

Design and Manufacture of Hob Mills for the Formation of Straight Slots Using the Principles of Screw Backing

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Abstract

The article shows the possibility of designing and manufacturing using multi-coordinate grinding and sharpening machines with CNC for workable worm mills for machining straight-slotted slots. Screw backing provides the necessary values of the rear side corners, and the ability of CNC machines to achieve the required accuracy and manufacturability of the tool. The lack of such tools consists in the increase of the diametrical sizes in comparison with the classically used ones. A positive effect when using the principles of screw backlash is the shaping of the cutting edges of the teeth in a checkerboard pattern, which significantly reduces the cutting forces. The use of technological 3D models as a result of the design allows, at the design stage, to evaluate the arising design flaws and to make the necessary corrective actions into the initial data of the tool.

Keywords- Hob cutter, Tool-grinding machines with CNC, Screw backing, Technological 3D model.

1. Introduction

Hob cutters are multi-blade cutting tools of rack-and-pinion type, working by the method of rolling, and used for high-performance process of cutting the teeth of gears, splined joints, etc. They are made on the basis of a hob, in which, for the formation of cutting edges, chip grooves are cut, forming the front surface in the form of a rack. The back surfaces of the teeth are formed by the backing, which is necessary for the tool to flow along the front surface and to provide the necessary gaps between the back surfaces and the treated surface.

The widespread use of worm milling cutters in modern engineering is due to the advent of CNC milling machines and specialized devices for CNC lathes for machining surfaces of gear wheels, splined shafts and periodic profiles for various purposes.

The use of worm milling cutters, especially carbide, dramatically improves the performance of gear milling operations and the tool durability period.

The technological disadvantage of the worm milling design is the teeth grinding operation - it is dynamically unbalanced because it uses reciprocating working cycles, grinding wheels of small diametrical dimensions, which affects their durability and, as a consequence, a possible reduction in accuracy from-d.

Screw backing does not have these drawbacks, but it requires the use of design solutions that

allow the side surfaces of the teeth to be processed according to the regular grinding scheme of the screw surfaces of the right and left directions.

Such processing can be performed on universal thread grinding machines, and in the case of using similar CNC equipment, the efficiency of the process increases several times.

2. Study of Literature

Hob "straight-sided" cutters (by GOST 8027) are applied for processing splined shafts with straight-sided profile. These tools can provide the necessary productivity and accuracy by using the roll motion, but according to the work (Inozemtsev, 1984) they have unacceptably small values of the working rear angles α_s on the side cutting edges.

Values α_s are calculated according to the equation (1)

$$\operatorname{tg} \alpha_s = \operatorname{tg} \alpha_b \cdot \frac{r_{\max}}{r_i} \cdot \operatorname{Sin} \sigma \quad (1)$$

where α_b – the angle at the top of the teeth, provided by the backing; σ - profile angle at the considered point of the side cutting edge; r_{\max} , r_i – radiuses of the initial and maximum circumference (respectively) at the considered point on the tooth profile.

For example, if $\alpha_b = 12^\circ$, $r_{\max} = 65\text{mm}$, $r_i = 60\text{ mm}$, $\sigma = 2^\circ$, that $\alpha_s = 0.4^\circ$. Such a tool is inoperable, and therefore structural and technological changes are needed to ensure its performance (Kolesnikova et al., 2018; Pshenay-Severin et al., 2018).

3. Problem Statement

In Protas'ev et al. (2003) proposed a method for relieving work of side surfaces of the teeth using a multistart helical surface with a constant pitch of the right and left directions, and the corresponding design of hob (Indeitsev et al., 2018). However, this work does not give an example of calculating the "straight-sided" hob cutter, in which the lateral rear angles α_s have the same values on both sides of the tooth (Repin and Valdman, 2018).

In order to eliminate the above drawback (lack of lateral rear corners), which reduces the efficiency of the use of hob cutters, consider the design scheme (Figure 1) to determine the main design parameters of the hob with the use of a spiral relief and are used in their manufacture on tool grinding machines with CNC.

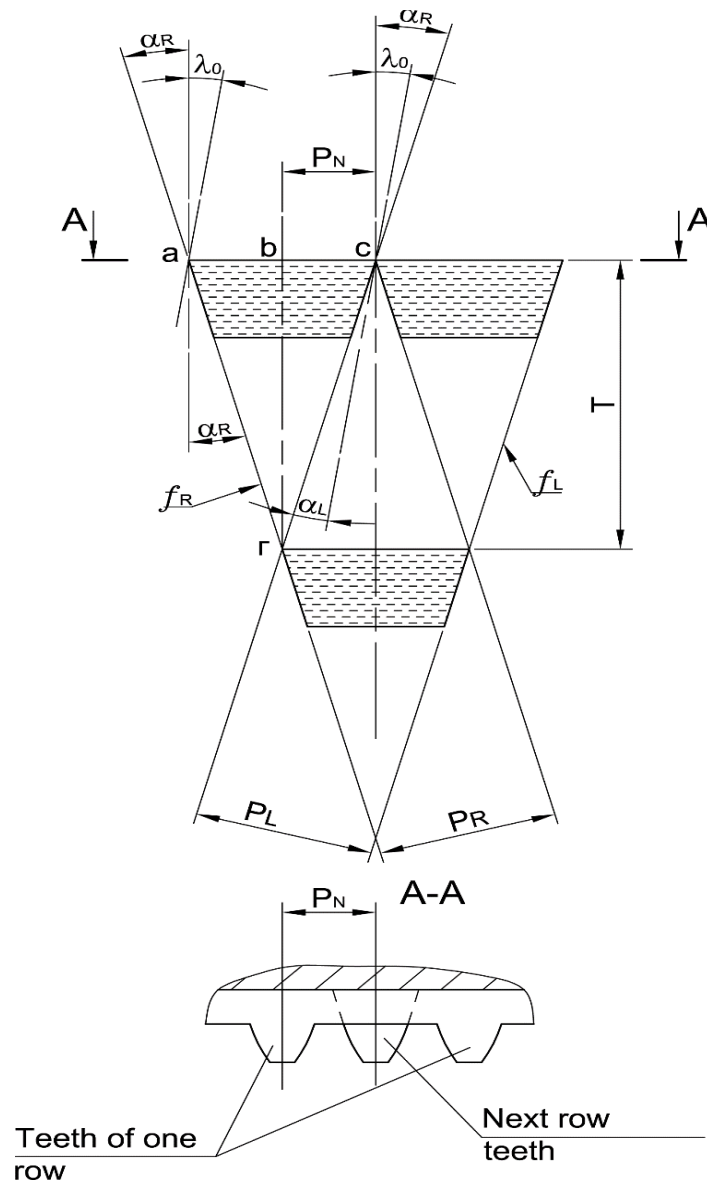


Figure 1. Determination of design parameters of hobs manufactured screw backing

4. Design "straight-sided" Hob Cutters Using the Relieving Work

Figure 1 shows the sweep of the hob cutter on the main circle, where the angle of inclination of the main hob λ_0 is visible in full size. The peculiarity of these mills is the possibility of grinding the rear side surfaces of the teeth according to the scheme of treatment of the right and left of multistart helical surface with guide curves f_R when grinding the rear surfaces of the right and f_L – when grinding left.

At the same time removed all restrictions from the diametrical dimensions of the second order tools – grinding wheels, since it is not used, the reciprocating motion of relieving work (Rudskoy et al., 2016, 2018).

The objective of the calculation is that it is necessary to calculate the values of, P_R and P_L of the right and left helical surfaces, the number of their entries i_R and i_L in which the rear corners α_6 on the sides of the teeth are equal to each other and their values for efficient chip removal (Getsov et al., 2017; Klochkov, 2018; Klochkov et al., 2018).

Figure 2 shows the complete (corresponding to one revolution) reamer cutters with screw backing. A priori it is accepted that the cutter has 11 teeth, staggered, the angle of rise of the main hob λ_0 , the steps of the right and left directions P_R and P_L and guide lines f_R and f_L ($Z_T=11$, $i_R=6$, $i_L=5$) (Zobacheva et.al., 2017; Borovkov et.al., 2018).

The fragment on the right side shows the construction, allowing to determine the relationship between the normal step P_N and the axial step P_0 . It follows from the Figure 2 that the main step of the hob cutter is equal to P_N . This value is known from the initial information about the profile of the work piece.

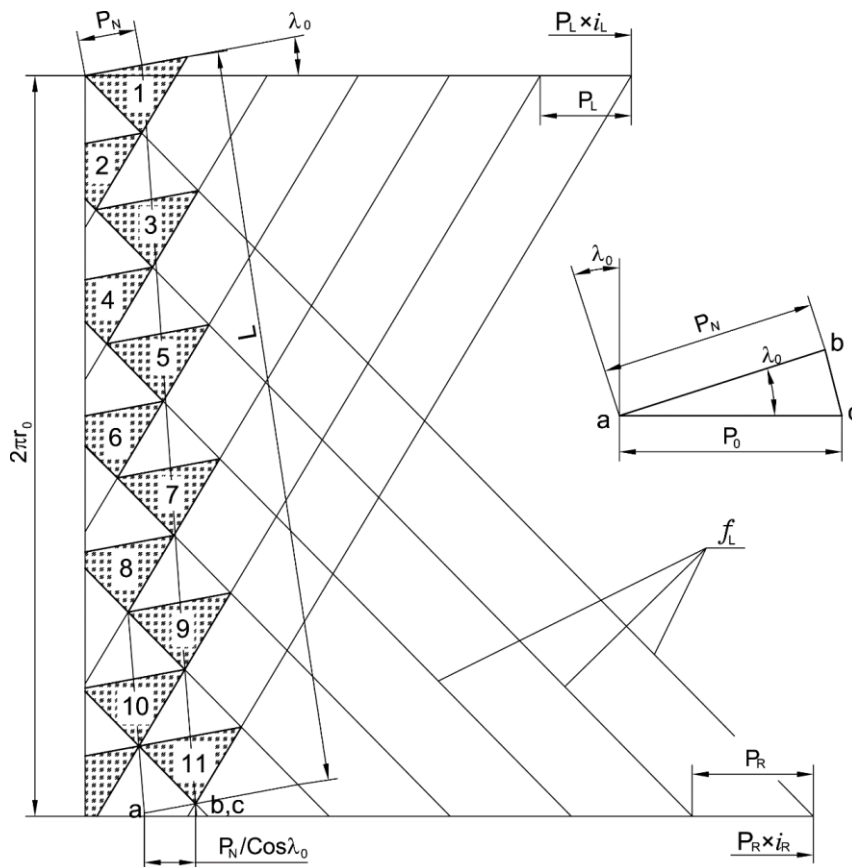


Figure 2. Determination of the number of teeth of the cutter and of the relationship of normal P_N and P_0 is the axial steps

Here is an example of the calculation of the hob cutter, accompanied by its numerical data:

Take a valid value of the lateral posterior angles $\alpha_s = 12^\circ$ main step $P_N = 10$ mm.

$$T = \frac{P_N}{\operatorname{tg} \alpha_s} = \frac{10}{\operatorname{tg} 12} = 47.0463 \text{ mm} \quad (2)$$

We define, using Figure 2, the radius of the main circle r_0 , assuming that the cutter has 11 teeth.

To do this, first determine the length of the segment required to accommodate eleven teeth

$$L = T \cdot 11 = 47.0463 \cdot 11 = 517.5093 \text{ mm} \quad (3)$$

When the received data

$$r_0 = \frac{L}{2 \cdot \pi} = \frac{517.5093}{6.2832} = 82.3641 \text{ mm} \quad (4)$$

Calculate the angle of rise of the main hob. According to the construction of the fragment in Figure 2, we obtain

$$\operatorname{Sin} \lambda_0 = \frac{P_N}{2 \cdot \pi \cdot r_0} = \frac{10}{6.2832 \cdot 82.3641} = 0.01932 \quad (5)$$

Respectively $\lambda_0 = 1.1072^\circ$.

Determine the values of the right and left steps forming the side rear surfaces and the number of their inputs. According to the construction of Figure 1 (see point a, b) we have

$$\alpha_R = \lambda_0 + \alpha_s \quad (6)$$

$$\alpha_L = \alpha_s - \lambda_0 \quad (7)$$

In our case

$$\alpha_R = \lambda_0 + \alpha_s = 1.1072 + 12 = 13.1072^\circ,$$

$$\alpha_L = \alpha_s - \lambda_0 = 12 - 1.1072 = 10.8928^\circ.$$

From other side

$$\operatorname{tg} \alpha_R = \frac{P_R \cdot i_R}{2 \cdot \pi \cdot r_0}, \quad (8)$$

where P_R – step of right screw surfaces; i_R – the number of inputs of the right screw surfaces.

Since the right single-pass ($Z_0=1$) hob cutter is designed

$$i_R + i_L = Z_T \quad (9)$$

and

$$Z_0 = i_R - i_L \quad (10)$$

At the values accepted earlier $Z_T=11$, $i_R=6$ and $i_L=5$, deciding (8) on P_R get:

$$P_R = \frac{\operatorname{tg} \alpha_R \cdot 2 \cdot \pi \cdot r_0}{i_R} = \frac{\operatorname{tg} 13.1072 \cdot 6.2832 \cdot 82.3641}{6} = 20.0828 \text{ mm} \quad (11)$$

Similarly, we calculate the value of the left step

$$P_L = \frac{\operatorname{tg} \alpha_L \cdot 2 \cdot \pi \cdot r_0}{i_L} = \frac{\operatorname{tg} 10.8928 \cdot 6.2832 \cdot 82.3641}{5} = 19.9178 \text{ mm} \quad (12)$$

The construction of Figure 1 allows us to obtain an equation for determining the angle λ_0 , differently from the dependence (5).

$$\lambda_0 = \frac{\alpha_R - \alpha_L}{2} = \frac{13.1072 - 10.8928}{2} = 1.1072^\circ \quad (13)$$

The resulting value is the same as the value defined by the equation (5). Comparison of the results can be used to verify the correctness of the calculations. Such a small angle of rise of the main hob allows you to ignore it and make a straight-toothed tool, thus ensuring maximum simplicity of its regrinding on the front surface (Kudinova et al., 2016).

The problems of calculating the shape-forming profiles of the teeth of hob mills, necessary to ensure the profile of the slots with sufficient completeness are considered in (Lashnev and Yulikov, 1975), therefore, this article is not considered.

5. Analysis of the Results

After analyzing the above calculation algorithm, it is worth noting that the disadvantage of hob cutters made with the use of relieving work is an increase (approximately 1.8...2 times in comparison with (by GOST 8027-86)) of their diametrical dimensions while maintaining the same number of teeth Z_T .

At the same diametrical values, the back angles α_s increase to 25...30°, which is unacceptable in the processing of metals, but can be effectively used in the processing of non-metallic materials.

A positive feature of the mills is the location of the teeth in staggered order. Figure 1 and section A-A confirm this possibility (Guchinsky and Petinov, 2016).

When processing small profiles, this can significantly increase the size of the teeth and, as a consequence, their strength and manufacturability of the tool, but in the case of processing large profiles, the considered feature becomes a significant drawback (Ziniakov et al., 2016). Therefore, the area of use of such phrases translated into involute engagement-wheels with modules from 0.5 to 1.5 mm.

For forming the cutting tool with the implementation of the above algorithm it is expedient to use modern tool grinding machines, such as VZ-452F4 ideal for tools with screw backing. In (Istotskiy and Protas'ev, 2006; Protas'ev and Istotskiy, 2011; Istotskiy and Protasev, 2017) provides the features of the design, construction and operation of tools, including screw backing,

and the above information indicates the expansion of sustainable exploitation tools with screw backing. Modern tool production at the stage of its preparation is unthinkable without the formation of a technological 3D model (Ni, 2006; Istotskiy and Protas'ev, 2007; Pham and Ko, 2010), obtained using a virtual analogue of the grinding and grinding machine, where it is formed using the principles of Boolean algebra (Abushawashi et al., 2017). The result of this simulation using the calculations performed above is shown in Figure 3.

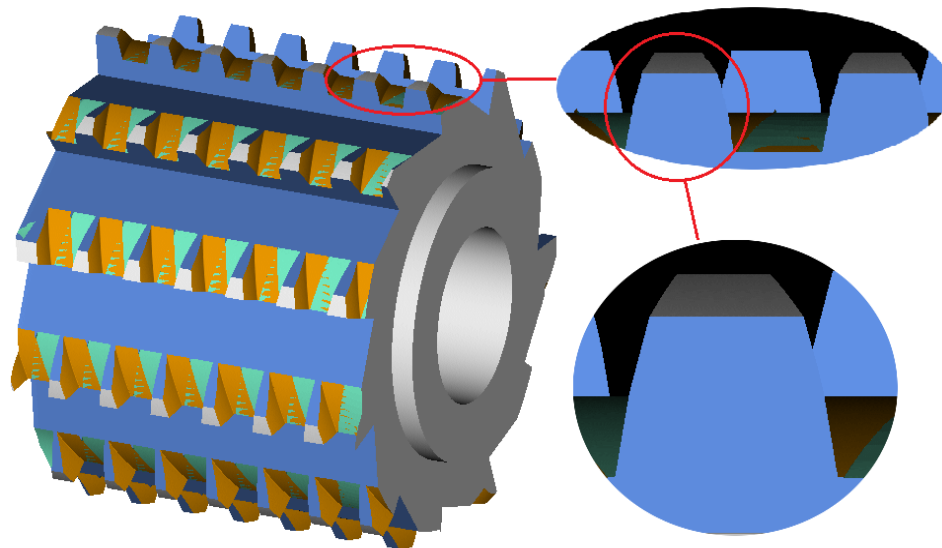


Figure 3. Technological 3D model of hob, designed with the principles of the relieving work (relieving work on cylinder not shown).

The principle of the screw backing of at least 10 years is successfully used by specialists of the company “RIT-Engineering” in the manufacture of axial threading tools, forming chip-brake grooving tools for machining of difficult to machine materials, hobs (Shymchenko et al., 2016; Solopchenko, 2016). In all cases, there is an increase in tool life, improves the dynamics of the process of removing the allowance and reduces the roughness of the treated surface.

6. Conclusion

Application of the method of design "straight-sided" hobs with the principles of the relieving work provides the necessary values of the rear side of the angles in the range $m=0.5\dots1.5$ (with translation of involute gearing), and the possibility of tool grinding CNC machines ensure their production in a single clamping of the workpiece, which ensures improved quality and reduced labor costs on the production of such high-tech products hob.

The screw relieving work can effectively be used not only by production of worm mills, but also at production thread-milling attachment, "corn" mills, special vertical drills, including for formation of shaped openings.

Screw backing can be effectively used not only in the manufacture of worm mills, but also in the manufacture of thread mills, "corn" mills, special countersinks, including for the formation of shaped holes.

In the manufacture of fine-cut mills for the production of clockwork mechanisms, in which cycloidal gearing is used, the teeth of which have small values of profile angles and are close in shape to rectangular slots, applying the principles of screw backlash when designing tools is the best solution.

Using the designed tool as a tool for controlling technological 3D models makes it possible, at the preproduction stage, to optimize its parameters for real process equipment, while minimizing costs and design flaws.

Conflict of Interest

The authors confirm that there is no conflict of interest to declare for this publication.

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