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A Method to Design Profiled Cutting Tools for Inner Turning

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Abstract: Designing the profile of cutting tools is a specific problem in manufacturing engineering. The profile of the cutting tool has a direct influence on the dimensional and shape precision of the machined parts. When it comes to cutting tools for internal turning, the problem of profile design becomes even more complex, because of the added restrictions the profile and the cutting tool itself are subjected to. Despite its importance and complexity, this problem has been rather poorly considered in the literature. Some side aspects, such as measuring the profile, its wear, and its influence on the part's geometrical precision have been studied, but not the design process of the profiled shape of cutting edges. This research fills a gap in the literature. It considers profiled cutting tools, in general; and, in particular, investigates tilted cutting edges. The novelty of the present article lies in a method to determine the profile of cutting tools for turning inner-profiled surfaces. The method is CAD-based and provides accurate results. It considers the part's inner profile, its inner diameter, and the tilting angle of the cutting edge. In addition, possible undercuts are taken into account. The method was validated using two relevant case studies. Despite profiled cutting tools having a certain drawback, which is emphasized in the article, this is balanced by the advantages that their use offers manufacturing.

Keywords: turning inner surfaces; profiled cutting tools; tilted cutting edge; special cutting tools design; undercut; cutting forces; symmetrical profile

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Citation: Dragoi, M.-V.; Parv, L.; Mija, A.; Oancea, G. A Method to Design Profiled Cutting Tools for Inner Turning. *Symmetry* **2022**, *14*, 2690. https://doi.org/10.3390/sym14122690

Academic Editor: Fernando Veiga

Received: 8 November 2022
Accepted: 15 December 2022
Published: 19 December 2022

1. Introduction

Manufacturing engineering deals often with profiled surfaces. They can be machined properly either using the appropriate tool path or using a profiled cutting tool. When the profiled surface is not wide, the best way to approach this is through profiled cutting tools. It should be noted that depending on the type of machining (turning, milling, or grinding) and the type of surface (outer or inner), in many cases the profile of the cutting tool is not the same as that of the surface to be machined (that is the cutting tool profile does not coincide with the profile to be machined). When the profile is placed along a helical surface, more problems are encountered. Furthermore, in certain cases, possible undercuts have to be considered. These are the reasons why designing the profile of a cutting tool is not an easy task, and the subject of designing the shape of cutting tools' profiled edge is worth studying.

1.1. Literature Review on Profiled Cutting Tools

The literature is lacking in treating this subject, and instead side aspects are mentioned. One of the most approached is the geometrical precision of the profile, either of the parts machined, or of the cutting tool. In Ref. [1], the influence of the wear of different machine tool elements on the alteration of the machined profile was studied. It was proven that irregularities were induced on the machined surface, caused by the mentioned wear. An amplitude–frequency analysis was used to emphasize and evaluate the changes of turned lateral profiles. Lu et al. [2] proposed a method to pre-evaluate the influence of cutting parameters on the precision of the profile using a neural network, to save the cost of investigation in situ with physical machining. The cutting parameters involved were cutting speed, cutting depth, and feed rate. In addition, the influence of tool wear on prediction accuracy was investigated. Based on a comparison of the prediction results and the experimental data, the conclusion was that the prediction method was precise enough to replace machining in scientific research. Liu et al. [3] investigated the influence of the tilting angle of the cutting tool on the precision of the deep aspheric profile. A cutting tool has to be tilted to ensure an effective flank angle. The tilt angle is limited by the strength of the cutting edge, so an alteration of the machined profile occurs. This alteration can be removed by adjusting the tool path. In Ref. [4], the square and minimum zone methods were used to estimate the out-of-roundness value of a simulated profile and to validate two empirical models of roundness of profiles machined by turning. The influence of tool nose tolerance on the profile of a tuned part was studied by Sung et al. [5]. In addition, the effect on the surface roughness was analyzed. In Refs. [6,7], particular problems concerning the profile of a ratchet machined by turning, and using a rack-typed tool, respectively, were considered. The research presented in [8–10] deals with designing the profile of the cutting tools used for manufacturing helical surfaces. In particular, the circular profile was displaced on a helical surface [9]. The specific problem of the cutting tool's profile was discussed. The grinding tool's profile was the subject of discussion [10]. The authors proposed a new method to design the correct profile for grinding the helical surface of cutting tools, in a way that optimizes the profile and that takes into account the possibility of the occurrence of undercuts. The optimal design of the cutting tool profile was approached in [11]. The problem of rectilinear flanked surfaces processed by the turn-milling process was discussed by Kulikov et al. [12]. Although the flanks of a machined surface are straight, the cutting tool's flanks must have a certain curvature. The radius of this curvature was calculated using a specific formula, provided by the authors. The extent to which the error setting of the tool influences the accuracy of the turned profile was investigated [13]. This emphasizes that the problem of the cutting tool profile and the precision of the profiled machined surfaces has concerned scientists since the 1970s. In two works [14,15] that were issued by the same group of researchers, the problem of designing profiled cutting tools for machining gears with non-involuted profiles was approached. Some particular aspects, such as the profile of the tangential cutters, the complex problem of single-point cutting tools with a generic profile, and cutting tools for conventional and synchronized whirling are presented in Refs. [16–18]. Another kind of profile, the polyhedral, which is placed in the cross-section instead of the axial, was approached in [19]. Its machining does not involve a profiled cutting tool, but is kinematic. The micro-profile of turned parts has captured the attention of various researchers. Thus, Xu et al. [20] examined the influence of cutting parameters in high-speed turning on the roughness of the surface. Their conclusion was that increasing the hardness of the material and the cutting speed are factors that improve the quality of the surface, in terms of roughness. The influence of cutting forces on the profile along the tool path with high precision turning was presented by Yuan et al. [21]. The impact of the forces in three specific directions, when turning using a diamond, on the roughness was studied. It was found that the most significant influence was that of the force in the primary cutting direction. Some side aspects related to the profile of the cutting edge were approached in Refs. [22,23]: on-machine measuring of the profile of the cutting edge, and manufacturing the profiled cutting tools by hydrostatic extrusion were presented as novel subjects.

The authors of the present research have some previous achievements in the domain of profiled cutting tools, publishing three scientific papers [24–27] and issuing a patent proposal [28].

1.2. Conclusion on the Literature Review

After reviewing some relevant research works in the literature, some conclusions can be drawn related to the subject of profiled cutting tools, as follows:

- The range of subjects approached is wide, including the geometry of the profiled cutting tools, different cutting processes (turning, milling, and grinding), the precision of the profiled surfaces engendered, the micro profile of the surface, that is the roughness, and other factors;
- The researchers approached cutting tools for profiled surfaces placed both on cylindrical and helical surfaces;

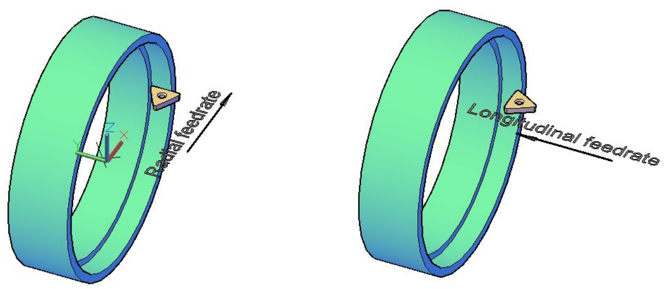
  Research was devoted to both radial and tangential cutting tools for turning:
- Designing the profile of cutting tools has rarely been approached;
- Inner turning of the profiled surfaces was not considered.

Taking into account the remarks above, some research directions can be foreseen, focused on some specific aspects, such as the design of the profile of cutting tools, the particular cutting conditions of inner turning of the profiled surfaces, and the possible occurrence of undercuts. In these conditions, the current research considers the niche subject of the design of the profile of the cutting tool for inner turning of profiled surfaces, working with the radial feed rate, using a cutting tool with a tilted cutting edge, and considering undercuts.

2. Materials and Method

The method proposed for determining the profile of the cutting tool is CAD-based. The input data consist mainly of the 3D profiled part to be machined and a generic cutting tool, i.e., a general cutting insert, that equips the cutting tool. Using specific CAD processing of the 3D objects, and taking into account the specific features desired for the cutting tool, its particular profile is determined. Usually, the starting point for shaping the cutting insert is an existing general example, provided by specialized producers, but in certain cases, the designer himself makes a decision on the starting shape and size of the cutting insert to be modified, in order to obtain the final profile of the cutting tool.

When using profiled cutting tools for turning, the machining is exclusively performed with a radial feed rate. In some particular cases, even for cylindrical short surfaces, a radial feed rate is preferred to the longitudinal, for effectiveness reasons, as shown in Figure 1 for the case of internal surfaces.



(**a**) (**b**)

Figure 1. Turning internal surfaces; (**a**) working with radial feed rate; (**b**) working with longitudinal feed rate.

As one can see, for the particular case in Figure 1, the travel of the cutting tool is much shorter if cut radially than longitudinally, that is the machining is more effective in the (a) case. However, approaching the part with a cutting tool having the cutting edge parallel to the generatrix of the part causes dangerous shocks when the cutting tool engages with the workpiece. Such shocks may cause damage of the cutting tool and breakage of the cutting insert. Events such as these involve financial losses. To eliminate this serious technological problem, a solution must be found. The present research proposes a way to remove this disadvantage: tilting the cutting edge, so it is no longer parallel to the axis/generatrix of the workpiece. In such a case, the cutting edge is no longer straight, but it has to be reshaped to fit the tilted section through the workpiece. Only in this way can the profile of the machined part in its radial section not be affected and conform to the shop-floor drawing of the part. Due to this tilting, the ends of a cutting insert that has straight cutting edges will pierce through the surface of the workpiece in the case of inner turning. In technical terms, this is called an undercut. This is why the edge of the cutting insert has to be reshaped. The present research aimed to provide practitioners with a method to design an appropriate shape of the tilted cutting edge of the cutting tools.

In Figure 2, two inserts are shown: the leftmost one has an edge parallel to the axis of the workpiece, and the rightmost is tilted by an exaggerated angle of 30°. In detail D the interference between the cutting insert and the workpiece is shown scaled 2×. The image of the interference is rotated for a better view. Note that despite the cutting insert being placed symmetrically, with respect to the horizontal plane of the workpiece, the interference is dissymmetrical. This is caused by the effective clearance angle of the cutting insert: at the side below the horizontal plane, it becomes larger than the constructive one, while at the side above, it decreases.

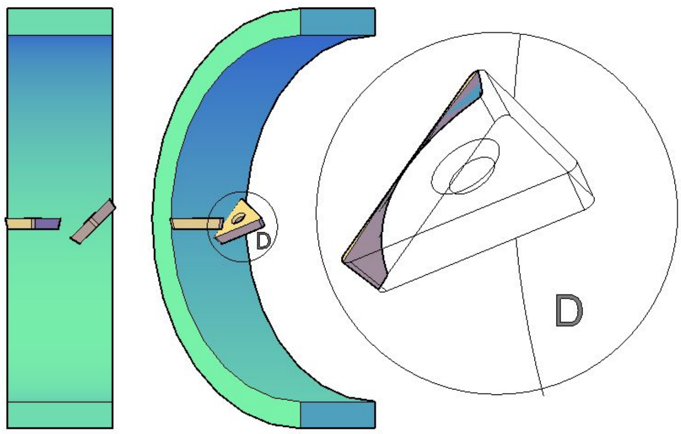


Figure 2. The horizontal and tilted cutting insert (detail D shows the interference scaled by 5×).

Figure 3 shows the difference between the surfaces machined with a radial feed rate having the cutting insert in the radial plane of the workpiece, and respectively, tilted by 45°; the tilting angle is intentionally exaggerated, to make it easier to notice the effect produced on the machined surface.

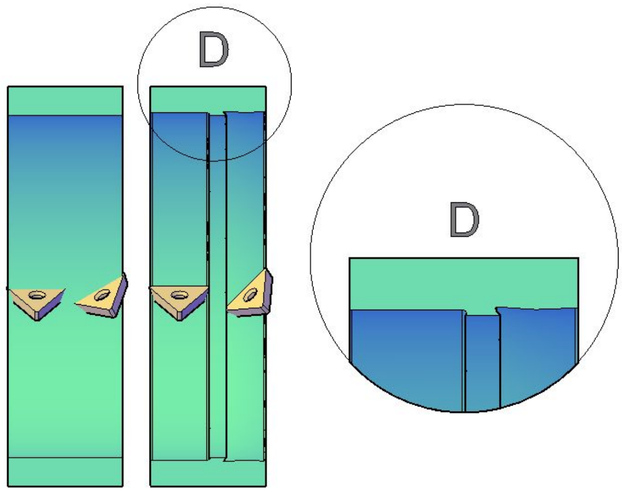


Figure 3. The surface machined with horizontal and tilted cutting inserts; (**a**) initial position of the inserts; (**b**) the surfaces obtained on the workpiece; (**c**) the difference between the surfaces machined, scaled 2×.

2.1. Method

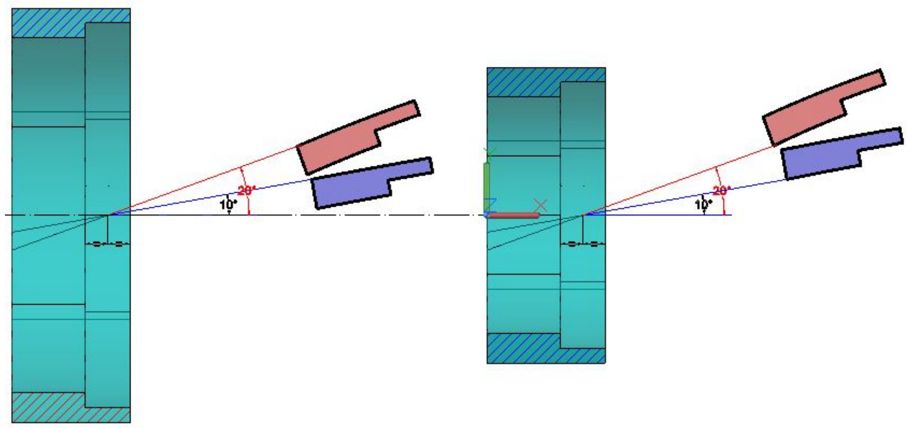
Despite the example above being very simple, it can be used to illustrate the methodology of designing a cutting tool profile for inner turning with a radial feed rate.

The main aspects to be considered when the profile of the cutting tool for inner turning is determined are as follows:

- The angle at the cutting insert is tilted against the direction of the workpiece's axis;
- Due to the curvature of the part, special attention has to be paid to the clearance angle of the cutting tool. It is noted above that this acts dissymmetrically on the two sides of the workpiece. Depending on the direction in which the cutting edge is tilted, the actual clearance angle increases at one side and decreases at the other one. Even for the side with the smaller effective clearance angle, this still has to be positive and at a reasonable value (at least 2.5°, depending on the material to be machined);
- The bigger the tilting angle of the cutting insert, the bigger the undercut;
- The inner radius of the workpiece directly influences the shape of the cutting insert.

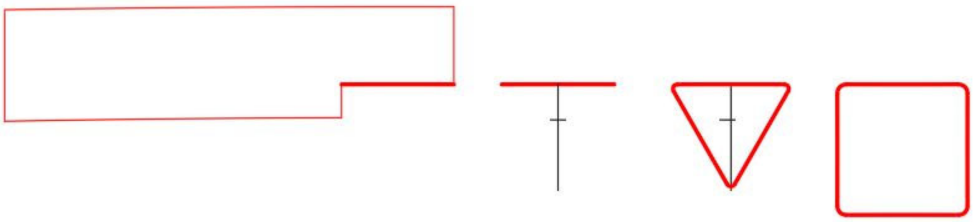
The main steps followed to design a cutting insert having its profile adjusted to the tilting angle of the cutting insert are as follows:

1. Create a section through the workpiece with a plane that contains the intended cutting edge. If the profile is a symmetric one, it is recommended that the plane be rotated against the radius of the workpiece, at the level of the symmetric plane of the profile (Figure 4). In this way, during machining, half of the cutting edge is above the horizontal radial plane of the workpiece, and half is below it;
2. Cut the section (Figure 5a), and keep only the needed elements (Figure 5b);
3. Create the contour of the cutting insert with the desired number of edges and nose radius (Figure 5c,d);
4. Create a tapered extrusion of the contour to obtain the body of the cutting insert, and add a hole for clamping the cutting insert onto its support (Figure 6);
5. If needed, some flanks of the cutting insert can also be tapered, to obtain even clearance angles on both sides of the insert.



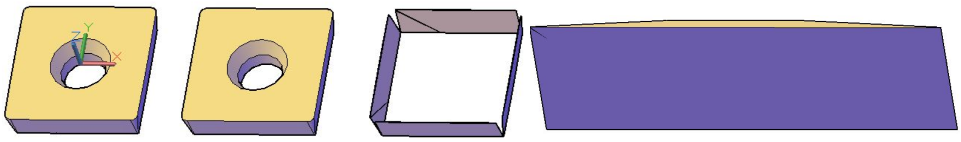
(**a**) (**b**)

Figure 4. The section through the workpiece. The sectioning plane is aligned with the desired cutting edge; (**a**) part diameter Ø140 mm; (**b**) part diameter Ø100 mm.



(**a**) (**b**) (**c**) (**d**)

Figure 5. Creating the contour of the cutting insert; (**a**) the section through the workpiece; (**b**) the useful segment of the section and some auxiliary construction; (**c**) the contour of a triangular cutting insert; (**d**) the contour of a rectangular cutting insert.



(**a**) (**b**) (**c**) (**d**)

Figure 6. Cutting inserts for the part having an outer diameter of 140 mm and an edge tilting angle of 20°; (**a**) insert with profiled edges; (**b**) insert with straight edges; (**c**) the difference between the two different cutting inserts. This is obtained by subtracting the second insert from the first one; (**d**) the difference of the two inserts along a single cutting edge, scaled by 5×.

Figure 4 shows two sections corresponding to a tilting angle of the cutting edge of 10° and 20°, respectively. The two sections are represented as rotated views (perpendicular to the plane they were generated in). One can notice that the bigger the rotation angle, the wider and more deformed the section becomes. The rotation of 20° is too large to be used in practice, but it is useful for emphasizing the difference with the rotation of 10°. The construction is replicated for two similar parts, having outer diameters of 140 mm (a) and 100 mm (b). Despite it being difficult to observe visually, the homologous sections display differences, both in terms of their shape and of their area; for the sections rotated by 20° the values of the section areas are 347.8 mm^2 (a) and 350 mm^2 (b).

The difference in volume between the profiled and straight-edged cutting insert is 9.76 mm^3. The cutting inserts can be designed with a corner radius (0.8 mm in the sample presented), or with sharp cornered edges. In the first case, the size of the radius is added to the length of the edge, and this might affect the shape of the shoulder at the junction of the two adjacent cylindrical parts. The inserts with sharp corners preserve the shoulder shape, but are weaker in terms of robustness. The inserts with rounded corners can only be used for open profiles, that is profiles placed at the end of the part.

Of course, for inner profiled surfaces, the problem of designing the cutting tool's profile becomes a little more complicated, but it follows the same stages. The main difference from cylindrical inner surfaces is that the cutting insert no longer looks like a classical cutting insert, either triangular, rectangular, or of any other shape.

2.2. Conclusion on the Method

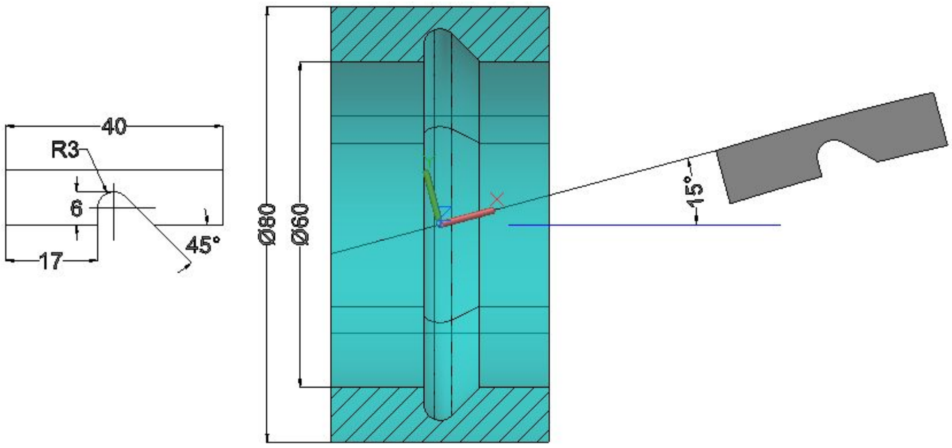
The main conclusion on the method proposed here is that it is easy to implement and provides accurate results. The technologist decides on the magnitude of the tilting angle of the cutting edge. The extent to which the cutting tool's profile differs from that of the workpiece's is directly influenced by the value of the tilting angle and by the radius (curvature) of the workpiece. Increasing the tilting angle of the cutting edge and decreasing the diameter of the part are factors that contribute to a larger deviation of the cutting tool's profile from that of the part.

3. Results

Two case studies are used to illustrate the application of the method, to determine the profile of the tilted cutting edge for turning an inner profiled surface, using the radial feed rate, and its results.

3.1. Case Study #1

The first case study refers to the profile presented in Figure 7a. This was applied at the inner side of the part in Figure 7b, and it was machined with a cutting tool having the cutting edge tilted against the axis of the workpiece. To obtain the tilting angle of the cutting edge, the upper face of the cutter was rotated about the radius of the workpiece at the level of the deepest point on the profile. The tilting angle of the cutting edge was 15°.

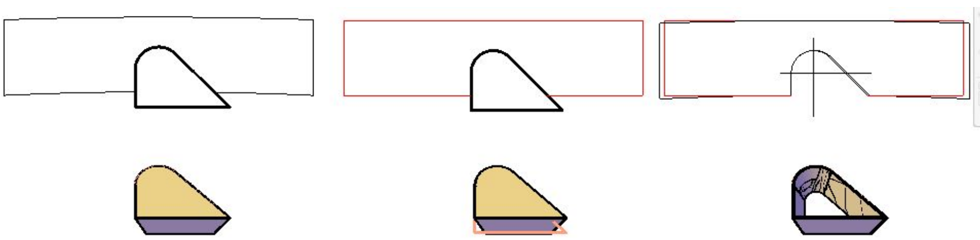


(**a**) (**b**) (**c**)

Figure 7. Case study #1; (**a**) the inner profile of the part to be machined; (**b**) the part—radial section and the tilting angle of the cutting edge; (**c**) the tilted section through the part—orthogonal view.

The starting point for designing the profile of the cutting edge was the section (Figure 7c) through the part by a plane that contained the desired upper face of the cutting tool. All the geometrical data that describe the sample are available in Figure 7.

According to the stages described above, the part profile was cut out from the tilted section and further processed to obtain a closed loop. The profile thus obtained was extruded with a tapper angle to form the body of the cutting insert. The backside of the insert was not affected by the tapering, to ensure proper conditions for clamping the insert in its support. The hole needed to clamp the insert on its support was also designed. In Figure 8, the sections through the part, the profile, and the cutting insert in the two variants, are shown and overlapped, to emphasize the difference.



(**a**) (**b**) (**c**)

Figure 8. The sections through the part and the corresponding cutting insert; (**a**) tilted by 15° section; (**b**) radial section; (**c**) overlapped sections.

The difference in the volume of the tilted and non-tilted cutting inserts was 9.08 mm^3. The cutting insert must be clamped on a specially designed support that fits the profile of the cutting tool (Figure 9). To avoid interference between the workpiece and the cutting tool's shank, one of its flanks had to be tapered, as can be seen in Figure 9.

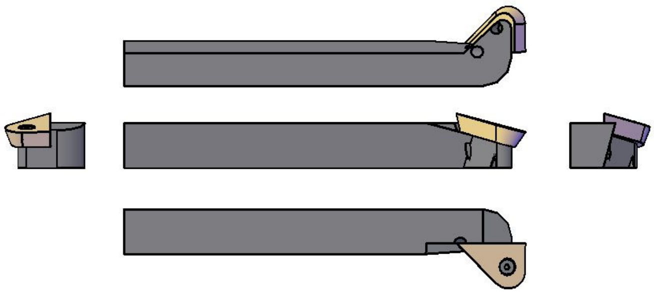
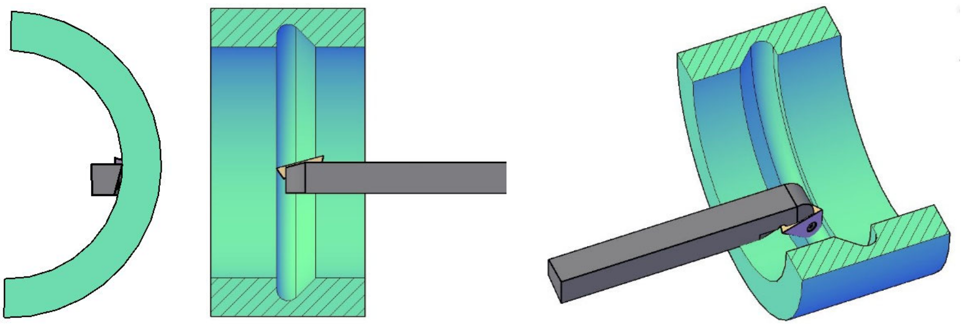


Figure 9. The cutting insert clamped on its support.

Possible undercuts or interferences between the workpiece and the cutting tool were checked using the CAD system. No overlaps of the cutting tool and workpiece were identified. Proof that the cutting insert and its support were correctly designed is presented in Figure 10, where different views of the cutting tool in the working position are displayed.

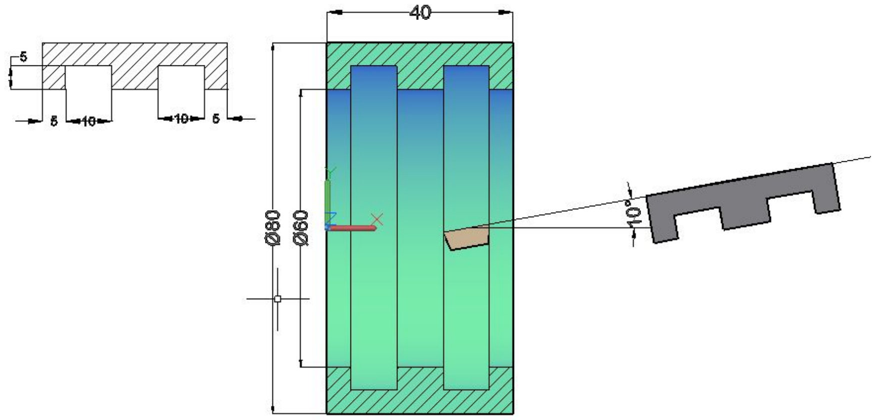


(**a**) (**b**) (**c**)

Figure 10. The cutting tool in the working position at the end of processing the inner profiled surface with radial feed rate; (**a**) front view; (**b**) side view; (**c**) 3D view.

3.2. Case Study #2

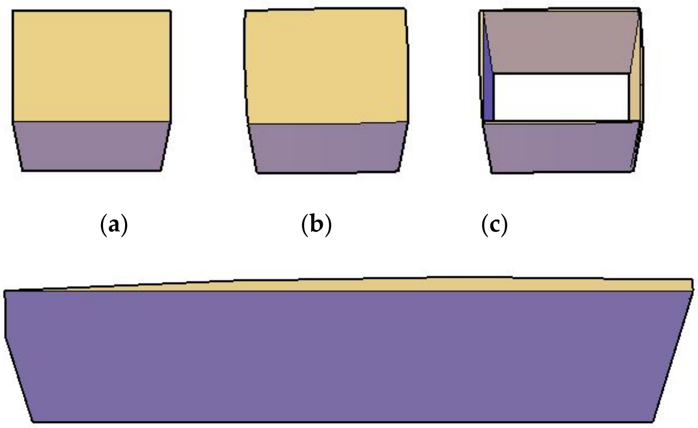
The second case study considered a part that had two inner radial grooves, as shown in Figure 11. Taking into account that the two cutting edges were long, they had to be tilted to avoid shocks when placing the cutting tool in the workpiece. Due to the symmetry of the part, the two cutting edges could be tilted with opposite angles, +10° and −10°, respectively. In this way, the total axial cutting force was balanced. As the profile of the groove was symmetrical, both of the two groves could be machined with identical cutting inserts, but differently tilted. To design of the modified cutting inserts followed the same procedure as in Case study #1, which was described in Section 2.1 Method, in steps 1–5. Furthermore, since the cutting movement was the same for the two groves, the inserts could be clamped on the same support. A special cutting insert holder was designed. Machining the two grooves simultaneously doubled the effectiveness of the operation.



(**a**) (**b**) (**c**)

Figure 11. The sample part for case study #2; (**a**) the inner profile of the grooves; (**b**) the part and a tilted cutting insert; (**c**) orthogonal view of the tilted section through the part.

Figure 12 shows a rectangular insert, designed to work in the radial plane of the workpiece and the specially designed that was designed to work tilted. As has already been stated, the second insert has a modified shape, to fit the profile of the groove, being tilted. The difference in volume between the two inserts was 6.23 mm^3.



(**a**) (**b**) (**c**)

(**d**)

Figure 12. The cutting inserts for machining the grooves; (**a**) the classical one, to work in the radial plane of the workpiece, not tilted, and with a straight edge; (**b**) the specially designed cutting insert, whose profile fits the part profile, to work tilted; (**c**) the difference between the two cutting inserts. This was obtained by subtracting the first insert from the second one; (**d**) the difference between the two inserts along a single cutting edge, scaled by 5×. Note the dissymmetry.

In Figure 13 the special cutting insert holder is shown. This ensured the correct orientation of the two cutting inserts, and provided some other advantages: it balanced the total axial cutting force, increased the effectiveness of the operation, removed the need to adjust the distance between the grooves, and ensured the even depth of the groves, without any other precautions.

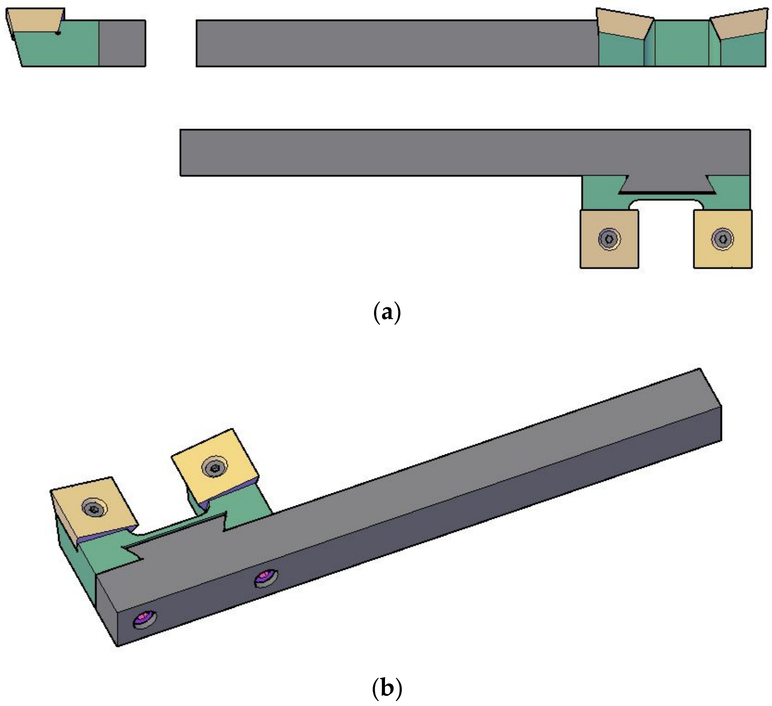


Figure 13. The special cutting insert holder (**a**) orthogonal views; (**b**) 3D view.

The cutting inserts were designed with two profiled cutting edges placed on two opposite faces of the insert. In this way, after wearing an edge, the insert can be rotated 180°, so the tool life is doubled. The rear face of the dwelling for the cutting insert on the holder had the same shape as the flank of the insert, ensuring the proper positioning of the two relative to each other. If the lateral sections of the profile are short enough, an insert with all four cutting edges being active could be considered. Otherwise, the lateral sections of the part profile might be altered.

The results of the design were checked in terms of the interference between the cutting tool and the workpiece. No problems were identified. Figure 14 shows the part and the cutting tool put together. One can see that the cutting inserts fit exactly into the grooves.

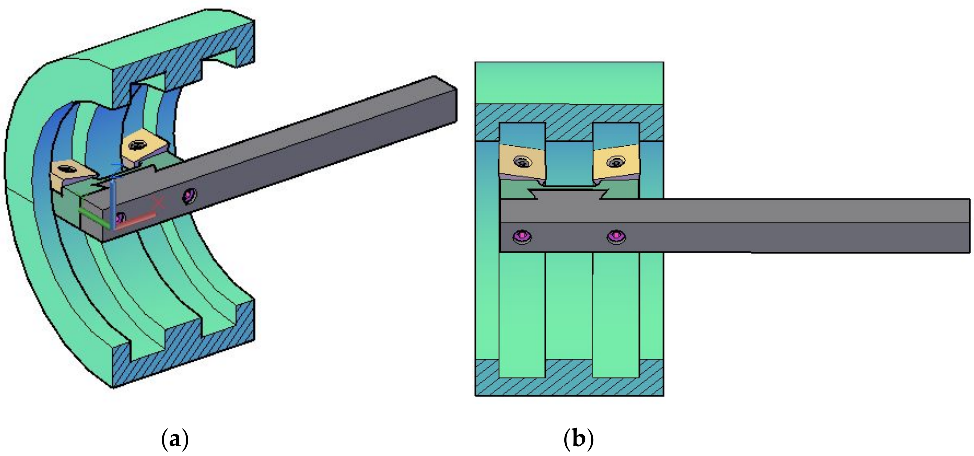


Figure 14. The cutting tool fits the profile of the part; (**a**) 3D view; (**b**) mid-upper view.

4. Discussion

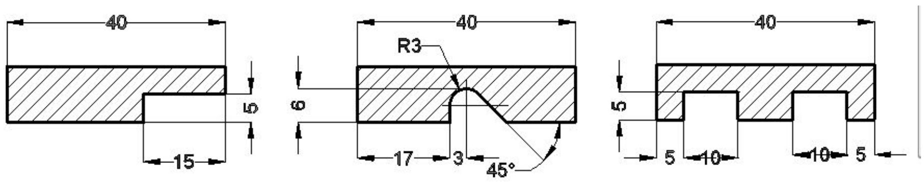
The method presented in this paper approaches in a different way the problem of machining profiled inner surfaces by turning with a radial feed rate. The particular aspect the authors considered was tilting the cutting edge, for the main reason of avoiding shocks when the cutting tool enters the workpiece. In addition, removing undercuts was targeted. Depending on the specific conditions, some other advantages can be gained. According to the principles of design for manufacturability, the designer should deal simultaneously with the constructive and technological aspects of the design. Thus, designing special cutting tools must take into account the particularities of the part to be machined. According to these particularities, the designer makes decisions on tilting or not the cutting edge, the value of the tilting angle, and others aspects. Correctly choosing the tilting angle is crucial, because the cutting conditions depend on this (i.e., forming the chips), as well as the constructive clearance angle. Special attention must be paid to the constructive clearance angle, because a functional one prevents negative effects on the workpiece; the functional clearance angle increases on one flank of the cutting insert and decreases on the opposite flank. The functional clearance angle must be at least 2°.

The greater the tilting angle of the cutting edge, the more the profile of the edge is deformed, and the cutting insert becomes wider. In Table 1 data concerning the width and depth of the profile, the tilting and clearance angle of the insert, the biggest deviation of the cutting edge profile from that of the part, and the difference in volume between the classical cutting insert and the tilted insert are presented, according to Figure 15.

Table 1. Data concerning the dimensions of the profile and the influence of the tilting angle on the profile of the cutting insert.

Profile [1]	Width of Profile (mm)	Depth of Profile (mm)	The Tilting Angle (°)	α_c [2] (°)	α_f [3] (°)	Profile Deviation (mm)	Difference in Volume (mm^3)
(a)	15	5	10	12	2.22	0.014	2.17
(a) [4]	15	5	20	22	2.42	0.057	9.76
(b)	10.24	6	15	20	5.35	0.15	9.08
(c)	10	5	10	15	5.25	0.012	6.23

[1] According to the data in Figure 15. [2] The constructive clearance angle. [3] The functional angle. This is a range: minimum..maximum [4] This value is exaggerated. It is used only to emphasize the effect of the tilting line on the cutting-edge profile, and cannot be applied in practice.



(**a**) (**b**) (**c**)

Figure 15. Data describing the profile; (**a**) the sample analyzed in chapter 2; (**b**) case study #1; (**c**) case study #2.

As one can see in Table 2, the increase in the length of the cutting edge affecting the length of the profile, because of the tilting the profile, is at most 6.13% (note that this value was recorded for an exaggerated tilting angle of the profile, for normal tilting angle was smaller—see case b and c). This led to the conclusion that the modification of the cutting-edge profile did not significantly affect the cutting force. Since the other cutting conditions were not affected by the increase in length of the cutting edge profile, one may conclude that the temperature in the cutting zone was not affected.

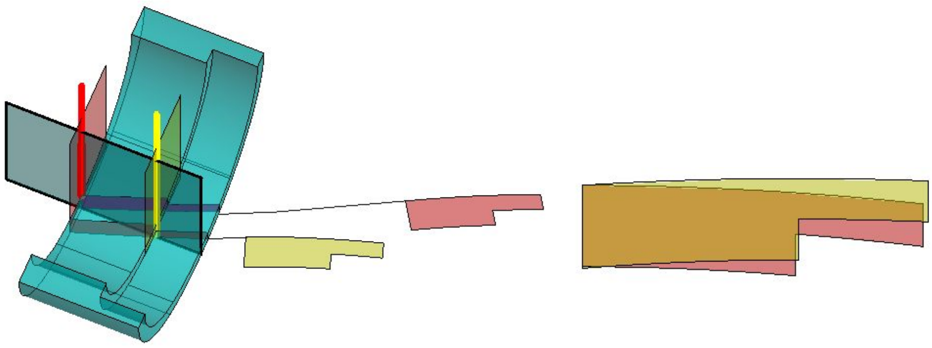
When making a decision about the value of the tilting angle, one must consider that the larger this angle, the danger of a collision between the tool holder and the workpiece increases. Moreover, a collision between the two is more likely to occur with the decrease of the diameter of the inner surface that the profile is placed on.

Table 2. Data concerning the length of the tilted and non-tilted profile.

Profile	Length of Not Tilted Profile (mm)	Length of Tilted Profile (mm)	The Tilting Angle (°)	The Length Increase of the Profile (%)
(a)	15	15.73	10	4.87
(a) [1]	15	15.92	20	6.13
(b)	10.24	10.46	15	2.16
(c)	20	20.22	10	1.10

[1] This value is exaggerated. It is used only to emphasize the effect of the tilting line on the cutting-edge profile, and cannot be applied in practice.

For a good dimensional and geometrical precision of the profiled inner surface, it is crucial that the cutting tool is correctly positioned against the workpiece. That is, the rotation of the rake face of the cutting tool and that of the section through the part has to be made with respect to the same radius (level) along the axis of the part. This is because the shape of the two sections tilted by the same angle differs, depending on their position along the axis of the part, as one can see in Figure 16. The position of the section along the axis has been emphasized. The two thick lines mark the radii, the intersecting line between the axial plane and that containing the section. On the right side of Figure 16, the difference between the two sections can be observed.



(**a**) (**b**)

Figure 16. The two sections made at different positions along the part axis differ in their shape; (**a**) general view; (**b**) the two sections are overlapped to better emphasize the difference between them. The sections are scaled and aligned to their left side, to make a relevant overlap possible.

All the presented cases assumed that the rake angle of the cutting tool was 0°.

As subjects to be studied in future research, the problems of determining the profile for machining outer surfaces by turning with a radial feed rate and using a cutting tool with a tilted edge, as well as that of the profile of the cutter to machine helicoidal surfaces, can be mentioned. The first is very similar to that considered in the present paper, with the difference that, in this case, the undercuts/collisions of the cutting tool with the workpiece are no longer important. The second direction of research refers to the milling process, and there the undercutting problem is crucial.

Compared with the analytical method used to determine the profile of the rake angle of tangential turning cutting tools, the present method has the main advantage of the precision offered by a CAD system. Using the analytical method, the contour of the profile of the part is divided into short sections. It applies a coordinate transformation to the points at the end of each section of the part, to determine the points of the cutting edge profile. This involves laborious mathematical calculations. Furthermore, between the ending points of the sections, the cutting edge profile is approximated using straight segments. The precision of a profile determined in such a way is affected by these approximations.

The method presented here is more effective. It does not involve mathematical calculations but utilizes the computing facilities of CAD systems. It excludes time-consuming calculations and offers a higher precision. The designer focuses mainly on the technological aspects of the design process (clearance angle) and not on the geometrical ones of determining the cutting edge profile.

5. Conclusions

A particular feature of profiled cutting tools is that they produce long chips. The main consequence of this is the large cutting forces occur during machining. This is why using profiled cutting tools suit processes for easy-to-machine materials. Examples in this sense are aluminum and its alloys, which are often used to produce, among other things, housings for electrical motors. The present research was developed as a response to the need to provide industry with solutions for increasing the effectiveness of machining such products.

The method to determine the profile of the cutting edge and design the cutting insert for machining profiled inner surfaces, through turning with a radial feed rate and tilted cutting edge, provides the theoretical and practical resources to solve a problem that has not been sufficiently approached in the literature. The subject of machining profiled surfaces has been approached in the literature, instead, through some of its side aspects, not the particular aspects discussed here. The method is quite simple and provides accurate results. However, using profiled cutting tools has the disadvantage that they are dedicated to certain very specific conditions, depending on several factors, including the profile to be machined, the desired tilting angle of the cutting edge, the inner diameter of the part, and others. All of these issues make profiled cutting tools quite expensive. However, the advantages they offer (attenuated vibration, shockless entering of the cutting tool into the workpiece, and sometimes the significant increase in effectiveness) balance their higher cost.

Author Contributions: Conceptualization, M.-V.D. and G.O.; methodology, M.-V.D. and G.O.; software, M.-V.D.; validation, L.P. and A.M.; formal analysis, G.O.; investigation, M.-V.D. and G.O.; resources, L.P. and A.M.; writing—original draft preparation, M.-V.D. and G.O.; writing—review and editing, G.O. and M.-V.D.; supervision, G.O.; project administration, L.P.; funding acquisition, A.M. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by Ministerul Cercetării, Inovării și Digitalizării prin Programul Operational Competitivitate, Romania (Ministry of Research, Innovation, and Digitalization through the Operational Program Competitivity, Romania) project "Cresterea competitivitatii Electroprecizia Electrical Motors prin dezvoltarea in parteneriat cu Universitatea Transilvania a unei noi familii de motoare electrice, cu eficienta energetica de clasa superpremium (IE4) (Increasing the competitiveness of Electroprecizia Electrical Motors by developing in partnership with Transilvania University a new electrical motors family with super-premium energetical class (IE4))/121228/POC/163/1/3" (translation from Romanian). The APC was funded by Transilvania University of Brasov.

Conflicts of Interest: The authors declare no conflict of interest.

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