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The Design of Gear Hobs Construction

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ABSTRACT: In the gear production area there are developed the new constructional solutions which shorten production time, improve quality of produced gears and increase productivity. Every solution is based on traditional constructional solutions which offer good and long time verified base. The contribution describe of distribution of present types of gear hobs which are offered for the current gear producers by the world developers which develop these tools long time. Their product fulfil the conditions of traditional the gear producers. In the specified cases the gear producers need to work with special tools which are based on traditional construction base and provide a starting point for their realization. Because of there is described procedure of a calculation for gear hob construction which can be used for their special conditions or develop of new type of gear hob. On the based the general calculation every producer can to improve the gear production.

KEYWORDS: Gear hobs, hobs construction, geometry, hob design, gear production.

1 INTRODUCTION

Recently, the trends in the field of gearing making by using selfgenerating method are focused on increasing of quality demands, costs lowering and selection of an appropriate way of gear wheels making. Regarding to the fact that the area of gear wheels making is wide, it enables to fulfil these requirements in a positive way. New approaches in this field are appearing in a very short time periods. The basic trends in gear wheels making can be divided into three basic courses: The first course is concentrated on in hobs material changes. Another course deals especially with tool construction developing itself, i. e. the hob. The last group is an area of gear wheel making general machine and machine systems constructions.

In this paper, we deal with design of construction gear hobs in generally. There are introduced current types of gear hob construction which are presented on the present manufacturing processes by world-wide companies, which are the main providers. The paper is divided to two main parts. In the first part of the paper we introduce present types of gear hobs construction. In the next part is described procedure of design elements of gear hob.

2 FRONT INVOLUTE GEARING CONSTRUCTION DESIGN SOLUTIONS

A small revolution arose in years 2002 to 2005 within development of high-performance tools for gear wheels roughing at mass production. Also speed-cutting hobs showed very high productivity. However, toolmakers have developed self-generating all-carbide coated hobs. Their operating life in short time since introducing on the market has been doubled. Those tools enable also hard cutting of backed-off hardened wheels, so called peeling.

2.1 SOLID HOBS

The solid hobs basic shape is of involute helix which is divided by grooves for chip removal from working area. The helix can be simple or multi-path. The chip grooves create the cutting edge of the tool. Tooth faces are formed by surface of the helix. They are usually backed-off so that the back-off angle was formed.

The hobs are divided into tools for roughing and tools for finishing. The hobs for roughing are simple (Fig. 1a) or multi-path (Fig. 1 b, c) and they are less accurate. The finishing hobs are simple and tooth faces are always backed-off. The profile of a hob tooth is derived from required tooth profile of cut gear wheel.

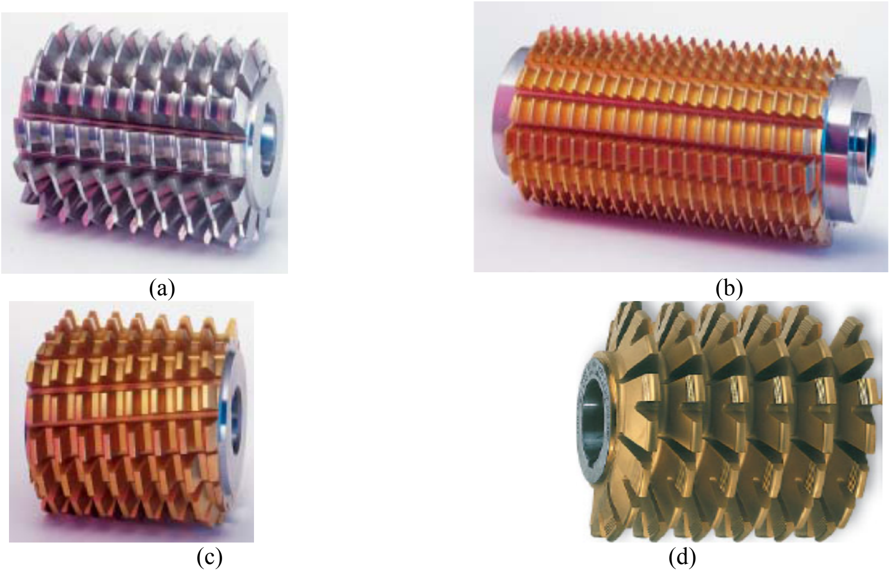


Fig. 1. Selected types of in-feed bobs with solid cutters.

The hobs are usually manufactured as push hobs secured against clockwise turning by a standard tight key. They can be both clockwise and anticlockwise and backed-off. The grooves for chips removal are cut by the angle cutter 18° to 30°. The grooves can be mostly perpendicular to the helix (Fig 1. a, b) cut at an angles 18° to 45° (Fig 1. c) or special combined grooves with high material removal and quieter working during hobbing (Fig 1. d). The cutting length of the hob is equal to the distance of the outer generating gears enlarged by one tooth spacing for the tool reset after its partial blunting.

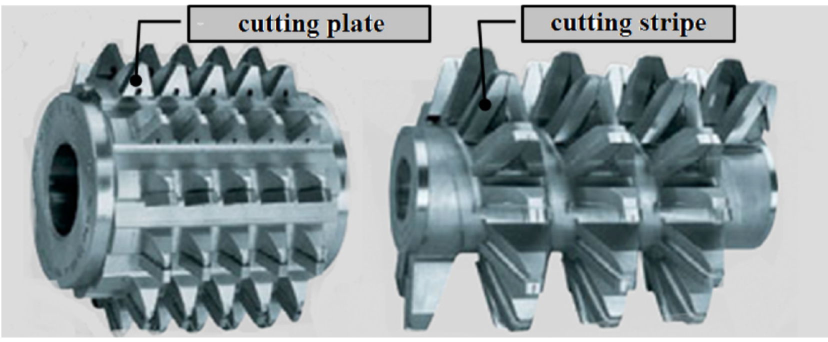
2.2 GEAR HOBS WITH CUTTING ELEMENTS

Unlike the solid knives of the gear hobs, gear hobs with inserted plates are commonly used for generating larger gears with module bigger than 4 mm. The gear hobs with cutting elements are most made in two basic models (see Fig. 2):

- with cutting plates fixed on the hob tooth frontal area,

- with cutting stripes fixed on the sides of the hob tooth frontal area profile.

Those gear hobs are suitable for roughing. The sharpening of tooth side area is not necessary, which is their advantage.



(a) gear hob with cutting plates (b) gear hob with cutting stripes

Fig. 2. The gear hobs with cutting elements

2.3 STACKED HOBS WITH CUTTING ELEMENTS

The hobs with inserted plates made of cemented carbides, which are manufactured for roughing and finishing, consist of high-quality five or six segments. These segments are inserted into each of the hob body slots with very high precision. The segments are placed one next to another with precise cross openings which provide a large area for mounting and they do not weaken the hob body.

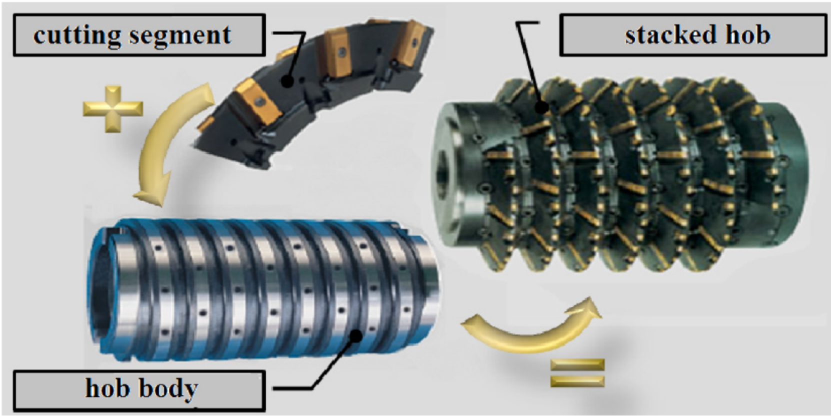


Fig. 3. Construction of stacked hob

Those gear hobs provide a simply structural solution to perform simple and precise assembly and disassembly. The segments are joined with bolts going through the segment to the hob body. To lengthen the hob it is necessary to add just another segment. The individual inserts can be replaced without demounting the hob. Just a screwdriver is needed.

2.4 TOOL SYSTEMS FOR GEARING

The manufacturing of gearing does not consist of only one operation. One of others steps is also gear bevelling. Each operation requires using another tool which means time consuming for manufacturing and economical loss. The Fette company developed a unique tool system which performs hobbing-roughing and bevelling by one tool system called CHAMFER CUT (Fig. 4). The tool system saves time needed for a tool replacement. All the system consisting of the gear hobs and tools for burring is placed on one shaft.

Advantages of the tool system:

- Manufacturing of gearing and burring on one machine,
- The tools are fixed on one shaft,
- The manufacturing of gearing is controlled by software support,
- Burring possible also on helical gearing.

Fig. 4. Fette CHAMFER CUT tool system

The tool system CHAMFER CUT is manufactured in two models, i. e. with one or two tools for burring. The advantage of the double tool is the fact that the first part removes sharp edges on the surface and forms uniform burring on the upper frontal area. The other part burs the edges on the lower side of the gear frontal area. The result is gearing which does not need any additional machining.

3 GEAR HOB DESIGN AND CALCULATION

The typical part of the calculation and structure is original tool surface.

3.1 IN-FEED STRUCTURAL ELEMENT DESIGN PROCEDURE

The transformation of the gear hob original surface into a cutting tool is done as follows: on that surface cutting parts with cutting features are formed. The original surface is milled, i. e. grooves for chips removal are formed and in the same time the frontal part of the tool is made. The back areas are formed by cutting edge along a curve. In the next step it is necessary to make mounting, control, setting and other areas.

1. Making tooth front and cutting edge. The gear hob front can be a surface both planar and helical. The planar area can be in several positions. For zero front angle which intersects the axis of the tool, for the positive and negative front angle which is skew to the axis. Similarly, it can be realized at gear hobs with helical surface. The helix of the groove is perpendicular to the helix of the hob gears. Technologically, the easiest way is to manufacture the front in the plannar area shape. When the frontal part is parallel to the hob axis, the front angle of one of the side part is positive and on the other side negative, so it is good to choose the planar front for small angles of the helix pitch. The intersection of the front and the original surface is a profile of the gear hob cutting edge. Thus, the profile of the cutting edge depends on the groove shape.

2. Tooth back area manufacturing. Commonly, the back areas of a tool are manufactured by means of a certain movement. The cutting edge profiles the back surface in space, its shape has to meet the following requirements:

a) back angles have to be created in all points of the cutting edge,

b) all cutting edges of the hob have to be situated on the original surface or on the surface of the basic helix,

c) technological requirements have to be met.

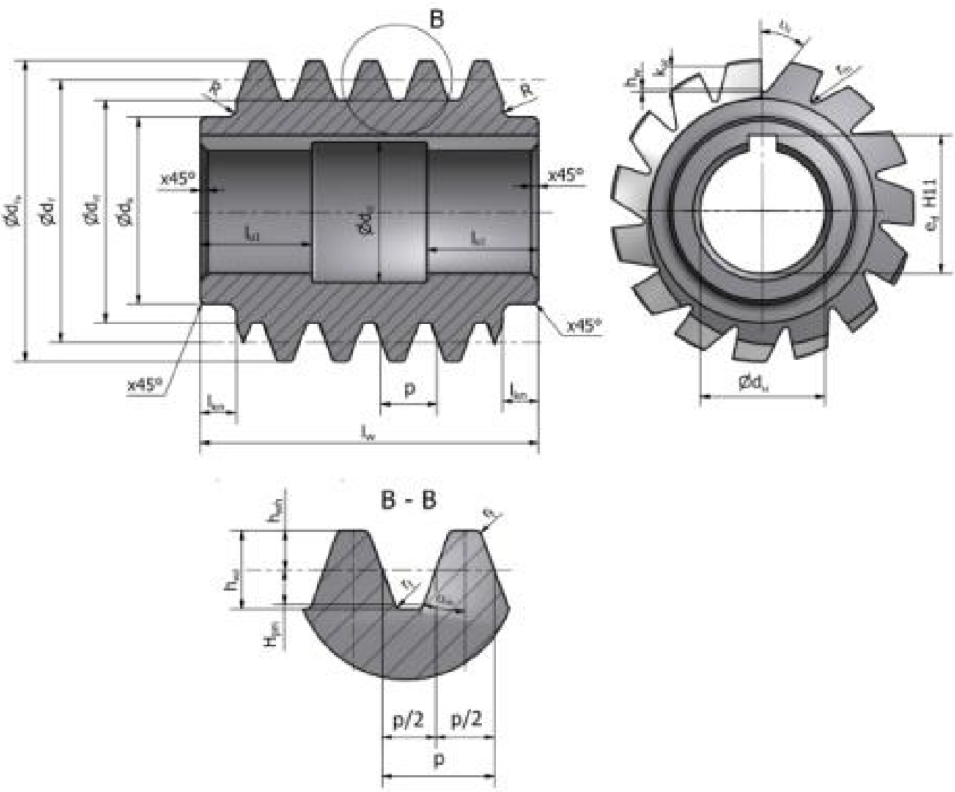


Fig. 5. Description of the gear hob structural elements

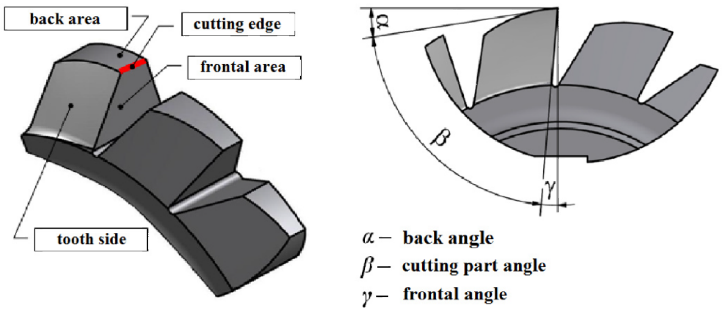


Fig. 6. Description of the hob gearing

The attitude to the hob back shape designing depends on the fact whether it is possible to set the cutting edge position after tooth sharpening or not. For the former possibility the surface of the tooth has to be such so that the shape of the groove stays without any changes after sharpening. To fulfill that requirement, the surface of the tooth back should allow mutual movement. In most cases, however, the hob design does not allow tooth adjustment and that is why the outer pitch cylinder is reduced after every sharpening.

3. Cutting part geometry. The cutting edge of the gear hob consists of three parts. Each of them fills different position, i. e. is different.

4. Hob diameter. It is appropriate to select as biggest diameter as possible because it leads to increasing accuracy of the gearing and durability of the cutting part. The bigger diameter of the hob allows to enlarge the chuck opening and thus the firmness of the mounting is increased and vibration reduced. By enlarging the mounting hole diameter the number of cutting racks can be increased, the tooth shift is reduced and the cutting part durability is increased.

5. Longitudinal groove dedendum diameter d_{ff} – it is chosen depending on the machining device and an arbor diameter.

$$d_{ff} = (1{,}4up\,2{,}0)d_{fa} \qquad (1)$$

6. Longitudinal tooth rack fillet radius - it is chosen in range

$$r_m = (1{,}5up3{,}5)mm \qquad (2)$$

or can be calculated as follows:

$$r_m = \frac{\pi(d_a - 2h_w)}{10z_w} \qquad (3)$$

7. Mounting hole diameter. The hole serves for mounting the hob on the arbor. Approximate value for sizing:

$$d_u = (0{,}20up0{,}45)d_a \qquad (4)$$

8. Strength of the body. The minimal thickness between the hole and the bottom of the groove can be $0{,}3d_u$. When it is less, a hob with a stem should be designed.

9. Key groove – it is usually placed either in the hole opposite the tooth gap or in the front of the hob. It is sized according the standards.

10. Number of tooth racks – it influences roughness of the surface along the teeth and also thickenss of chips. The number of the racks can be calculated as follows:

$$z_w = \frac{360^\circ}{\varphi_z} \qquad (5)$$

$$\cos\varphi_z = (1{,}0up4{,}5)\frac{d_{ff}}{d_{fa}} \qquad (6)$$

11. Tooth groove shape and dimensions – the grooves serves for runout of machining tools during the manufacturing and during milling for chips removal. Those purposes are taken in the account during designing.

Tooth groove depth:

$$h_w = \frac{d_{fa} - d_{ff}}{2} \qquad (7)$$

Groove span angle υ_d depends on accuracy of a manufactured hob. For sharpened tools and number of the racks:

$$z_w \geq 12 \quad \text{is} \quad \upsilon_d = 18^\circ,$$
$$z_w = 9up10 \quad \text{is} \quad \upsilon_d = 22^\circ, \qquad (8)$$
$$z_w \leq 8 \quad \text{is} \quad \upsilon_d = 25up30^\circ.$$

12. Foot rack tooth width:

$$S_p = \frac{r_j \varphi_z}{z_w} \qquad (9)$$

13. Strength of the foot. The checking footh rack tooth width substitutes a stregth control and is recommended to be in the range (0,5 - 1)h_w

14. Control shoulder dimensions

Length:

$$l_{kn} = 2{,}5up5mm \qquad (10)$$

Diameter:

$$d_k = (1{,}5up1{,}7)d_u \qquad (11)$$

Chamfering:

$$(0{,}5up\,2)x45^\circ \qquad (12)$$

15. Cutting part length – it should correspond with the length of the hob total working range l_c. However, it is necessary to add several threads for stepping, i. e. hob moving in the axis direction to lengthen its lifetime.

$$l_{zn} = (4up5)\pi m + (10up15)mm \qquad (13)$$

16. Hob total length – it is formed by the length of the thread part and control shoulders for flapping control. It is valid that:

$$l_w = l_{zn} + 2l_{kn} \qquad (14)$$

The length twice longer than the thread part is recommended. By means of lengthened hob a triple machining performance can be reached with slightly grown expenses.

17. Hob pitch diameter – is a basic calculating hob diameter. Other parameters are related to it: pitch thread and groove. The pitch diameter can be calculated as follows:

$$d_f = d_{fa} - 2h_{wh} - \frac{k_{az}}{2} \qquad (15)$$

where h_{wh} is a hob tooth head height.

The helix lead angle is changed with change of span circle λ_{zn}:

$$sin\gamma = \frac{m}{d'_f} \qquad (16)$$

Pitch diameter of a new hob:

$$d'_f = d_{fa} - 2h_{wh} \qquad (17)$$

18. Normal pitch:

$$p_n = \pi . m \qquad (18)$$

19. Axis pitch:

$$p = \frac{p_n}{cos \gamma} \qquad (19)$$

20. Pitch roll climbing angle:

$$tg\gamma = \frac{m}{d_f} \qquad (20)$$

For gear manufacturing it is necessary to set the gear hob so as the hob axis would be positioned in the given distance from the frontal plane of the machined part and in the same time in the shortest distance from the hob axis and from machined part. The gear hob should have a definite value of the onset angle. It consists of hob slope length l_n and from safe distance at hob sloping l_{nb} (1-7). Similarly, for manufacturing the gearing, the so called run consisting of hob course length l_p and from safe distance of hob run l_{pb} should be taken into account. Ten minimal length of milling is:

$$L_a = l_{nb} + l_n + b_{fo} + l_p + l_{pb} \qquad (21)$$

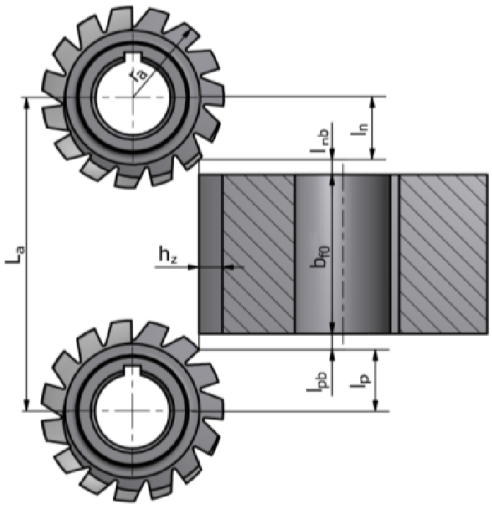


Fig. 7. Slope and run-out of the gear hob

4 CONCLUSIONS

From the analysis of present types of gear hobs, which are produced by world producers, we can to observe that every offered type is suitable for different type of produced gear. The suitable choice of used tool for gear production is depended on type of produced gear, module size, number of teeth etc. The tools can be produced like solid hobs or stacked hobs which are suitable for mass production.

For the specially develop of new constructional solution of gear hobs we can use the designed calculation of basic gear hob features. The design is based on the transformation of the gear hob original surface into a cutting tool which is done on that surface cutting parts with cutting features are formed.

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