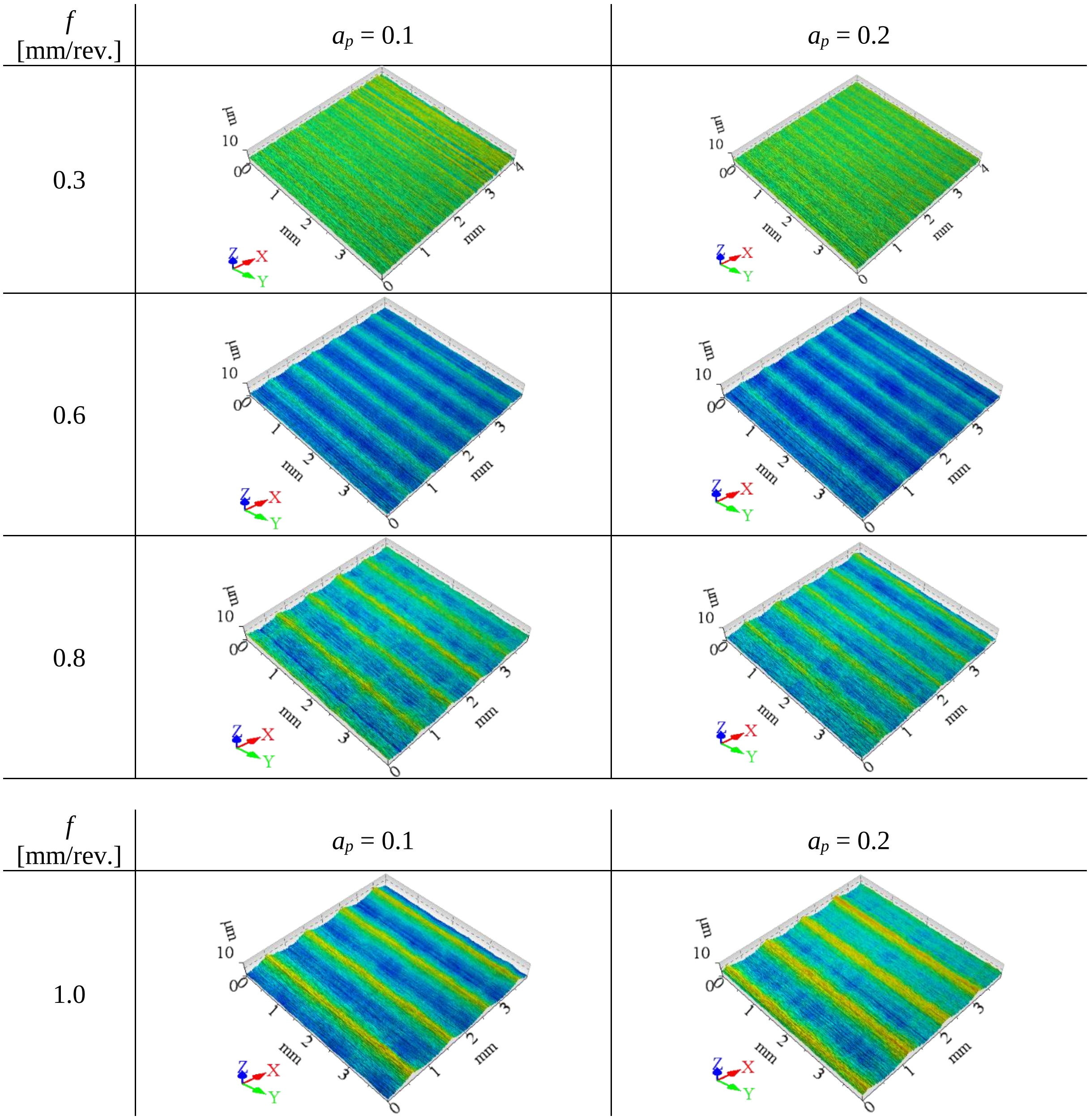


***Figure 2.*** *The measured surfaces of the 8 machined workpieces*

The cutting force measurements were also registered, and the corresponding major cutting force values are collected. The specific values of the cutting force component were calculated as follows: $k_c = F_c / (a_p \cdot f)$. The results of the measurements and the evaluation can be seen in *Table 2*.

***Table 2.*** *Experimental results*

| Setup | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| $S_a$ [µm] | 0.42 | 0.43 | 0.71 | 0.96 | 0.71 | 0.41 | 0.67 | 0.94 |
| $S_{sk}$ [–] | –0.77 | 0.52 | 0.41 | 0.62 | –1.09 | 0.33 | 0.44 | 0.59 |
| $S_{ku}$ [–] | 5.40 | 3.02 | 2.69 | 2.43 | 6.51 | 2.92 | 2.63 | 2.48 |
| $F_c$ [N] | 192.4 | 279.2 | 376.7 | 415.9 | 379.8 | 549.7 | 608.9 | 688.7 |
| $k_c$ [N/mm$^2$] | 6414.3 | 4653.8 | 4708.2 | 4158.8 | 6330.3 | 4580.5 | 3805.8 | 3443.5 |

## 4. Discussion

After the experiments were completed and the measurements were carried out, the results are analysed to show the effect of the feed increase in tangential turning. Firstly, the parameters describing the micro-geometric error of the machined surface are analysed. Secondly, the change in the cutting force is shown.

The alteration of the Arithmetical Mean Height can be seen in *Figure 3*. The first observation, which can be concluded, is the low effect of the depth of cut on the surface roughness. Although there is a relatively high difference in case of 0.3 mm/rev. feed between the results measured after experimenting with different depth of cuts; the $S_a$ value is almost the same on the other feeds. The second observation, that increasing the feed from 0.3 mm/rev. to 0.6 mm/rev. resulted in a lower or at least the same surface roughness. the further increase of the feed led to proportionate increase in the $S_a$ value. These two findings shows that there is an optimal feed value in the point of view of the surface roughness, where the micro-geometrical error is the lowest. The chip removal mechanism should change between 0.3 mm/rev. and 0.6 mm/rev. feeds, which value can be determined by further experiments.

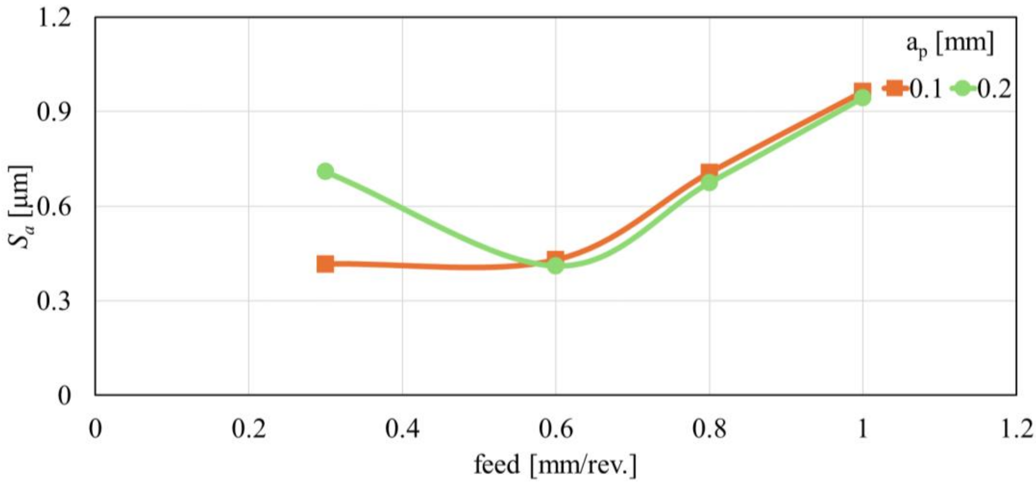


***Figure 3.*** *Effect of the feed rate on the Arithmetical Mean Height of the evaluated area*

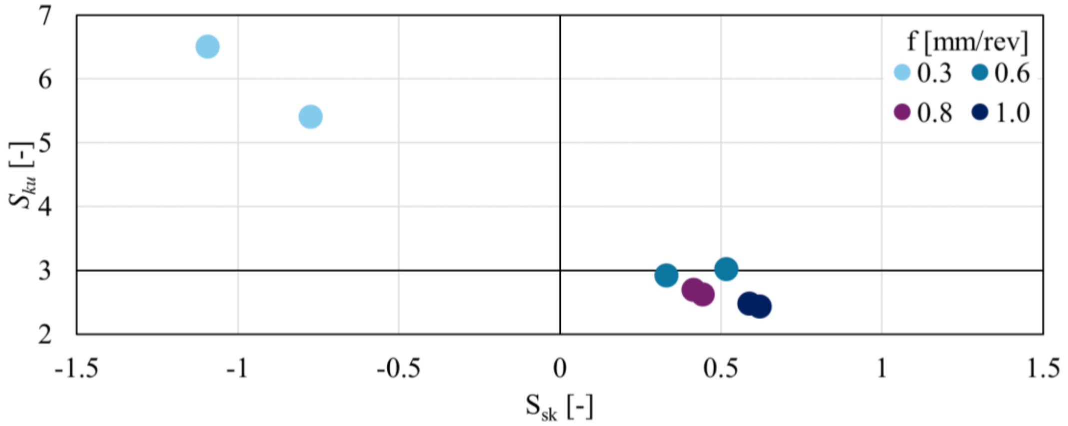


***Figure 4.*** *Topological map of the experimental results*

The kurtosis and the skewness of the measured profile is analysed by the application of the so-called topological map, where the two parameters are presented in the same graph. This method is often used, because the tribological properties of the machined surface can be characterised by the combination of these two parameters. *Figure 4* shows the topological map of the 8 experimental setups. In this figure the results of the experiments with the lowest feed are in a different position of the map, than the remaining 6. The results of the experiments with 0.6 mm/rev., 0.8 mm/rev. and 1.0 mm/rev. are located close to each other. The increasing feed results in a slightly higher skewness and a slightly lower kurtosis. This means that tangentially turning with a relatively low feed results in a flatter surface where narrow valleys are presented. After the beforementioned critical feed reached, the characteristic of the surface also changes: more peaks are observed with higher periodicity. This finding also shows the change in the chip removal process at a given feed value (between 0.3 mm/rev. and 0.6 mm/rev).

The alteration of the cutting force is also studied to present a more detailed overview of the effect of the feed increase in tangential turning. The major cutting force in function of the feed is shown in *Figure 5*. As expected, the increase of the depth of cut or the feed results in an increasing major cutting force, since both parameter changes the cross-sectional area of the chip.

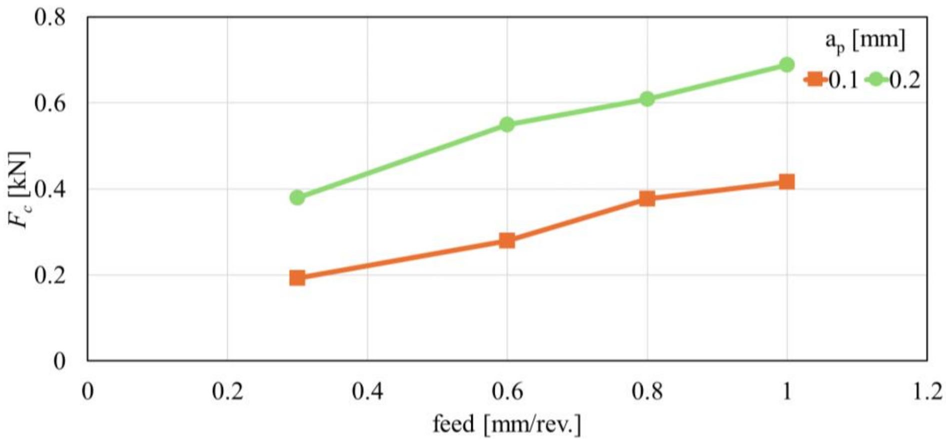


***Figure 5.*** *Effect of the feed rate on the major cutting force*

The effect of the depth of cut is almost directly proportional: a two-fold increase in the depth of cut led to an almost two-fold increase of the studied force component. However, although the increase of the feed increases the major cutting force, it can be seen, that its effect is lower.

This can be explained by using *Figure 6*, which presents the alteration of the specific cutting force component. Here we can see that the depth of cut has almost no effect on this characteristic parameter, since it increases the width of the chip, which has almost now effect on the load of the cutting edge in each point. However, if the feed is increased, it also increases proportionally the chip thickness. There is the well-known phenomenon, that the higher the thickness of the chip become, the lower the energy requirement of the removal of the specific material will be. This can be observed in tangential turning as well. This leads to the previously observed fact, that the increase of the feed has a lesser increasing effect than the increase of the depth of cut.

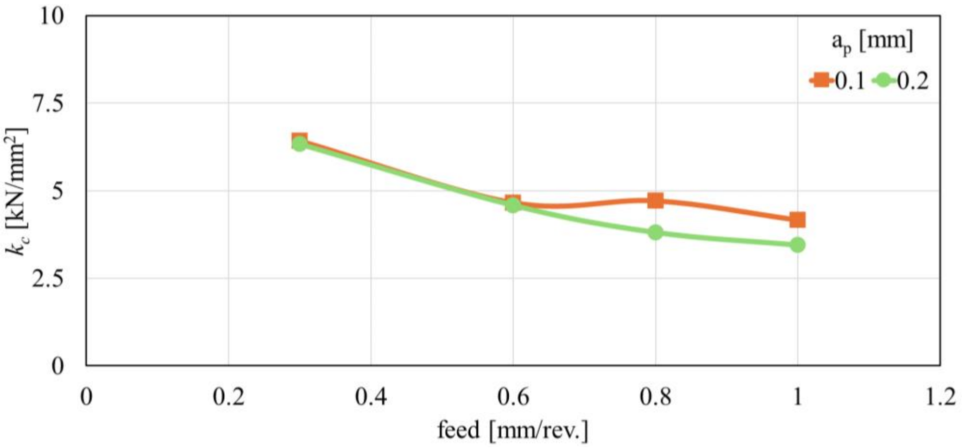


***Figure 6.*** *Effect of the feed rate on the specific value of the major cutting force*

## 5. Summary

The effect of the feed increase is analysed in tangential turning. Experiments were carried out with 4 types of feed and 2 types of depth of cut. The machined surface roughness and the major cutting force is measured in the experiments. The surface roughness is evaluated, and the Skewness and the Kurtosis of the evaluated roughness profile are studied thoroughly.

Based on the study the following finding can be highlighted:

- The feed can be increased to a value, until which the roughness of the surface is low.
- Skewness and Kurtosis shows the different form of chip removal according to the feed.
- The cutting force increases in a lower extent than the increase of the feed.

In summary it can be said that the increase of the feed can be beneficial on the machined surface topography, as low surface roughness can still be achieved. However, it is shown, that the topography of the surface also changes.

## References

[1] Kovács, G. (2020). Combination of Lean value-oriented conception and facility layout design for even more significant efficiency improvement and cost reduction. *International Journal of Production Research*, 58 (10), 2916–2936. **https://doi.org/10.1080/00207543.2020.1712490**

[2] Dávid, Á. T., Szabó, Á., Kuti, R. & Rohde-Brandenburger, J. (2021). Tribological investigation of applicability of nano-sized cupricoxide (CuO) ceramic material in automotive vehicles. *FME Transaction*, 49 (2), 335–343. **https://doi.org/10.5937/fme2102335T**

[3] Kittali, P., Kalwa, V., Athith, D., Prashanth, K. P. & Venkatesh, B. K. (2022). Optimization of machining parameters in turning operation to minimize the surface roughness using Taguchi technique for EN1A alloy steel. *Materials Today Proceedings*, 54, 463–467. **https://doi.org/10.1016/j.matpr.2021.10.323**

[4] Kundrak, J., Makkai, T., Nagy, A. & Emri, G. (2020). Roughness of Aluminum Surfaces Face Milled with A Diamond Tool. *Cutting & Tools in Technological System*, 92, 26–34. **https://doi.org/10.20998/2078-7405.2020.92.04**

[5] Kundrák, J., Felhő, C. & Nagy, A. (2022). Analysis and prediction of roughness of face milled surfaces using CAD model. *Manufacturing Technology*, 22 (5), 558–572. **https://doi.org/10.21062/mft.2022.061**

[6] Ferencsik, V. & Varga, G. (2022). The influence of diamond burnishing process parameters on surface roughness of Low-Alloyed Aluminium workpieces. *Machines*, 10 (7), 564. **https://doi.org/10.3390/machines10070564**

[7] Kun-Bodnár, K. & Maros, Z. (2021). Some characteristics of surfaces machined with abrasive waterjet turning. *Pollack Periodica*. **https://doi.org/10.1556/606.2021.00400**

[8] Kumar, N. S., Shetty, A., Shetty, A., Ananth K. & Shetty, H. (2012). Effect of spindle speed and feed rate on surface roughness of carbon steels in CNC turning. *Procedia Engineering*, 38, 691–697. **https://doi.org/10.1016/j.proeng.2012.06.087**

[9] Gadelmawla, E., Koura, M., Maksoud, T., Elewa, I. & Soliman, H. (2002). Roughness parameters. *Journal of Materials Processing Technology*, 123 (1), 133–145. **https://doi.org/10.1016/s0924-0136(02)00060-2**

[10] Khorasani, A. M., Yazdi, M. R. S. & Safizadeh, M. S. (2012). Analysis of machining parameters effects on surface roughness: a review. *International Journal of Computational Materials Science and Surface Engineering*, 5 (1), 68. **https://doi.org/10.1504/ijcmsse.2012.049055**

[11] Abellán-Nebot, J. V., Pastor, C. V. & Siller, H. R. (2024). A review of the factors influencing surface roughness in machining and their impact on sustainability. *Sustainability*, 16 (5), 1917. **https://doi.org/10.3390/su16051917**

[12] M'Saoubi, R., Outeiro, J., Chandrasekaran, H., Dillon, O., Jr. & Jawahir, I. (2008). A review of surface integrity in machining and its impact on functional performance and life of machined products. *International Journal of Sustainable Manufacturing*, 1 (1/2), 203. **https://doi.org/10.1504/IJSM.2008.019234**