Acta Mechanica Slovaca **27 (2): 32 - 41,** June **2023**
https://doi.org/10.21496/ams.2023.023

Acta Mechanica Slovaca
ISSN 1335-2393
www.actamechanica.sk

Comparison of the Surface Roughness and its Geometric Model in Case of Z-level Milling

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Abstract: The Z-level milling technology is one of the most often used finishing milling strategy in case of the CNC milling of the steep free form surfaces. A main spindle parallel end-milling cutter can be used with or without corner radius, and the depth of cut means the axis parallel distance between the tool paths. During the planning of machining process two main aspects should be considered: the productivity and the accuracy. The accuracy means macro and micro accuracy. In this article the surface roughness, as a part of micro accuracy, is investigated, and a geometric approach of its estimation is presented. The tool corner geometry, the depth of cut and the inclination of the surface are considered, and the critical inclination is introduced. The theoretical description of the surface roughness is compared with the results of milling tests. As concluded, the cusp height, as the geometric model of the surface roughness can be a good base of the estimation, but a detailed and case depend model is required. The results ensure a better selection of tool path parameters in CAM systems considering the properties of cutting tool and the surface.

Keywords: Free form surface; Surface roughness; Z-level milling; Cusp height; Geometric model

Nomenclature:

α – Inclination angle of the surface [°]
α^* – Critical value of the inclination angle [°]
a_e – Width of cut (side step) [mm]
a_p – Depth of cut (Z step)[mm]
c – Corner chamfer of the end mill [mm]
Ch – Cusp height [µm]
D – Tool diameter [mm]
f_z – Feed per tooth [mm]
R – Corner radius of the end mill [mm]
R_z – Surface roughness [µm]
v_c – Cutting speed [m/min]
v_f – Feed speed [mm/min]
z – Number of teeth [-]

1. Introduction

The moulding and forming tools consist of several different surfaces in order to make complex plastic, metal or sheet metal part geometries. During the production of these tools CNC milling technology is used generally. The CNC programming can be performed by CAM systems, where appropriate milling strategies have to be selected and the parameters (tool, cutting condition, tool path parameters) have to be set. Two main stages of the milling are the roughing and the finishing. In case of roughing the productivity has higher importance, while in finishing the accuracy and the surface quality are the primary aspects.

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The meaning of surface roughness is defined by standards, but the creation of it is the task of process planner. Benardos and Vosniakos [1] list 19 parameters, which have effect on the surface roughness of a machined surface. The four main groups named are: cutting tool, machining parameters, workpiece properties and cutting phenomena (Figure 1). There are four approaches in order to estimate the surface roughness [1]: (1) machining theory based approach, (2) experimental investigation approach, (3) designed experiments approach and (4) artificial intelligence approach (artificial neural network, neuro-fuzzy systems, genetic algorithm).

The geometric approach is one of the machining theory based approach and considers the geometric data of the cutting tool and the surface geometry. It describes the cutting tool generated cusp geometry on the surface, and the surface roughness is estimated by the cusp height [2]. The advantage of this approach is the clear description of the surface micro geometry, but it cannot take the other circumstances into consideration, like the properties of the part material, the vibration of the system (tool, fixture, and machine tool), the cutting parameters etc.

The experiment-based approach investigates the whole system, and considers a whole range of parameters. Based on milling experiments a relationship can be discovered between the surface roughness and the selected parameters. This relationship can be described by statistical methods, regression analysis or artificial neural networks.

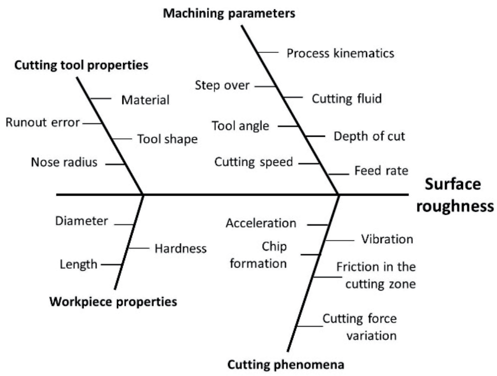


Figure 1: The Ishikawa diagram of the surface roughness [1].

Wang et al [3] present a combined parametric model of Rz surface roughness, which considers geometric, material and technology parameters in case of the face milling of titanium alloy. Bílek et al. [4] show the effect of the inclination of the surface in case of ball-end milling. Matras and Zębala [5] investigate ball-end milling by different strategies in case of hardened tool steel. The statistical analysis shows the role of feed and step over (a_e) in surface roughness. Ižol et al. [6] compare the effect of the different tool path strategies on the surface roughness. The tool path patterns cause different Rz surface roughness, but smaller than the calculated cusp height. The cutting method, and the workpiece material can modify the surface roughness too [7][8][9]. In case of turning, the feed has the same role in the geometric model, like the width of cut (a_e) in case of ball-end milling or the depth of cut (a_p) in case of Z-level milling.

The cutting tool geometry modifies the chip removal process, which has effect on the surface roughness, as Karpuschewski et al. [10] present in case of face milling. Bílek et al. [11] presents the effect of rake angle of the tool on the surface roughness, but it depends on surface inclination. Kundrák and Felhő [12] investigate the face milling, and shows the effect of the number of teeth on the surface roughness.

Shaik and Srinivas [13] use the statistical model of surface roughness for optimization of slot milling by genetic algorithm.

Kovač et al. [7] present the estimation of Ra surface roughness by neuro-fuzzy system based on v_c, f and a in case of steel turning. They found, the feed has the largest effect. Karkalos et al [8] compare statistical method and artificial neural network (ANN) in case of face milling of titanium alloy. They found, that the ANN based prediction is more accurate, but the difference is small, and optimization of the structure of ANN is required. Rifai et al. [14] predict the surface roughness by convolutional neural network, but instead of different kind of parameters the image of the surface is used as input.

In case of finishing milling of free form surface, two types of finishing strategy can be applied on 3D CNC machining centres depending on the nature of the surfaces (Figure 2). The 3D ball-end milling strategy is suitable for finishing of shallow surfaces, and the Z-level milling is appropriate for steep surfaces. The Z-level milling is a 2.5D milling strategy, when the tool moves in X-Y plane, and follow the contour of the current section. There are a great number of different methods in the literature about, how it can be determined [15].

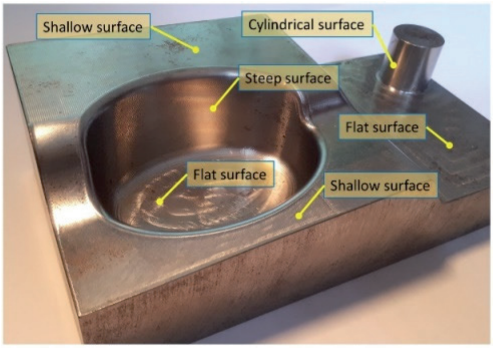


Figure 2: An example for free form surfaces.

The aim of the research is to investigate the surface roughness in case of different kind of free-form surface milling. The parameters of CAM tool path strategies define the productivity and the accuracy of the machining. The results of the research support the work with CAM systems, and ensure better parameter selection and more accurate simulation of the surface quality. In the current article, the geometric description of the surface roughness is presented in case of the Z-level milling of steep surfaces.

The aim of this paper is to present a new geometric model of the estimation of the surface roughness which considers the inclination of the surface and use different geometric models in the different sections. The new, combined model considers the changing of the surface inclination, the tool's corner geometry. The critical inclination of the surface has very large importance, because it divides the machined surface into two sections, where different mathematical models of the cusp height have to be applied in order to get a more accurate description of cusp height. The aim of the article is to present the surface roughness in the area of critical inclination, and verify the above described theory by measured data when Z-level milling.

2. Geometric description of the cusp height of Z-level milling

The surface roughness can be approximated by cusp height of the machined surface. The cusp height is just a part of the surface roughness, but it can be calculated from the tool and surface data.

In case of end mill, when the corner radius is 0, the cusp height is the height of a right angle triangle (Figure 3):

$$Ch = a_p \cdot \cos(\alpha) \tag{1}$$

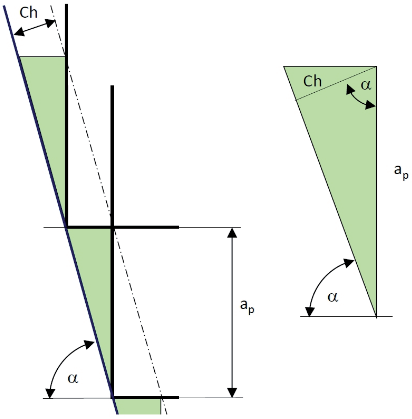


Figure 3: Cusp height of the end mil (R = 0).

Generally, tool manufacturers use a small chamfer on the tool corner for higher edge stability and wear resistance ($c \; x \; 45°$). In this case the geometric model is more complicated and a different geometric state has to be sketched. If the tool corner chamfer is smaller than the depth of cut ($c < a_p$) and the surface inclination is larger than a critical ($\alpha > \alpha^*$) value (see later), based on Figure 4, the theoretical cusp height is:

$$Ch = I - II - III \tag{2}$$

where

$$I = c \cdot \sin(\alpha) \tag{3}$$

$$II = c \cdot \sin(90° - \alpha) = c \cdot \cos(\alpha) \tag{4}$$

$$III = \sin(\alpha - 45°) \cdot \sqrt{2 \cdot \left(c - \frac{a_p}{tg(\alpha)}\right)^2} \tag{5}$$

$$Ch = c \cdot (\sin(\alpha) - \cos(\alpha)) - \sin(\alpha - 45°) \cdot \sqrt{2 \cdot \left(c - \frac{a_p}{tg(\alpha)}\right)^2} \tag{6}$$

In case of the critical inclination, the depth of cut (a_p) is equal with the corner chamfer. This critical position is defined by the a_p and c parameters (Figure 4 d):

$$c = \frac{a_p}{tg(\alpha^*)} \rightarrow \alpha^* = arctg\left(\frac{a_p}{c}\right) \tag{7}$$

If the $a_p > c$, and $\alpha < \alpha^*$, the cusp height is (Figure 5):

$$Ch = I - MIN(II; III) \tag{8}$$

$$Ch = a_p \cdot \cos(\alpha) - c \cdot MIN(\sin(\alpha); \cos(\alpha)) \tag{9}$$

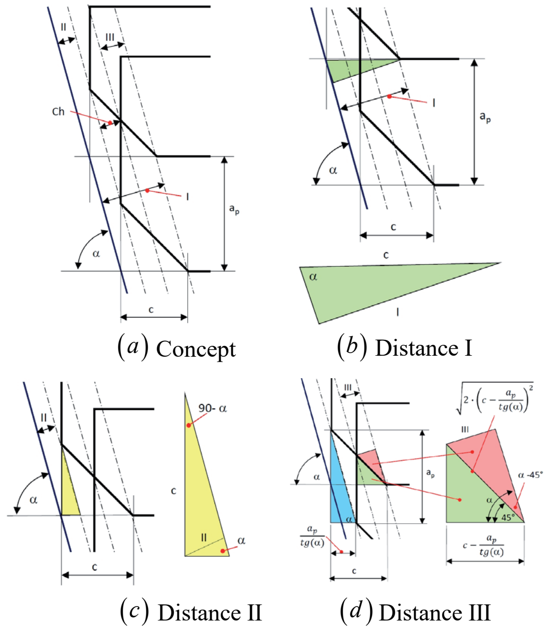


Figure 4: Cusp height of chamfered end mill, when $a_p > c$, and $\alpha > \alpha^*$.

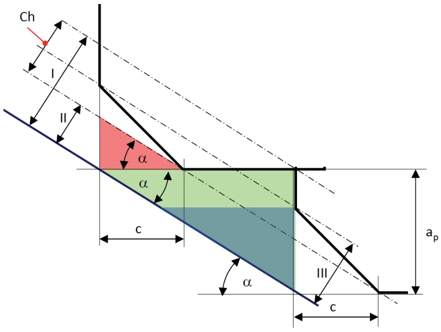


Figure 5: Cusp height of chamfered end mill, when $a_p > c$, and $\alpha < \alpha^*$.

Depending on the inclination, the part II or the part III should be used during the calculation. In case of Figure 5, the II part is smaller than III, so it has to be used. A critical inclination can be defined, but it is different from α^*. This value is equal with the angle of the chamfer, which is 45°.

In case of $R > 0$ tool corner radius, the cusp height can be described by different equations in function of ratio of R and ap, and critical inclination angle (α^*). Over the critical inclination, the cylindrical part of the milling cutter works too, not just the radial section [16]. If $\alpha < \alpha^*$ and $R > a_p$, the cusp height is (Figure 6):

$$Ch = R \cdot \left(1 - \sin\left(\arccos\left(\frac{a_p}{2 \cdot R \cdot \sin(\alpha)}\right)\right)\right) \qquad (10)$$

If A > A* the cusp height is:

$$Ch = R.\left(1 - \cos\left(\alpha - \arcsin\left(1 - \frac{a_p}{R.tg(\alpha)}\right)\right)\right) \qquad (11)$$

The critical inclination, where the cylindrical part of the tool starts to work, is:

$$\alpha^* = \frac{\arccos\left(\frac{a_p}{R}\right) + 90°}{2} \qquad (12)$$

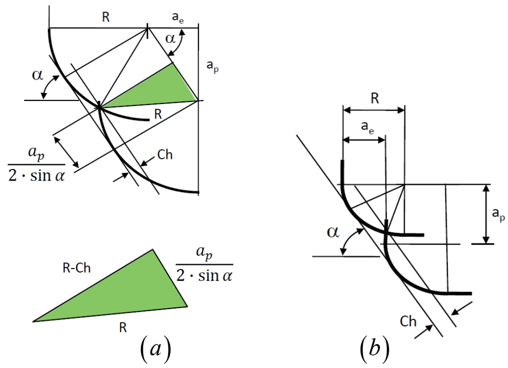


Figure 6: Cusp height of rounded end mill [16].

The accurate estimation of the surface roughness of the machined surface makes it possible to create a more realistic simulation and process optimization.

3. Material, equipment and method

The aim of the cutting test phase is to present the tendency of the changing on surface roughness. In order to verify the presented theory, four milling cutters were selected from the range of Fraisa SA for test production. The diameter of the tools is 8 mm; values of the corner radius are 0, 0.5, 1.0 and 4.0 mm (Table 1 and Figure 7). The officially $R=0$ tool has a 0.15x45° chamfer on the corner. The test surfaces were milled by Mazak 410A-II CNC machining centre, and the CNC codes were generated by ProEngineer WF4 CAM system.

Table 1: Properties of the cutting tool.

No	*Tool ID*	*D [mm]*	*R [mm]*	*z [-]*
1	P5355.391	8	0.0	4
2	U45319.388	8	0.5	4
3	U45319.391	8	1.0	4
4	U5286.391	8	4.0	2

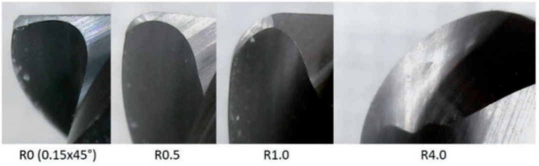


Figure 7: The corner chamfer and radius of the tools.

The cusp height is influenced by the depth of cut (a_p), so two levels of ap were applied (0.15 and 0.25 mm). The cutting speed (v_c = 160 m/min) and the feed per tooth ($f_z = 0.05$ mm) were the same in this test series. The parameters were defined based on the industrial application and recommendation of the tool catalogue. However, the feed per tooth was the same, in case of ball-end milling cutter, the feed speed was smaller because of the number of teeth (z=2).

The Z-level milling strategy can be performed by down milling, when the tool is lifted to a safety plane at the end of the tool path and the milling is continued on the same side. Or it can be performed by the zig-zag milling strategy, when no lifting of the tool is conducted, but the milling is continued with opposite direction. In this case down milling and up milling strategies alternate. Because of the limited number and levels of parameters and the short machining time the full factorial DOE method was used, 16 different combinations were generated (Table 2). The tools and cutting parameters were selected based on the industrial practice.

Table 2: Test parameters.

No	*R [mm]*	*ap [mm]*	*Milling direction*	α^* *[°]*	α_{min} *[°]*
1	0.0	0.15	Down milling	45	70
2	0.0	0.15	Zig-zag milling	45	70
3	0.0	0.25	Down milling	59	70
4	0.0	0.25	Zig-zag milling	59	70
5	0.5	0.15	Down milling	81.3	70
6	0.5	0.15	Zig-zag milling	81.3	70
7	0.5	0.25	Down milling	75.0	70
8	0.5	0.25	Zig-zag milling	75.0	70
9	1.0	0.15	Down milling	85.7	80
10	1.0	0.15	Zig-zag milling	85.7	80
11	1.0	0.25	Down milling	82.8	70
12	1.0	0.25	Zig-zag milling	82.8	70
13	4.0	0.15	Down milling	88.9	85
14	4.0	0.15	Zig-zag milling	88.9	85
15	4.0	0.25	Down milling	88.2	85
16	4.0	0.25	Zig-zag milling	88.2	85

The test parts were made of C45 medium carbon steel (W.Nr. 1.0503, Rm = 630-780 MPa), the size of the machined surface was 50x20 mm (Figure 8 a).

The inclination of the test surface is changed from 90° to 85°, 80° or 70° (α_{min}), depending on the critical inclination (α^*). The critical inclination depends on the tool radius (R) and the depth of cut (a_p). Table 3 shows the values of the inclination angles for the test surfaces also.

The surface roughness was measured by a Mitutoyo SJ-301 contact type instrument. The contact type measure of the surface roughness cannot scan the real profile because of the filtering effect of the probe, but this method is the most often used in the industry. In order to make accurate measuring, the horizontal position of the surface section has to be adjusted. A special fixture ensured this appropriate position (Figure 8 b). The surface roughness was measured in 13 positions, 3 times in different heights. The 13 positions were defined from the 90° side by linear distance (L) (Table 3). The analysis of the 624 measured data was performed in MS Excel and MiniTab v14.

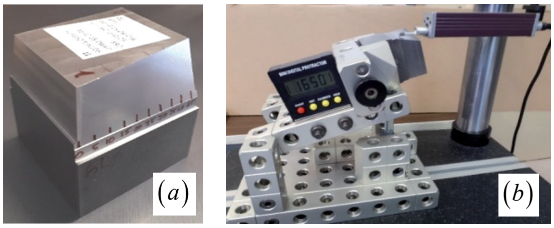


Figure 8: A test specimen (a) and the fixture (b) for surface roughness measurement.

The Rz surface roughness parameter was measured and investigated. The Rz parameter is the average of five peak-to-valley distances, and its definition is close to the definition of cusp height. The Ra arithmetical mean parameter is the most

Table 3: Surface inclination in function of measuring position (L).

L	2.5	5	7.5	10	12.5	15	17.5	20	25	30	35	40	45
A(70°)	89.0	87.9	86.9	85.8	84.8	83.8	82.7	81.7	79.6	77.5	75.4	73.3	71.3
A(80°)	89.5	89.0	88.4	87.9	87.4	86.9	86.4	85.8	84.8	83.8	82.7	81.7	80.6
A(85°)	89.7	89.5	89.2	89.0	88.7	88.4	88.2	87.9	87.4	86.9	86.4	85.8	85.3

often used roughness parameter in the industry, but it hides the character of peaks and valleys. The Rz parameter do not consider the geometric deviation of the surface, like the Pz parameter. The presented geometric method of surface roughness prediction describes the theoretic surface roughness.

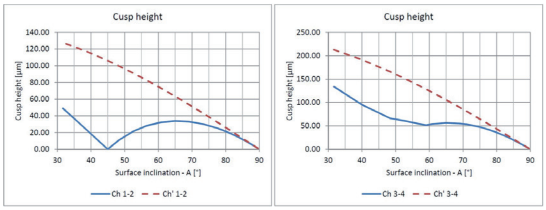
4. Results

4.1 Cusp height

The investigation of the presented geometric model of the cusp height shows the effect of the tool geometry (chamfer and radius). The Figure 9 shows the values of the theoretical cusp height in case of the investigated tools and cutting parameters (a) $a_p = 0.15$ mm, b) $a_p = 0.25$ mm). The red dashed curve shows the theoretical values of the cusp height when the corner radius is 0. When corner chamfer is considered in the geometric model ($c = 0.15$ mm) the cusp height is different, as the continuous blue curves show.

The corner chamfer has a large effect on the cusp height over the critical inclination. Under this inclination the calculated cusp height is closer to the basic case $R = 0$.

The cusp height values increase under the critical inclination. At the critical inclination the cusp height curve shows a local minimum point. When $a_p = c$, the cusp height at $\alpha = 45°$ theoretically is 0, because the chamfer surface fits to the surface segment. If the ap is larger than the chamfer, the local minimum value is larger too. Left to the local minimum, a break point can be seen on the curve, where the III element becomes smaller than the II in Eq.8 (Figure 5). The position of the break points depends on the value of the chamfer and the depth of cut. If the depth of cut is larger than the chamfer of the corner, the local minimum point appears too, but the minimum value is larger than 0, and the inclination of the surface is larger than 45°.

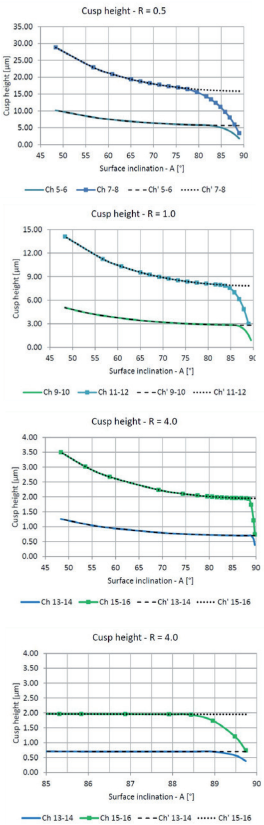


(a) $a_p = 0.15mm$ (b) $a_p = 0.25mm$

Figure 9: Theoretical cusp height in case of end mill R=0.

In case of round corner end mill and ball end milling cutter (Figure 10), the difference from the original model can be seen only at steep section. The Ch indicates the result of the new theory, the Ch′ shows the original geometric approach. The transition between the two models is not so dramatic, but the improvement of the cusp height is significant. From the critical inclination the different section of the cutting tool starts to work, so the geometric description of the cusp height changes. This change can be seen on the diagrams. The critical inclination depends on the value of the corner radius. The Figure 10 d shows the investigated range, when the cusp height changes are very small. In case of large corner radius, the critical inclination angle is very close to 90°, and the accurate positioning of the surface roughness measuring head is problematic.

The question of the research is, whether the decreasing value of the cusp height can be perceived in the measured values of the surface roughness.



(a) $R = 0.5\ mm$, $a_{p5-6} = 0.15\ mm$, $a_{p7-8} = 0.25\ mm$

(b) $R = 1.0\ mm$, $a_{p9-10} = 0.15\ mm$, $a_{p11-12} = 0.25\ mm$

(c) $R = 4.0\ mm$, $a_{p13-14} = 0.15\ mm$, $a_{p15-16} = 0.25\ mm$

(d) $R = 4.0\ mm, a > 85°$

Figure 10: Theoretical cusp height in case of end mills R ≠ 0.

4.2 Surface roughness (Rz)

The measured surface roughness data shows similar nature to the cusp height data (Figure 11). The dashed curves show the cusp height values based on original concept, and the continuous curves show the modified cusp height values.

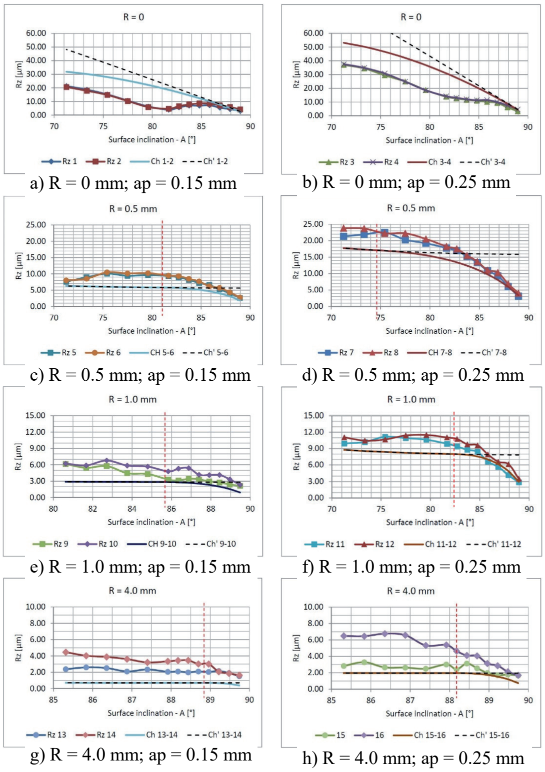


Figure 11: The Rz values of surface roughness in case of different tools.

In case of $R = 0$ (Figure 11 a-b), the measured Rz values are smaller than the cusp height, when $R > 0$ (Figure 11 c-h), Rz values are larger. In every case the measured values follow the modified cusp height data, the value of the critical inclination is observed, but a little bit higher, then the calculated. The effect of the edge geometry can be the reason of it. Around the critical inclination, the theoretical cusp height has just a minimal difference, and the contact surface roughness measuring technology cannot evince this.

In case of $R = 0$ a valley can be seen on the measured curves, which is similar to the nature of theoretical cusp height (Figure 11 a-b), but the investigated inclination is larger than the critical value, so the reason of this decreasing is not known. The pattern is very similar to the theoretical diagram (Figure 9), but the local minimum point is shifted. The corner chamfer of the tool ends in two very small radii. During the wear process of the milling cutter, the value of them can increase and modify the surface roughness.

In case of large corner radius (Figure 11 g-h, R = 4.0) the theoretical cusp height values change very little, but the measured data of the Rz is higher and rugged. Nonetheless the decreasing section can be identified over the critical inclination. In case of small surface roughness, the other factors have increasing role: like the vibration during the machining, or the cutting parameters, and the uncertainty of the measuring could have larger effect on the measured data.

The difference between the Rz of down milling and zig-zag milling becomes larger, parallel with the increasing R. At $R = 0$ and $R = 0.5$, the difference is very small, and at $R = 1.0$ the zig-zag milling has a little disadvantage, but at $R = 4.0$ the difference is evident, the down milling is much better.

5. Discussion

Based on the measured data, statistical analysis can be performed. The technique of the main effect plot shows the general effect of the selected input parameters on the investigated output parameter. Through the regression analysis, a mathematical model can be created in order to support the estimation process and asses the role of the input parameters.

The main effect plot shows the average value of the all measured data, which are grouped by selected parameter. It is an effective statistical analysis tool in order to study the effect of the selected parameter. If the curve is close to horizontal, the effect is not remarkable, during the regression analyses it is not necessary to consider.

Based on main effects plot (Figure 12), the position of the repeated measure in different levels (Pos) does not have effect on the surface roughness, so the machined surface is homogeneous in one inclination of the surface. The milling direction (Strategy: down milling or zig-zag milling) also has no effect, so the milling strategy is irrelevant from the viewpoint of the surface roughness. The zig-zag milling takes shorter time, so it is preferred.

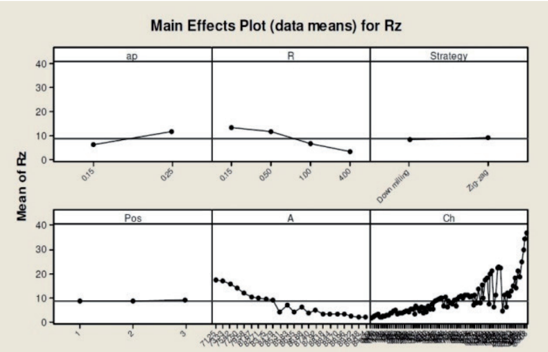


Figure 12: Main effect plots for Rz values.

The larger depth of cut increases the surface roughness, the larger corner radius and the steeper surface decrease it, but these results meet our expectation. The tool corner radius has the largest effect on the input parameter.

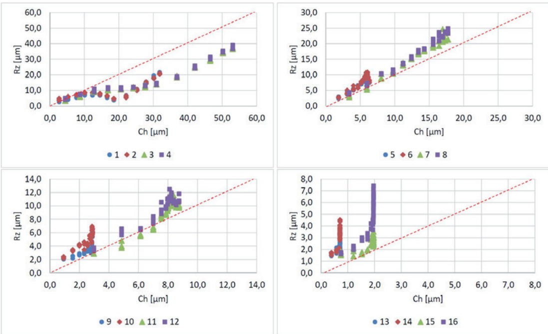


Figure 13: Cusp height and surface roughness.

The surface roughness generally moves parallel with the cusp height (Figure 13). The red dashed line shows the ideal state, when the surface roughness is equal with the cusp height. The difference between the cusp height and the Rz surface roughness parameter in some cases is larger than 100 %. In case of large corner radius and small cusp height values (13-16: R=4 mm), the surface roughness can be very different from cusp height. Here, a vertical pattern can be seen on the diagram, so there are several roughness data at one cusp height. In the case of large corner radius (especially at ball-end milling cutter) the cusp height changes little, and the surface roughness is driven by other factors and circumstances. These factors can't be described by the geometrical model. Based on it, the cusp height is not the only parameter, which defines the surface roughness; other circumstances have effect on it.

The regression analyses prove this observation too. The regression analyses were performed based on the original 624 measured data, not on average values. The aim is to demonstrate the importance of each parameter. Therefore, a simple linear regression was applied.

If the regression analysis considers only the cusp height, the $R^2(adj)$, which shows the accuracy of the regression, is 75.2%, so the cusp height is not suitable for estimation itself.

$Rz = 3.43 + 0.549\,Ch$

Predictor	Coef	SE Coef	T	P
Constant	3.4306	0.1857	18.47	0.000
Ch	0.54943	0.01264	43.46	0.000

S = 3.53232 R-Sq = 75.2% R-Sq(adj) = 75.2%

When the geometric parameters are added to the model, the accuracy of the regression is improved ($R^2(adj)=84.4\%$). Based on the P values every parameter have importance in the regression.

$Rz = 32.7 + 0.39\,Ch + 30.2\,ap - 0.16\,R - 0.4\,A$

Predictor	Coef	SE Coef	T	P
Constant	32.731	2.142	15.28	0.000
Ch	0.38934	0.01383	28.16	0.000
ap	30.176	2.398	12.58	0.000
R	-0.15711	0.09102	-1.73	0.085
A	-0.40420	0.02572	-15.72	0.000

S = 2.80167 R-Sq = 84.5% R-Sq(adj) = 84.4%

However, the definition of the cusp height contains the geometric parameters, therefore, if only the geometric parameters are considered without Ch, the result is very poor ($R^2(adj)=64.5\%$).

$Rz = 58.8 + 54.1\,ap - 1.12\,R - 0.714\,A$

Predictor	Coef	SE Coef	T	P
Constant	58.80	2.915	20.17	0.000
ap	54.080	3.385	15.98	0.000
R	-1.1201	0.1273	-8.80	0.000
A	-0.71446	0.03507	-20.37	0.000

S = 4.22780 R-Sq = 64.6% R-Sq(adj) = 64.5%

Summarizing the results of the statistical analysis, the surface roughness can be estimated by the cusp height and the selected geometric parameters of the tool and the surface. The cusp height describes the nature of the changing of the surface roughness, but other parameters have effect on it also. In case of geometric approach, the surface inclination, the tool corner radius and the depth of cut are the influential parameters.

6. Conclusion

The surface roughness is one of the most important accuracy parameters in case of machined parts. During the manufacturing process planning, process elements and parameters have to be selected and determined based on requirements. The application of CAM systems during the tool path design and CNC programming requires to consider the geometric parameters of the cutting tool and the surface.

The article presents the geometric approach of estimation of surface roughness in case of the Z-level milling of inclined surface.

The cusp height is an important parameter, which combines the effect of geometric parameters of the tool, the surface and the tool path. It ensures more accurate estimation of the surface roughness, but it is not suitable to estimate the surface roughness on itself.

The accurate calculation of the cusp height requires a circumspect analysis of the geometric relationship of the parameters. In case of different tool geometries, the surface inclination and the ratio of tool parameters (R, c) and tool path parameter (ap, ae), the equation can change.

In the current article the Z-level milling strategy was investigated, and the calculation of cusp height was presented in case of chamfered and rounded end mill. The critical inclination of the surface was introduced, when the equation of the cusp height should be changed because of the changing of the geometric circumstances. The critical inclination of the surface has a very large importance, because it divides the machined surface into two sections, where different mathematical model of the cusp height has to be applied in order to have a more accurate description of the cusp height.

The accurate cusp height parameter ensures the making of a more accurate simulation of the micro geometry of the machined surface and the optimization of the machining, tool and tool path parameters in CAM systems during the manufacturing process planning.

The importance of the cusp height parameter and the critical inclination of the surface were verified by milling tests, which show the appropriateness of the presented theory. The milling tests were performed by milling cutters with 8 mm diameter, the corner radius were 0; 0.5; 1 and 4 mm. The depth of cut was 0.15 and 0.25 mm. The parameters of the tools and the cutting conditions were defined based on the industrial application.

Based on the milling test and the statistical analysis of the results, the presented model of the cusp height describes the nature of the changing of the surface roughness, but other parameters have effect on it also. In case of geometric approach, the surface inclination, the tool corner radius and the depth of cut are the influential parameters.

The milling tests show, that the creation of surface roughness is a complex process, so it cannot be described based on geometric parameters only, cutting parameters should be considered too. The investigation of the effect of the cutting parameters is the next step of the research project.

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