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Involute Profile Internal Cylindrical Teeth Worm Hob Rolling Generation

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ABSTRACT

The involute profile internal cylindrical teeth worm hob rolling generation materializes, in the generation plane, the rolling between the externally toothed cylindrical generating gear profile and the internally toothed cylindrical generating gear profile
Keywords*: internal worm hob, cylindrical gearing*

1. The involute profile internal cylindrical teeth generation current development stage

By teeth generation one may understand the internal teeth-forming method using a certain tool and a certain machine-tool.

The generation is determined if the tool and the relative movements between the tool and the blank are mentioned. Taking into account the contraction cavity flank symmetry, the form of a flank may be analyzed. By means of the division operation (periodical or continuous), the contraction cavity form is transposed along the entire circumference of the gear, thus giving birth to the teeth.

During teeth generation, the guiding curve is obtained through a kinematical way by a rectilinear movement (in the case of the straight teeth) or by a combination of the rectilinear movement with a circular one (in the case of the angular teeth).

Thus, for the copying method, the generator is represented by the chipping edges of the tool, while, for the rolling method, the generator is obtained by kinematical way as a convolute curve of the tool edge successive positions.

The generation by high-gear internal cylindrical teeth is based on the materialization of the generating curve, which is made by transposing the generator on the chipping tool edge. Among all the copying mechanical processing methods, the milling is the most widespread. This is due to the teeth efficient processing possibilities, made on gear-cutting tools by means of worm hob rolling, to which an internal gear head is attached.

1.1. The side cutter teeth milling by copying

In the case of a side milling cutter teeth milling by copying, the tool is represented by a high-speed steel monobloc-formed or removable teeth side milling cutter with high-speed cemented-carbide tip.

The working mode for a straight teeth internal cylindrical gear side cutter milling results from figure 1.1.

The side milling cutter is positioned in such a way that the symmetry plane of the profile should contain the axis of the gear to be processed. In the case of the angular teeth, the symmetry plane of the milling cutter profile, which is perpendicular to the milling cutter rotation axis, should be tan to the piece teeth contraction cavity division rotator (the contraction cavity rotator being convoluted on the division cylinder). The milling cutter executes the chip removal (rotation) movement and the axial feed movement as compared to the blank piece.

The blank is carried along only in the intermittent division movement in the case of the straight teeth.

In the case of the angular teeth, the blank makes a circular feed movement connected to the tool axial feed movement.

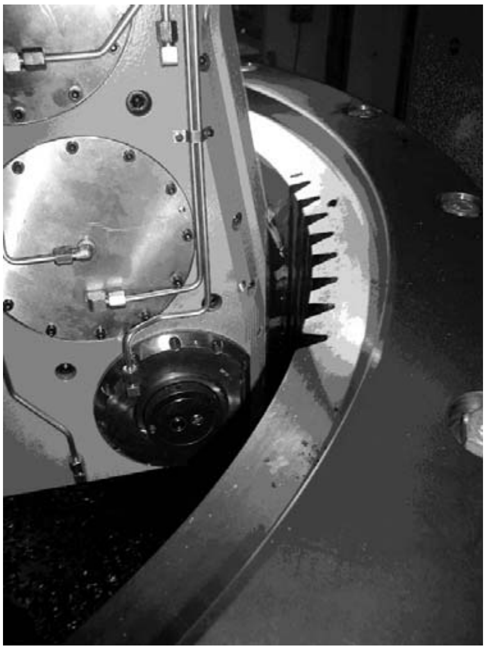

Fig. 1.1. Internal cylindrical teeth side cutter milling

These two movements are the threading movement components and they are achieved by means of the threading mechanism, which exists in any worm hob rolling teeth milling cutter.

Between the axial feed speed V and the blank rotation V_1, there is a kinematical connection, given by the relation:

$$\frac{V_1}{V} = \frac{\omega \cdot d_2}{2 \cdot V} = tg(\beta) \qquad (1)$$

In fact, this relation also determines the guiding curve (the line of the flank). If $\beta=0$, i.e. straight teeth gears are processed, then it results that $\acute{\omega}=0$.

A correctly-designed and well-executed tool, besides having a geometry proper to chip removal, to edges, must also have a chipping edge form identical to the teeth flank generator (in the case when the back-rake angle of the edges is null). This is why the main problem when it comes to teeth generation by copying is to determine and materialize the generating curve (the side milling cutter profile) and to maintain the cutter profile after re-sharpening.

1.2. The internal cylindrical teeth worm hob copying milling

The most widespread and the most productive external cylindrical teeth chip removal processing method is the worm hob rolling generation. This method materializes the generating rack bar teeth generation, but it cannot be applied to the internal cylindrical teeth, [2].

In the case of internal cylindrical teeth copying generation a profiled worm hob is used, (Fig. 4).

Fig. 2. Internal teeth profiled worm hob: m=10; z_2=95; x_2=0.
[PROMEX Brăila]

In order to generate by copying an angular teeth internal cylindrical teeth worm hob, the worm hob is positioned on the axial plane of the central tooth (which has the form of the gear teeth contraction cavity profile from the normal section) tan to the teeth contraction cavity rotator on the division cylinder. The processing can be achieved in this way: the tool has an axial feed movement, while the piece receives a supplementary rotation movement.

Most worm hob rolling teeth tools achieve a parallel worm hob axial feed, and the angular teeth gear rotation movement is obtained by means of a differential mechanism.

1.2.1. The cylindrical teeth worm hob rolling generation principle

Taking into consideration the fact that a rack bar internally teethed gear meshing is imaginary, it is obvious that this can be generated only by a generating rack bar, the only rolling generation possibility being by using a generating toothed gear, [2]. The generating toothed gear is bigger or identical with an externally toothed conjugated gear, which has a bigger head diameter in order to ensure clearance to the generated gear.

The internal cylindrical teeth generation reproduces the meshing (Fig. 1), which means that, in the generation plane, the meshing-established computing relations are valid [5].

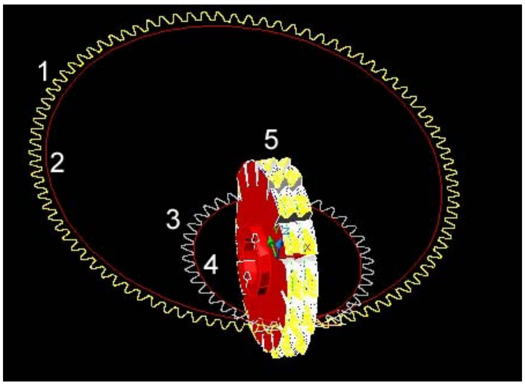

Fig. 3. Involute profile internal cylindrical teeth worm hob generation

From fig. 1 there results: 1. the internally teethed gear generated profile; 2. the internally teethed gear rolling circle; 3. the externally teethed generating gear teeth profile; 4. the externally teethed generating gear rolling circle; 5. internal cylindrical teeth generating worm hob.

The generating gear positioning as compared to the generated gear is made in such a way that, in the generation plane, the two rolling circles should be tan, thus the teeth profile of the two gears forming a generating technological gear.

The worm hob in the generation plane (the removal plane) materializes the generating gear teeth profile.

In the front plane, teeth generation reproduces the internal cylindrical meshing, which means that the front meshing established computing relations are valid, with the mention that the generating gear has a bigger tooth head in order to obtain clearance for the generated gear tooth. The meshing takes place between the profiles of the generating gear 7 and the profiles of the generated gear 6, on the meshing line 4, which is tan to the basic circles 1 and 2, (Fig. 3).

In the case of the internal technological meshing the study is made for the straight teeth cylindrical meshing, fact which allows the study in a front plane, (Fig. 4).

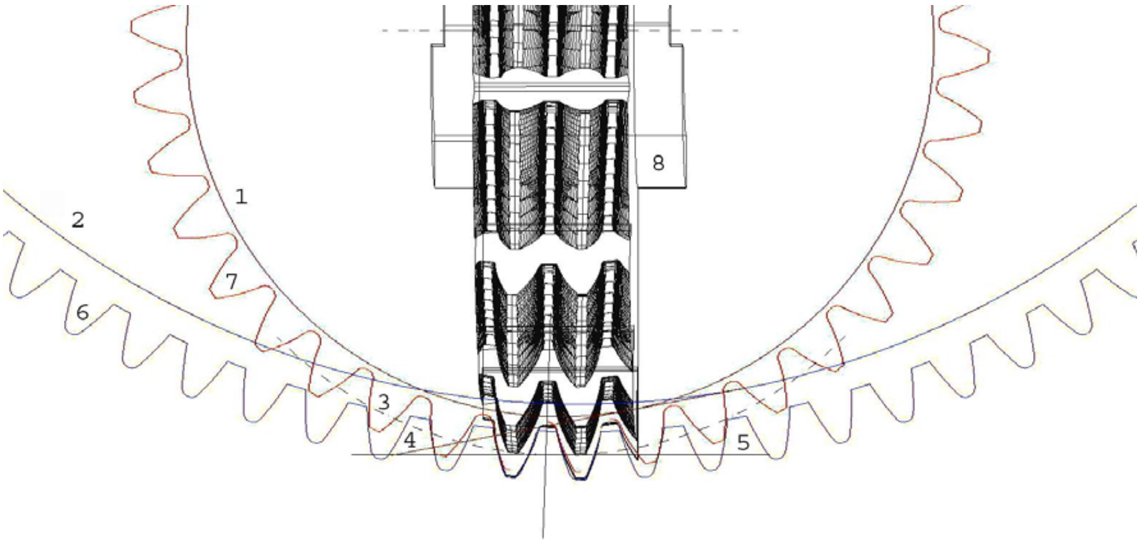

Fig. 4. The front plane of the technological meshing:
1. the basic circle of the generating gear; 2. the basic circle of the generated gear; 3. the rolling circle of the generated gear; 4. the meshing line; 5. the generating rack bar reference line; 6. the generated gear teeth profile; 7. the generating gear teeth profile; 8. the internal cylindrical teeth rolling generation worm hob.

2. The study of the internal cylindrical technological meshing

The study of the internal cylindrical technological meshing is made in the generation plane, (Fig. 5).

The generating gear geometrical elements were noted with the index 0 and those of the generated gear were noted with the index 2.

The technological meshing rolling circles meshing angle involute, inv ($\acute{\alpha}_w$) is:

$$inv(\alpha_w) = \frac{2 \cdot (x_2 - x_0) \cdot tg(\alpha)}{z_2 - z_0} + inv(\alpha) \quad (2)$$

in which:

x_0 – the generating gear profile shifting coefficient;

x_2 – the generated gear profile shifting coefficient;

z_0 – the generating gear teeth number;

z_2 – the generated gear teeth number;

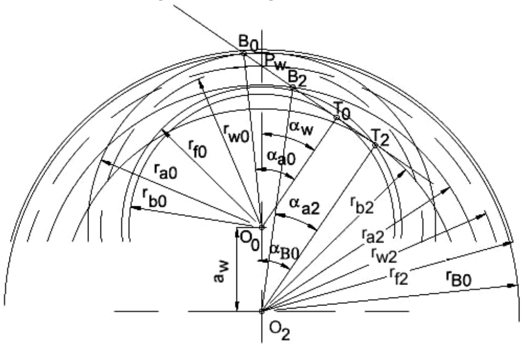

Fig. 5. Geometrical elements in the front plane for the internal cylindrical teeth rolling generating technological meshing

In the general case, the distance between the axes at generation is determined by the relation:

$$a_w = a \cdot \frac{cos(\alpha)}{cos(\alpha_w)} \tag{3}$$

in which the reference distance between the axes is determined by the relation:

$$a = \frac{m \cdot (z_2 - z_0)}{2} \tag{4}$$

The meshing angle at generation is:

$$\alpha_w = arg(inv(\alpha_w)) \tag{5}$$

And one may choose from the angle involute value tables or may determine it with the program from ***program 1*** of the present paper.

Program 1. The angle involute and the reversed involute

```
Function Involute(Angle)
Involute = Tan(Angle) - Angle
End Function
Function Angle(Involute) As Double
   Dim Delta As Single
   Dim Tg  As Double
   Angle = 1.5
   Do
      Angle = Angle - Delta
      Tg = Tan(Angle)
      Delta = (Tg - Angle - Involute) / (Tg * Tg)
   Loop While Delta > 0.0000000001

End Function
```

The technological meshing is limited by the input and output points from the meshing of the two gears. As it results from fig. 5, the generating gear active profile radius (gear 0) is the segment O_0B_2, where point B_2 results from the generated gear head circle intersection (gear 2) with the meshing line, as being the input point in generation meshing. Thus:

$$r_{B_2} = \overline{O_0B_2} = \sqrt{\overline{O_0T_0}^2 + \overline{B_2T_0}^2} = \sqrt{O_0T_0^2 + \left(\overline{B_2T_2}^2 - \overline{T_0T_2}^2\right)} \tag{6}$$

i.e.

$$r_{B2} = \sqrt{r_{b0}^2 + (r_{a2} \cdot sin(\alpha_{a2}) - a_w \cdot sin(\alpha_w))^2} \tag{7}$$

The pressure angle corresponding to the generating gear active profile radius (gear 0) is determined from the triangle $O_0T_0B_2$, i.e.:

$$tg\alpha_{B2} = \frac{z_2}{z_0} \cdot tg(\alpha_{a2}) - \left(\frac{z_2}{z_0} - 1\right) \cdot tg(\alpha_w) \tag{8}$$

The active profile radius is determined with the help of the relation:

$$r_{B_2} = \frac{r_{b0}}{cos\,\alpha_{B_2}} \tag{9}$$

For the generated teeth gear, the profile beginning radius r_{B0} determination is of great importance (Fig. 5). This is defined by the point in which the generating gear tooth tip generates the profile, i.e. point B_0, in which the generating gear head circle intersects the meshing line at generation. As per fig. 5, there results:

$$r_{B_0} = \sqrt{r_{b2}^2 + (a_w \cdot sin(\alpha_w) + \sqrt{r_{a0}^2 - r_{b0}^2})^2} = \frac{r_{b2}}{cos(\alpha_{B_0})}$$

10)

The pressure angle of the generated tooth profile, at its initial radius is also determined as per fig. 3:

$$tg(\alpha_{B_0}) = \frac{a_w \cdot sin(\alpha_w) + \sqrt{r_{a0}^2 - r_{b0}^2}}{r_{b2}} = $$

$$= \frac{a_w \cdot sin(\alpha_w) + r_{b0} \cdot tg(\alpha_{a0})}{r_{b2}} \tag{11}$$

$$tg\alpha_{B_0} = \left(1 - \frac{z_2}{z_0}\right) \cdot tg(\alpha_w) + \frac{z_2}{z_0} \cdot tg(\alpha_{a0})$$

(12)

The technological meshing angle involute $ά_{w0}$ (2/0) is:

$$inv(\alpha_{w0}) = \frac{2 \cdot (x_2 - x_0) \cdot tg(\alpha)}{z_2 - z_0} + inv(\alpha)$$

(13)

In the general case, the distance between the axes at generation is:

$$a_{w0} = a_0 \cdot \frac{cos(\alpha)}{cos(\alpha_{w0})} \qquad (14)$$

In which the reference distance is:

$$a_0 = \frac{m \cdot (z_2 - z_0)}{2} \qquad (15)$$

The meshing angle at generation being [59]:

$$\alpha_{w0} = arg(inv(\alpha_{w0})) \qquad (16)$$

3. Conclusions

The involute profile internal cylindrical teeth worm hob rolling generation materializes the internal cylindrical technological meshing, the study being made in the front generation plane. This generation method is universal, with the same worm hob one being able to generate internal cylindrical teeth with different numbers of teeth and with different values of the profile shifting.

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Generarea danturilor cilindrice evolventice interiore drepte prin rulare cu freza-melc

Rezumat

Prezentul articol prezintă un studiu asupra posibilităţii danturării danturii interioare cilindrice drepte prin rulare cu ajutorul unui nou tip de freza-melc dezvoltat de autori. Generarea profilului dinţilor cilindrici evolventici generaţi prin rulare cu freza-melc se materializează in planul de generare, respectiv rularea intre pinionul generator imaginar si roata cilindrica interioara generata. Studiul demonstrează posibilitatea de realizare a danturii cilindrice interioare cu acest nou tip de scula, respectiv posibilitatea realizării unei game de roti dinţate interior de acelaşi modul dar cu număr de dinţi diferiţi si diferite deplasări de profil.

Erzeugung des verwickelten Innerens des Zylinders durch das Rollen des verwendendes Prägens

Dieses Papier zeigt eine Übersicht über die Möglichkeit der Verzahnung der zylinderförmigen rechten Innenverzahnung, indem es mit einer neuen Art Prägevorrichtung entwickelt von den Autoren rollt. Generatation der Form der zylinderförmigen verwickelten Zähne, die erzeugt werden, indem man mit Prägevorrichtung rollt, wird in der Erzeugung Fläche, jeweiliges Rollen zwischen eingebildetem erzeugendem Zahnrad und zylinderförmigem Innenrad getan. Die Übersicht prüft posibility des Gebäudes der cilindrical Zähne mit dieser neuen Art des Instrumentes und Möglichkeit des Errichtens einer neuen Strecke des Innenzahnrades mit dem irgendeinem Modul aber mit unterschiedlicher Zahl der Zähne und unterschiedlicher Formversetzung.