BUDAPEST UNIVERSITY OF TECHNOLOGY AND ECONOMICS
FACULTY OF MECHANICAL ENGINEERING
DEPARTMENT OF MANUFACTURING SCIENCE AND ENGINEERING

Effect of chip thickness on burr formation in the case of face milling

PhD thesis booklet

Author:
György Póka
Mechanical engineer

Supervisor:
Dr. István Németh
Associate professor

The reviews of the doctoral dissertation and the minutes of the defence are available at the Dean's Office of the Budapest University of Technology and Economics, Faculty of Mechanical Engineering.

Budapest, 2021

1. Description of the research topic, main objectives

Having burr-free surfaces is an essential requirement of machined workpieces. It allows to perform later operations (e.g., assembly and measurement), it is necessary for the finished part to function properly. Manufacturers choose to avoid and minimise burr formation during manufacturing instead of later removal. Researchers examined the effect of tool geometry and tool path. They demonstrated that the exit order of tool edges and the in-plane exit angle significantly affect burr formation. With the help of the workpiece contour and the path of the tooltip, the exit angle can be determined. The path of the tooltip is often substituted for a circle for the simplification of the calculation. However, the accuracy of this approximation deteriorates when the feed rate is increased. One of the goals of my research was to determine the error of the approximation.

Burr formation can be reduced by generating feasible tool paths. However, many further requirements can be made (length, continuity, etc.), but satisfying all of them is usually impossible. Another aim of my research was to improve the tool path planning, which results in reduced burr size on the workpiece edges.

During my experiments, it was proved that the change of undeformed chip thickness (h) is not proportional to the exit angle; thus, the effect of the exit angle was not apparent. The main objective of my research was to discover the effect of h on burr formation. Firstly the examination of the existing undeformed chip thickness calculation methods was necessary. The effect of radial rake angle has great importance on burr formation; however, it is supposed to be 0° in all existing methods. So a new method had to be introduced that considers the radial rake angle of the tool.

To examine the effect of chip thickness, the qualitative evaluation of burr was not sufficient. It was crucial to know the size of the burr continuously along the workpiece edge. The height of burr based on my observation was between 0.1 and 2.0 mm on aluminium alloy workpieces. It means that it can be measured with optical instruments. Several methods exist to measure the burr. However, most of them are expensive, and the measurement takes a long time, so unsuitable for use on a machine tool. Furthermore, the analysis software tools are not able to measure the burr continuously on the workpiece edge. Therefore, a new method was introduced that meets these special requirements.

2. STATE OF THE ART, RESEARCH METHODS

The ISO 13715 standard defines the burr as follow: the workpiece is burred if it has an overhang greater than zero [ISO].

The ISO 13715 standard characterises the burr with one parameter: the smallest distance between the non-machined surface and the burr tip.

In the definition of Beier [Bei] the burr is a formation which always comes into being during machining accidentally. It exceeds the theoretical surface of the workpiece. Its volume can be measured, but it is significantly less than the volume of the workpiece.

Unlike the previous one, Gillespie [Gil] considers the theoretical surfaces as a reference, not the actually machined surfaces. Thus, the workpiece edge has to be considered burred if it has a material defect (edge breakout), not just excess material from the theoretical contour. So, the burr is formed during machining, and it is a deviation from the theoretical edge with a definite size and volume; it can be a material surplus or defect.

Ranking the edge of workpieces – i.e., the decision, if it is burred or not – is often not obvious. The function and the requirements of a part could be extremely various; thus, it is hard to create an international standard. Manufacturers mostly use their own unique instructions considering their special aspects. [Aur].

Gillespie was the first who categorised the different burr types [Gil2]. Based on his observations, four types of burrs were identified: Poisson burr, rollover burr, tear burr and cut off burr.

Gillespie [Gil] stated six physical processes which form burrs:

1. Lateral flow of material.
2. Bending of material (such as chip rollover).
3. Tearing of chip from workpiece.
4. Redeposition of material.
5. Incomplete cut-off.
6. Flow of material into cracks.

The processes depend on workpiece material features and technological parameters. The first three processes are caused by the plastic deformation of the workpiece material. The sixth process regards burr formed by moulding or primary shaping.

The burr formation process and burr formation reduction are two different research areas. Gillespie [Gil2] has already observed that burr cannot be prevented by changing the feed, speed or tool geometry alone.

Varying one parameter is not sufficient because of the interactions between the other parameters. Varying the tool path can only be limited because it increases the cycle time.

Hashimura [Has] described and classified burrs in the case of face milling. According to his consideration, burr formation is affected not only by the workpiece material properties and cutting parameters but also by the tool and workpiece geometry. He realised 8 stages in the burr formation process. After the fifth stage, the process splits depending on the workpiece material, whether brittle or ductile. The two types of material have different behaviour. The crack propagation and the deformation before crack propagation are different and affects the final burr shape. The burr formation process described by Hashimura was verified with FE-simulation using an elastic-plastic model with plain strain condition.

In Hashimura's [Has] observation, burr size and position in face milling was influenced by the exit order of the cutting tool. Furthermore burr formation is closely related to the chip flow angle. The determination of this angle in milling is extremely difficult. In the case of a tool with insert, it can be approximated by the orientation of the exit surface of the insert and workpiece edge orientation and corresponds with the tool exit order sequence (EOS) of the tool [Has, Has2]. The EOS is influenced by the radial and axial rake angle, the in-plane exit angle, the lead angle and the cutting conditions (the depth of cut, feed rate and spindle speed). With the help of the EOS, the dimensions and the location of milling burrs can be predicted very effectively.

Workpieces often have to be deburred, this operation means additional cost and production time. The deburring operations can be rated into four main categories [Gil3]: mechanical, thermal, chemical and electrical deburring operations. Gillespie described in his handbook over 100 different deburring methods. The different deburring processes and tools are developed for specific workpiece geometries and can be used limitedly and materials. For selecting a deburring process, it is necessary to know how it affects the dimensions, surface finish, cleanliness, flatness, plating, soldering, welding, residual stress, surface imperfections, corrosion rates, lustre and color.

The fundamental objective of research works are the reliable detection of remaining burr and the measurement of its parameters [Aur2]. The most important measurable parameters, are the burr height, burr thickness, burr volume and burr hardness. The most frequently measured values are the burr height and thickness, because of the easy measurement. Several method was developed for different application, burr parameters and accuracy. In industrial environment it is often more important to know which burr parameter causes problem in the production or in the product function than to describe the burr parameters numerically.

The different measuring and detecting methods can be classified as follows:

- one-, two- or three-dimensional
- destructive or non destructive
- with or without contact
- in-process or out of process.

Optical systems can be used for the contactless detection and measurement of the burr, such as camera systems, microscopes and laser interferometer.

A laser triangulation system for drilling burr detection was firstly proposed by Aurich [Aur3].

Chern [Che3] used an image processing software to measure drilling burr size, which was estimated with the number of black pixels on the captured image. This method was also feasible for intersecting holes.

Burr size can be also estimated by applying edge or contour detection on the captured images. Detecting the edges is easier with the segmentation of the image (only detecting black and white pixels). The method presented by Otsu [Ots] the threshold value of the segmentation (which determines which pixels belong which area) can be calculated automatically. Using this method, the difference between the average value of pixels on the original image belonging to the black and white areas is maximal. Another method proposed by Chan and Vese [ChV] starts with an appropriate curve on the image. This method minimises the weighted sum of the standard deviation of pixels in the inner and outer area of the curve with the variation of the shape of the curve. Two parameters can be set, μ adjusts the length of the curve (the bigger value results in a shorter curve), ν adjusts the size of the inner area of the curve (the bigger value results in a smaller area).

For edge detection the gradient method can be used, numerically implemented. The convolution is applicable for noise reduction, and for blurring or sharpening the images (Gauss filter). For blurring, the used kernel in the convolution is a discretised Gaussian surface. For sharpening the image, the first or second derivative of the Gaussian surface can be used. The Canny [Can] edge detection method uses a special approximation of the Gaussian derivative filter.

Burr formation is influenced by the process, when it enters and exits the material of the workpiece. Furthermore the tool and workpiece geometry and the tool path affect the exit. The conditions of the enter and exit of the cutting edge were examined by several researcher. Usually the tool and workpiece geometry cannot be changed, but the tool path can be varied. Burr formation can be reduced avoiding tool exits or limiting the in-plane exit angle in a predefined range [Aur2].

Having precise information about chip thickness is necessary in numerous cases of manufacturing. It is essential for determining the chip cross-section, the cutting force, and the specific cutting force. It is necessary for process modelling, including the tool life, micro- and macrogeometrical features, and stability.

For the determination of the undeformed chip thickness in the case of face milling, it is necessary to know the path of points of the tool edge which is determined by the speed of rotation and linear feed rate. Martellotti [Ma2] used cycloid curves in his research in the 1940s and later Spiewak [Sp2] confirmed the correctness of this model.

The simplest approximation of undeformed chip thickness takes into account the feed rate (f_z) and the angular position of the tool (ϕ): $h(\phi) = f_z \cdot \cos(\phi)$.

Utilising the similarity between the shape of the circle and the cycloid curve, a relatively simple relationship can be deduced analytically to calculate the chip thickness [Ma2]. In practice this method can be deemed accurate when the tool radius, r is significantly higher than the feed rate per tooth: $r >> f_z$. Therefore this method is used by several researchers. The path of tool edge points, with respect to a coordinate system fixed to the tool, was successfully described by Spiewak [Sp2]. Its benefit is that the chip thickness can be determined more accurately based on of the deduced transcendent equation.

Another possible way is to approximate the trigonometric functions using polynomials or Taylor series, which provide closed-form solutions. This method is also used by numerous researchers.

3. SUMMARY OF THE RESEARCH AND DESCRIPTION OF THESES

In this research, up milling was examined. In this case, when the tool exits from the workpiece burr is formed. In the case of simple workpiece geometry,the exit can be prevented. However, the exit cannot be prevented in other cases, so their research is necessary.

In the beginning of the research work, the error of the approximated calculation of the exit angle was examined. The theoretically accurate value of exit angle can be determined with two tangential line in the common intersection points of two curves. The first curve is the workpiece contour and the second is the tooltip path (See Fig.1.). Generally, when the tool exits the workpiece in the case of up milling, the exit angle, α is in the range between 0° and 180°.

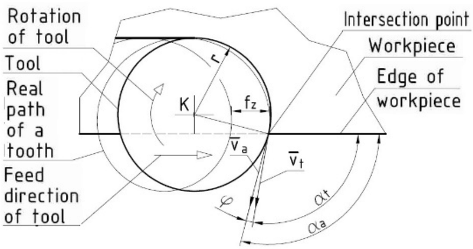

Fig. 1. The difference between the exact and approximated value of the exit angle

In Fig.1. in the exit point the tangential velocity vector of the tool is $\overline{v_t}$, the theoretically accurate value of the exit angle, α_t belongs to this. The tooltip path can be approximated with a circle. In this case, the tangential velocity vector of is $\overline{v_a}$, and the approximated value of the exit angle is α_a. φ is the angle between the two velocity vectors, which is equal to the difference between the exit angles. The deviation is affected by the orientation of the tool and the feed rate.

The accuracy of the approximation can be examined with the extremum of φ in the function of the feed per rotation. The value of φ can be calculated with the difference between the two slope functions, in radian. The maximum and minimum values of φ can be expressed with the following equations:

$$\Phi(k) = arcsin\left(f/2r\pi\right) \tag{1a}$$

$$\Phi(k) = -arcsin\left(f/2r\pi\right) \tag{1b}$$

In equations 1a and 1b, *f* is the feed per rotation, and *r* is the tool radius. The examination can be expanded to circular feed; in this case, the same result was yielded. Using the approximated value of the exit angle is suitably accurate for practical use and makes the calculation simpler.

This approximation method, substituting the tooltip path with a circle, can be efficiently used for special toolpath planning. The toolpaths can be calculated analytically, and it provides a constant exit angle. An experimental workpiece geometry was designed for which special toolpaths were created. The toolpaths provided constant exit angle between 0° and 180°. In Fig 2. it can be seen that linear units of toolpath belong to linear units of contour, and circular units of toolpath belong to circular units of contour. This can be confirmed with the equations describing the toolpath.

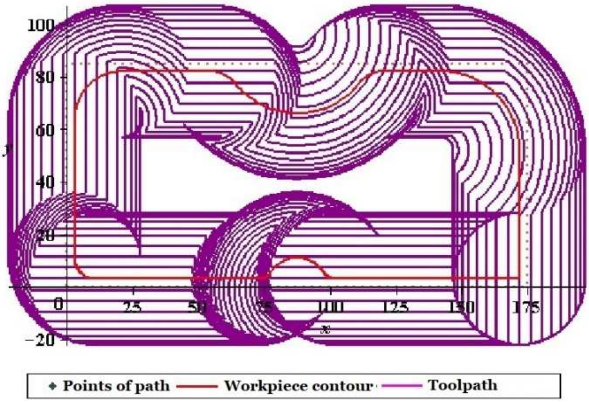

Fig. 2. The experimental workpiece and special tool paths, the exit angle is between 0-180°

After carrying out machining experiments, it was verifiable that around 60°and 150° exit angle the burr size decreased significantly with unchanged feed rate and spindle speed.

Regarding the proposed toolpaths, decreased burr formation are favourable; however, they have disadvantages from many other aspects. Compared to conventional toolpaths, they are significantly longer. In the case of bigger workpieces, material islands may remain on the workpiece, which has to be removed at a later operation. The toolpaths that result minimal burr are more discontinuous; thus, the constant feed rate cannot be guaranteed, and the machining time is increased. If exit occurs in more than one point, the predefined exit angle cannot be provided in all exit points. The toolpath can be further tuned with the aspects described above, but the research work continued in a different direction.

The effect of the exit angle was examined, where the exit angle changed continuously in a range of 0..+π. The experimental workpiece geometry was created where the edge of the workpiece was a simple line inclined with a constant angle to the feed direction; the tool exit occurred on this line. In the intersection points, the approximated (α_t) and the exact value (α_r) of exit angle can be calculated. In the same way, the undeformed chip thickness in the beginning (h) and finishing (h1) point (exit, in reality, occurs not in one point). The exit angle changed between the range of 0..+π, the chip thickness in the range of 0..f_z. In Fig.3. the exit angle proportionally to π (α/π), and the chip thickness proportionally to feed per tooth (h/f_z) are shown.

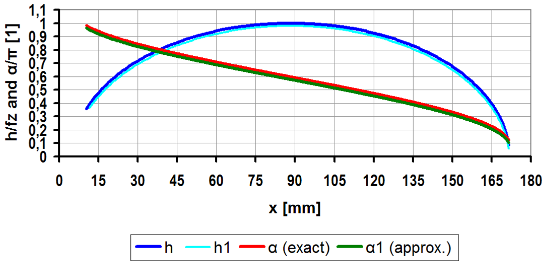

Fig. 3. The exit angle and chip thickness in the intersection points

The changing character of the chip thickness is considerable; it is different from the changing of the exit angle. It is supposed that the size of burr depends merely on the chip thickness; thus, the next topic of the research work was the investigation of the effect of the chip thickness on burr formation. Firstly, the existing calculation methods of chip thickness were revised. The radial rake angle of the tool is supposed to be 0° in all of the existing models. Because the exit order sequence and exit angle depend on the radial rake angle, the former models were refined to include a new tool model. The proposed tool models take into account the radial rake angle.

The working length of the cutting edge can be determined on the basis of the paths of two points: *P*1 on the examined edge and *P*2 on the forerunning edge (see Fig. 4.). The intersection point can be calculated numerically. Using a coordinate system fixed to the tool is favourable. The calculation can be simplified with substituting the tooltip path with a circle or substituting the trigonometrical function with its Taylor series. Replacing the sine function with a first degree polynomial gives a satisfactory result. A new solution is to replace the sine function with a third-degree polynomial, but in this way, the computational requirements grow significantly, and the accuracy improves very slightly. Another solution is to fit a fourth-degree polynomial on the numerically calculated points. A third-degree polynomial can also be fitted to the coefficients of each fourth-degree polynomial. This method is accurate in practice and can be calculated very efficiently and quickly. The undeformed chip thickness can be calculated from the working length of the cutting edge considering the correction derived from the direction of the speed vectors.

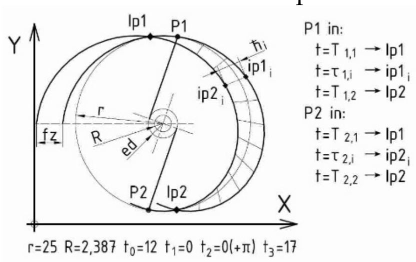

Fig. 4. The calculation of undeformed chip thickness in face milling

The model was verified with experiments. In the experiments, 1-to-4 mm feed per tooth was applied, and the cutting force was measured. In the evaluation, it was possible to demonstrate the effect of the radial rake angle. In the results of the experiments and the simulation, good correspondence was found.

For examining the effect of chip thickness on burr formation, it was necessary to know the burr size on the machined edge. Because of the special requirements and the numerous experiments, a new unique method was developed. The estimation of the burr size was based on image processing. The images were captured with a digital microscope. The mobile microscope can be attached to the spindle of the machine tool, and its position was adjustable. The configuration is shown in Fig. 5. Because of the shining of the machined surface, the use of a diffused light was necessary. The manufacturer of the microscope did not offer this accessory, so it was individually designed and prepared. The burred contour can be made visible with the painting of the surface of the workpiece and with using a special filter on the image. It is better for the later image processing if the resulting contour is a continuous line-chain. In the case of a large number of images, the processing speed is also an important factor. Because the existing algorithms only partly satisfy these special requirements, a unique method was developed and used for image segmentation.

The image processing software was verified with artificial test pictures and sample pictures. The achieved accuracy was ±0.06 mm. This value highly depended on the accurate set of position and orientation of the microscope and the lighting source. The positioning can be solved efficiently only with a precision holder. It should be designed and prepared individually because the manufacturer did not provide such equipment.

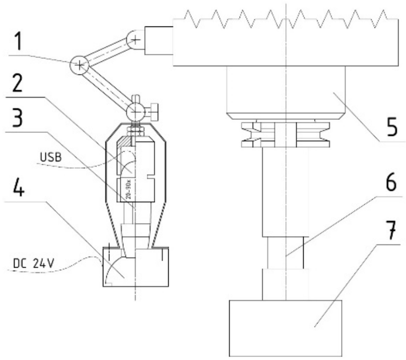

Fig. 5. Experimental set up for burr size estimation;
1: mount, 2: holder, 3: microscope, 4: light source, 5: spindle, 6: tool, 7: workpiece

The proposed method to estimate the burr size was deemed acceptable in this investigation. In the first experimental series, constant exit angle and constant chip thickness were applied. One of the experimental setups is shown in Fig. 6. A demonstrative analytical expression which describes the effect of chip thickness on burr formation was not found. The behaviour of burr formation shows a high deviation. However, it was proved that the distribution of burr size did not possess a normal distribution.

The edge breakout was also investigated. The image processing did not give a satisfactory result for most of the pictures. Due to this problem, numerous pictures were processed manually. The manual segmentation was significantly slower, though the accuracy and reliability were preserved. A better result can be expected using other special lighting in the future. A demonstrative analytical expression which describes the effect of chip thickness on edge breakout was not found. The behaviour of edge breakout formation shows a high deviation, such as the burr formation. It was proved that the distribution of edge breakout did not possess a normal distribution.

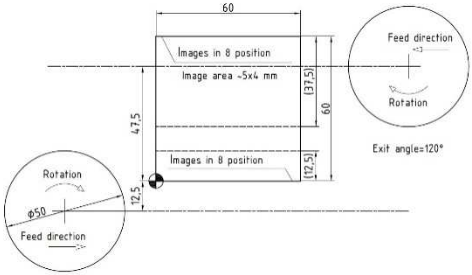

Fig. 6. Workpiece geometry for constant exit angle (α=60° and 120°) and constant chip thickness

During the second experimental series, constant exit angle and changing chip thickness were applied. A special workpiece geometry was designed (see Fig. 7.) that allows linear feed direction and constant speed. The range of the real exit angle is known using the formula derived earlier. Thanks to the designed contour, the chip thickness was changing in a wide range, but the rate of change was not constant. (I believe that it is impossible to make a curve which provides constant exit angle and constantly changing chip thickness.)

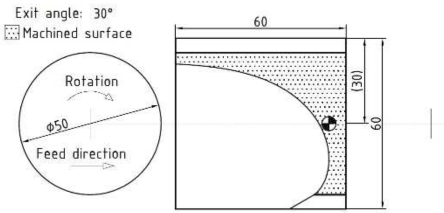

Fig. 7. Workpiece geometry for changing chip thickness and constant exit angle (α=30°)

A demonstrative analytical expression which describes the effect of the chip thickness and that of its changing on burr formation was not found based on the second experimental results. It illustrates the complexity of burr formation process.

The two experiments demonstrated the effect of chip thickness on burr formation. However, the conclusions can be generalised and utilised only with limits, because the workpiece material, tool and cutting speed was unchanged in the experiments. These conditions can be examined with numerous experiments, which exceeds this research work.

4. SCIENTIFIC THESES

The results of the research work can be summarised in the following scientific theses:

Thesis 1:

In the case of face milling, the difference of the theoretically accurate and approximated value of exit angle is within an exact range. The limits of the range can be expressed analytically with T1.1 for linear and circular feed direction if the feed rate is $f < 2r\pi$.

$$-arcsin\left(f/2r\pi\right) \leq \varphi \leq arcsin\left(f/2r\pi\right) \tag{T1.1}$$

The T1.1 expression gives a satisfactory result in practice if $f << r$ with the substitution of $arcsin\left(f/2r\pi\right) \simeq f/2r\pi$.

where:

f **- feed per revolution**

r **- tool radius**

φ **- the difference between the theoretically accurate and approximated value of exit angle, (α_r - α_t)**

α_t **- the theoretically accurate value of the exit angle**

α_a **- the approximated value of the exit angle**

Publications [S2, S5] belong to thesis 1.

Thesis 2:

When the path of the tooltip is substituted with a circle, and the workpiece contour is planar and can be described with a two-parameter expression (*X(t)* and *Y(t)*), in the case of up milling, the tool path that provides constant exit angle can be described analytically with the following expressions.

$$X_{center}\left(t\right) = X\left(t\right) + r1 \cdot cos\left(\mu\left(t\right) + \left(\pi/2\right) + \alpha\right) \tag{T2.1}$$

$$Y_{center}\left(t\right) = Y\left(t\right) + r1 \cdot sin\left(\mu\left(t\right) + \left(\pi/2\right) + \alpha\right) \tag{T2.2}$$

Where

t **parameter that belongs to the tool rotation**

α **exit angle**

$\mu\left(t\right)$ **the slope of the contour in radian within the range –π… π, which can be described with expression (T2.3):**

$$\mu(t) = 2\,arctan\frac{\left(\sqrt{\left(dX(t)/dt\right)^2 + \left(dY(t)/dt\right)^2} - \left(dX(t)/dt\right)\right)}{\left(dY(t)/dt\right)} \qquad \textbf{(T2.3)}$$

Publications [S1, S4] belong to thesis 2.

<u>Thesis 3:</u>

In the case of face milling and linear feed direction, the working length of the cutting edge can be modelled with a new method that considers not only the feed per tooth and tool radius but also the radial rake angle of tool. The new model is based on the numerical search for intersection points using a coordinate system fixed to the tool. The undeformed chip thickness can be calculated more accurately using the working length of the cutting edge corrected with the directions of the speed vectors, which provides a more accurate calculation of the theoretical chip thickness compared to the former methods.

The mean of the angular position of the tool in the start- and end-point of cutting – the centerpoint of cutting, determined by the proposed method – is independent from the feed with good approximation. If the radial rake angle is greater than 0°, then the location of the maximum of the undeformed chip thickness and cutting force differ from the centerpoint of cutting. So the change of chip thickness is asymmetric with respect to the angular position of the tool, the duration of the growth period of chip forming is longer.

Publications [S3, S6] belong to thesis 3.

<u>Thesis 4:</u>

In the case of face milling, the length of burr formed on the workpiece edge can be determined with a new method. The proposed method uses a digital microscope and is based on image processing; its main steps are the following:

1. Taking pictures in well-defined positions on the burr-free and burred edges.

2. Segmentation of images, determination of the contour line.

3. Determination of the distance between the points of the contour and the theoretical contour.

4. Determination of the length of burr from the difference between the

distances in the normal direction.

5. Plotting and saving of the results.

The main advantages of the proposed method are as follows:

- the size of burr along the workpiece edge can be determined continuously;

- the size of burr can be determined on the machine tool; it is not necessary to remove the workpiece;

- the processing is fast, and the result can be obtained quickly.

The method is very sensitive to the position and orientation of the microscope, the lighting and the accuracy of the positioning of the workpiece (or microscope).

Publications [S7, S8] belong to thesis 4.

<u>Thesis 5:</u>

In the case of face milling and up milling method, the size of burr is influenced by the chip thickness in the exit point. The effect of the chip thickness is smaller than the effect of the exit angle, and it can be detached from the effect of the exit angle. In the exit point, constant chip thickness has a smaller effect on the average size of the burr if the exit angle is 30°, 60°, 90° or 120°, and it has a significant effect at 150° exit angle.

Regarding the burr formation, the favourable setting is 30° or 60° exit angle, or 0.1-0.3 mm chip thickness in the exit point. In this case, the average size of the burr is 0.1 mm, and its standard deviation is 0.1 mm or smaller. These settings are also valid if the edge breakout is considered.

The continuous change of chip thickness in the exit point has an influence on burr formation, and it increases the uncertainty of expected burr size.

In the case of face milling and up milling method with constant exit angle, cutting speed and cutting depth, the distribution of burr size and edge breakout size is not normal. A feasible model can be constructed by combining 2 or 3 distribution functions. Based on the maximisation of the Loglikelihood function, in the case of modelling the burr size, the best result can be obtained by combining 2 Normal or 2 Skewnormal distribution functions. In the case of modelling the size of the edge breakout, the best result can be obtained by combining 3 Normal or 2 Skewnormal distribution functions.

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6. LIST OF OWN PUBLICATIONS RELATED TO THE WORK TOPIC

[S1] Póka György, Mátyási Gyula, Rakita Tamás: Sorjaképződés minimalizálása homlokmarásnál a szerszámpálya új módszerrel történő meghatározásával. . XXI. Nemzetközi Gépészeti Találkozó, Arad (Románia), 2013. 04. 25-28., Erdélyi Magyar Műszaki Tudományos Társaság, Konferenciakiadvány, pp. 273-277

[S2] Póka György: Ciklois szerszámpálya körrel történő közelítésének hibája. XXII. Nemzetközi Gépészeti Találkozó, Nagyszeben (Románia), 2014. 04. 24-27., Erdélyi Magyar Műszaki Tudományos Társaság, Konferenciakiadvány, pp. 293-296.

[S3] Póka György, Németh István: Ciklois szerszámpálya körrel történő közelítésének hibája a forgácsvastagság meghatározásánál. Gyártás 2015, Budapest, 2015. nov. 20., Gépgyártás 55, pp. 109-114

[S4] Póka György, Németh István, Mátyási Gyula: Burr minimisation in face milling with optimised tool path. 49th CIRP Conference on Manufacturing Systems, Stuttgart, 25-27 May 2016, PROCEDIA CIRP (Westkamper, E; Bauernhansl, T), pp. 653-657, doi: 10.1016/j.procir.2016.11.113

[S5] György Póka, István Németh: Cycloid approximation with circle for the calculation of exit angle. Tehnički Vjesnik - Technical Gazette, 26, 4, 893-901, (2019)

[S6] György Póka, István Németh: The effect of radial rake angle on chip thickness in the case of face milling. Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture, 234, 1-2, 40-51, (2020)

[S7] Geier Norbert, Póka György, Szalay Tibor: Direct monitoring of hole damage in carbon fibre-reinforced polymer (CFRP) composite. IOP CONFERENCE SERIES: MATERIALS SCIENCE AND ENGINEERING 448:1 pp. 1-7., 7 p. (2018), DOI ISSN: 1757-899X

[S8] Geier Norbert, Póka György, Pereszlai Csongor: Monitoring of orbital drilling process in CFRP based on digital image processing of characteristics of uncut fibres. PROCEDIA CIRP 85 pp. 165-170. , 6 p. (2019)