Mathematical description of tooth flank surface of globoidal worm gear with straight axial tooth profile

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Abstract: In this article, a mathematical description of tooth flank surface of the globoidal worm and worm wheel generated by the hourglass worm hob with straight tooth axial profile is presented. The kinematic system of globoidal worm gear is shown. The equation of globoid helix and tooth axial profile of worm is derived to determine worm tooth surface. Based on the equation of meshing the contact lines are obtained. The mathematical description of globoidal worm wheel tooth flank is performed on the basis of contact lines and generating the tooth side by the extreme cutting edge of worm hob. The presented mathematical model of tooth flank of TA worm and worm wheel can be used e.g. to analyse the contact pattern of the gear.

Keywords: globoid worm gear, TA worm, meshing analysis

1 Introduction

The double enveloping hourglass worm drive was initially invented approximately in 1765 by H. Hindley [1, 2]. The hourglass worm is lathed by a lathe tool with straight blade. The meshing worm wheel is generated by an hourglass hob similar to the hourglass worm. This type of gear is called TA worm drive. In the beginning of XX century, Samuel I. Cone patented the applicable technology to manufacture this worm drive [3, 4]. The special shape of the worm increases the number of teeth that are simultaneous in mesh and improves the conditions of force transmission. This kind of gear drive has the increased load capacity due to the higher contact ratio in comparison with the conventional worm gear drives, higher efficiency results from the existence of more favourable lubrication conditions [2, 5]. The experience of many years allows establishing design proportion for Hindley’s gear geometry. The standard [6] presents the formulas for calculating general gearset proportions for the globoidal wormgearing assembled with axes at a 90° degree angle. There are also available another standards, which provide incomplete guidelines for the design of double enveloping worm gear [7–9].

Simplified geometrical analysis of TA worm drive was presented in [5]. The helicoidal surface of the worm was not taken into consideration in the analysis. The investigation was divided into unmodified and modified drives and relevant modification parameter as centre distance and velocity ratio. A new type of double-enveloping worm gear drive was proposed [10, 11]. The gear tooth surface of the worm gearing is smooth, and it is shaped by a flying tool whose cutting edge is identical to the profile of the entering edge of worm. The worm surface is with a circular lead changed to the established rule. A method for the determination of load distribution in double enveloping worm gearing was developed [12]. A modified new type of double enveloping worm gearing was proposed. In this case the gear tooth surface is generated by a flying tool whose cutting edge has the modified profile of the entering edge of the worm. The load distributions were calculated and the elastohydrodynamic analysis of lubrication was carried out [13]. The meshing analysis for TA worm drive was presented in [14]. It was proved that the two contact lines exist simultaneously. The first determined as constant contact line and the second as set of the instantaneous contact points. The method for curvature analysis for the helicoidal surface of TA worm was shown in [15], but without meshing analysis. The geometrical simulation of worm wheel tooth generation using the different axial section profiles of worm representing hob cutting edges was proposed in [16]. The intersection profile method, described...
in [17], is suitable in case of not complex geometry of the cutter. In this article the generation of worm wheel tooth flank by the fly cutter representing end tooth of hob was presented. The proper design and control of the machined parts quality are important for creating precision applications [18]. The manufacturing of gears requires the generation of the complex surfaces. The machining processes are very often affected by an excessive vibration [19] and cutting conditions [20], potentially damaging the surface of the gear work piece [21].

The aim of this work is to present the full mathematical description of the tooth flank of worm and worm wheel in the globoidal worm gear. The axial section of the worm is straight-lined (TA worm), the worm wheel is generated by the hob cutter which is identical to the TA worm. The mathematical description of teeth surfaces of globoidal worm gear can be used e.g. to analyse contact region of such kind of gear.

2 Geometric and kinematic coordinate system of globoidal worm gear

As illustrated in Fig. 1 the two stationary coordinate system $S_1 (x_1 y_1 z_1)$ and $S_2 (x_2 y_2 z_2)$ connected with worm and worm wheel respectively were established. These systems can be handled as systems associated with housing. The moveable coordinate system $S'_1 (x'_1 y'_1 z'_1)$ of worm and $S'_2 (x'_2 y'_2 z'_2)$ of worm wheel was introduced. The axes of worm drive are orthogonal. Worm rotates clockwise about $z'_1$ axis by the angle $\varphi_1$. Then worm wheel rotates clockwise about $x'_2$ by the angle $\varphi'_2$ (in case of lead left worm). $\varphi_1$ is the geometric surface parameter and $\varphi'_2$ is the auxiliary parameter. Between $\varphi_1$ and $\varphi'_2$, as well $\varphi_1$ and $\varphi'_1$ exists relationship resulting from the worm drive transmission ratio:

$$i = \frac{\varphi'_2}{\varphi_1} = \frac{\varphi'_2}{\varphi_1}$$ (1)

Centres of coordinate systems are described as $O_1$ and $O_2$. The centre distance $a$ of the TA worm pair is also the distance between the centres of coordinate systems.

The surface of TA worm in $S'_1$ coordinate system is represented by a position vector $r_{1}^{(1)}$. Similarly, the surface of worm wheel in the $S'_2$ coordinate system is represented by position vector $r_{2}^{(2)}$. The worm and worm wheel surface as well meshing geometry is obtained using the transformation matrices. The matrices $M_{1\,1}$, $M_{2\,1}$, $M_{1\,2}$, $M_{2\,2}$ include the surface parameter $\varphi_1$ and $\varphi'_2$, while $M'_{1\,1}$, $M'_{2\,1}$, $M'_{1\,2}$, $M'_{2\,2}$ include rotation parameter of worm $\varphi'_1$ and worm wheel $\varphi_2$.

$$M_{2\,1} = \begin{bmatrix} \cos(\varphi_1) & -\sin(\varphi_1) & 0 & 0 \\ \sin(\varphi_1) & \cos(\varphi_1) & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$ (2)

For the homogenous matrix $M_{1\,1}$ in the equation (2) instead of $(\varphi_1)$, $(-\varphi_1)$ is inserted.

$$M_{2\,2} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & \cos(\varphi_2) & -\sin(\varphi_2) & 0 \\ 0 & \sin(\varphi_2) & \cos(\varphi_2) & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$ (3)

Inserting $(-a)$ in the equation (3) instead of $(a)$, the homogenous matrix $M_{1\,2}$ is obtained.

$$M'_{2\,1} = \begin{bmatrix} \cos(\varphi'_1) & -\sin(\varphi'_1) & 0 & 0 \\ \sin(\varphi'_1) & \cos(\varphi'_1) & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$ (4)

For the homogenous matrix $M'_{2\,2}$ in the equation (4) instead of $(\varphi'_2)$, $(-\varphi'_2)$ is inserted.
Inserting \((-\varphi_1')\) in the equation (5) instead of \((\varphi_1')\), the homogenous matrix \(M'_{11}\) is obtained.

\[
M'_{22} = \begin{bmatrix}
1 & 0 & 0 & 0 \\
0 & \cos(\varphi_2') & -\sin(\varphi_2') & 0 \\
0 & \sin(\varphi_2') & \cos(\varphi_2') & 0 \\
0 & 0 & 0 & 1 \\
\end{bmatrix}
\] (6)

Introducing \((-\varphi_2')\) for \((\varphi_1')\) in the equation (6) the homogenous matrix \(M'_{22}\) is obtained.

3 Equation of globoidal helix

The globoidal helix equation can be derived based on determination of next positions of point R on the worm thread (Fig. 2). Point R lies on the tooth flank in the plane \(y_1z_1\). This point is described by vector:

\[
r_R^{(1)} = \begin{bmatrix}
0 \\
y_1 \\
z_1 \\
1 \\
\end{bmatrix}
\] (7)

The parametric description of globoidal helix shows the vector \(r_R^{(1)}\):

\[
r_R^{(1)} = M'_{11} \cdot r_R^{(1)}
\] (9)

4 Mathematical model of globoidal worm with straight axial profile

Points \(A, B, C, D\) are introduced on the tooth profile for the zero backlash gear set in the central plane \((y_1z_1)\) (Fig. 3). They lie in order: point \(A\) on the gear root surface, point \(B\) on the worm addendum surface, point \(C\) on the gear addendum surface, point \(D\) on the worm root surface. To define the points \(A, B, C, D\), the auxiliary point \(E\) lying on the gear pitch circle and tooth profile was inserted.

The coordinates of point \(E\) can be determined as:

\[
y_{1E} = y_0 + \frac{d_{w2}}{2} \cdot \cos(\tau)
\]

\[
z_{1E} = z_0 + \frac{d_{w2}}{2} \cdot \sin(\tau)
\] (10)

where: \(y_0, z_0\) – coordinates of gear centre in worm coordinate system, \(d_{w2}\) – pitch diameter of gear, \(\tau\) – angle, which can be define basis on geometrical dependences from Fig. 3:

\[
\tau = \frac{s_{mx1}}{\pi \cdot d_{w2}} \cdot 360^\circ
\] (11)

where: \(s_{mx1}\) – axial worm thread thickness.

The equation of the straight line passing through point \(E\) in the \(S_1 (x_1y_1z_1)\) coordinate system is searched. The general equation of the straight line represents the formula:

\[
z = \tan(\alpha_1) \cdot y + b
\] (12)

The component \(b\) of the equation (12) is determined, substituting coordinates of point \(E\):

\[
b = z_{1E} - \tan(\alpha_1) \cdot y_{1E}
\] (13)
where: \( \alpha_1 \) – axial pressure angle of worm.

The equation of the straight line in the \( S_1 \) coordinate system passing through tooth profile of worm is expressed as:

\[
z = tg (\alpha_1) \cdot y + z_{1E} - tg (\alpha_1) \cdot y_{1E}
\]  

(14)

In order to determine the coordinates \( A, B, C \) or \( D \), the system of equations (15) is solved, taking into account the expressions (10) and (11).

\[
\begin{align*}
(y - y_0)^2 + (z - z_0)^2 &= R^2 \\
z &= tg (\alpha_1) \cdot y + z_{1E} - tg (\alpha_1) \cdot y_{1E}
\end{align*}
\]

(15)

The relationship between the pressure angle of the worm and worm wheel represents the formula [22]:

\[
\alpha_1 = \alpha_2 + \frac{\varepsilon}{2}
\]

(16)

where: \( \alpha_2 \) – pressure angle of worm wheel in the central plane, \( \alpha_4 = (\alpha_e - \text{axial pressure angle}), \varepsilon \) – angular pitch of globoidal worm drive (\( \varepsilon = \frac{160}{2}\pi \)).

In the equation (15) as \( R \) is taken:

- for point A: \( R = \frac{d_{1/2}}{2} + c_2 \),
- for point B: \( R = \frac{d_{1/2}}{2} \),
- for point C: \( R = \frac{d_{2/2}}{2} + c_1 \),
- for point D: \( R = \frac{d_{2/2}}{2} + c_1 \),

where: \( d_{1/2} \) – gear root diameter, \( d_{2/2} \) – gear throat diameter, \( c_1, c_2 \) – clearance in the worm and gear.

After solving the system of equations (15) for a given point, coordinates of this point are obtained \( \{A(y_{1A}, z_{1A}), B(y_{1B}, z_{1B}), C(y_{1C}, z_{1C}), D(y_{1D}, z_{1D})\} \). These are the coordinates of the tooth profile on the one side. For the profile on the second side the coordinates are defined as: \( A'(y_{1A}, -z_{1A}), B'(y_{1B}, -z_{1B}), C'(y_{1C}, -z_{1C}), D'(y_{1D}, -z_{1D}) \).

Introducing the clearance, the worm tooth thickness is reduced. The profile of worm can be obtained by tooth profile rotation of non-backlash drive with \( \delta \) angle corresponding to the half of the circumferential backlash defined in arc measure. The angle \( \delta \) is expressed as:

\[
\delta = \frac{j_x}{d_{w2}}
\]

(17)

A given point vector must be transformed. For example, for point B the transformation of the vector \( r_B^{(1)} = \begin{bmatrix} 0 \\ y_{1B} \\ z_{1B} \\ 1 \end{bmatrix} \) is described as:

\[
r_B^{(1)} = M_{12} \cdot M_{22} \cdot M_{21} \cdot r_B^{(1)}
\]

(18)

In the equation (18) in the homogenous matrix \( M_{22} \) for \( \varphi_2 \) the expression (17) is substituted. To obtain mathematical description of globoidal hob cutter, the points A and C have to be used. In description of worm the coordinates of points \( B' \) and \( D' \) are necessary. If the mathematical model will be used to define worm wheel tooth flank in the range of meshing as well for tooth contact pattern analysis, then the profile of worm cutter can be limited to points B and C and for worm to points \( B' \) and \( D' \). Section BC (or \( B'C' \)) determines the working depth along the tooth profile of engaged worm and worm gear. The parametric equation of hob cutter axial profile (section \( BC \)) in \( y_1 z_1 \) plane is determined as:

\[
r_{BC}^{(1)} = \begin{bmatrix} x_1(u) \\ y_1(u) \\ z_1(u) \end{bmatrix} = \begin{bmatrix} 0 \\ y_{1B} + (y_{1C} - y_{1B}) \cdot u \\ z_{1B} + (z_{1C} - z_{1B}) \cdot u \end{bmatrix}
\]

(19)

where: \( u \) – parameter \( (u_p \leq u \leq u_k, \, u_p = 0, \, u_k = 1) \).

The parametric equation of worm axial profile (section \( B'C' \)) in \( y_1 z_1 \) plane is expressed as:

\[
r_{BC}^{(1)} = \begin{bmatrix} 0 \\ y_{1B'} + (y_{1C'} - y_{1B'}) \cdot u \\ z_{1B'} + (z_{1C'} - z_{1B'}) \cdot u \end{bmatrix}
\]

(20)

Parametric equation of the worm tooth flank surface is obtained by moving the tooth profile along the globoidal helix. The position vector of this surface is expressed as:

\[
r_1^{(1)} = M_{11} \cdot \begin{bmatrix} x_1(u) \\ y_1(u) \\ z_1(u) \end{bmatrix}
\]

(21)

where: \( x_1(u), \, y_1(u), \, z_1(u) \) are the parametric equation of worm tooth axial section profile, \( \varphi_1 \) – parameter from matrix \( M_{11} \), which defines effective worm thread length \( (\varphi_1 \leq \varphi_1 \leq \varphi_{1k}) \).

The worm tooth surfaces are shown in Fig. 4.

The basic geometric parameters of the double enveloping worm gear appearing in the equations can be determined by the standards [6–9]. Depending on whether the worm or the worm cutter is modelled to generate the worm wheel tooth side, the appropriate parametric equation of the profile and the values of the threat range are introduced. The model of the second tooth side surface of worm can be derived, when the contact region analyses are made in case of small backlash or introduction gear set errors.

In consideration of worm wheel mathematical modellling, the model of the tool is rotated with respect to the
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Figure 4: Tooth surfaces of globoidal worm with straight axial profile.

Figure 5: Illustrative figure of tooth side of globoidal worm wheel with marked region I, II, III.

The coordinate system by cutting the worm wheel is the same like shown in Fig. 1. The description of one side of the tooth surface is presented. The worm wheel tooth surface is generated by the hob cutter model (Fig. 6), because the thread length of tool should be longer than in the worm. The presented gear hob model is without intermediate cutting edges. The continuous generative surface of the hob cutter between the extreme cutting edges is established.

It is noted that worm wheel surface is divided into three regions (Fig. 5) [5]. Region II is the envelope to the family of contact lines of the globoidal worm gear. Region I and III is formed by a first cutting edge of worm hob cutter (Fig. 6) [5]. One extreme cutting edge of the tool forms one side of worm wheel tooth and the second edge forms the another flank.

5 Mathematical model of worm wheel generated by the globoidal worm hob cutter with straight axial profile

The condition of existence of an envelope is represented by the equation of meshing:

\[ n \cdot v = 0 \] (22)

where:
- \( n (n_x, n_y, n_z) \) - normal vector to the surface,
- \( v (v_x, v_y, v_z) \) - tangent vector.

Relationship between rotation of worm wheel \( \varphi'_2 \) to rotation of tool \( \varphi'_1 \) is given by homogenous matrix \( M'_2 \cdot M'_1 \):

\[ M'_2 \cdot M'_1 = M'_{2,1} \] (23)
The developed form of homogenous matrix $M'_{2 \cdot 1}$ is presented:

$$
M'_{2 \cdot 1} = \begin{bmatrix}
\cos(\varphi_1) & -\sin(\varphi_1) & 0 & 0 \\
\cos(\varphi_2)\sin(\varphi_2) & \cos(\varphi_2)\cos(\varphi_1) & \sin(\varphi_2) & a \cdot \cos(\varphi_2) \\
\sin(\varphi_1)\sin(\varphi_2) & \cos(\varphi_1)\cos(\varphi_2) & \cos(\varphi_2) & a \cdot \sin(\varphi_2) \\
0 & 0 & 0 & 1
\end{bmatrix}
$$

(24)

The normal vector $n^{(2)}_1$ can be calculated on the basis of worm tooth surface description. It is expressed as:

$$
n^{(2)}_1 = \begin{bmatrix} n^{(2)}_{x1} \\ n^{(2)}_{y1} \\ n^{(2)}_{z1} \end{bmatrix} = L'_{2 \cdot 1} \cdot \left( \frac{\partial r^{(1)}_2}{\partial \varphi_1} \times \frac{\partial r^{(1)}_2}{\partial u} \right)
$$

(25)

$L'_{2 \cdot 1}$ is obtained by crossing out the last row and the last column of the homogenous matrix of transformation (24).

In equation (25) the partial derivative of position vector $r^{(1)}_1$ to surface parameter $\varphi_1$ and $u$ is calculated. Partial derivative $\frac{\partial r^{(1)}_2}{\partial \varphi_1}$ is obtained by substituting in equation (21) for $\varphi_2 = \varphi_1 \cdot i(\varphi_2$ - the auxiliary surface parameter). The expression $\frac{\partial r^{(1)}_2}{\partial u}$ can be calculated after extending the equation (21) by the parametric equation of tooth profile $x_1(u)$, $y_1(u)$ and $z_1(u)$.

Tangent vector can be calculated based on kinematics of worm gear machining. Tangent vector is given by the following expression:

$$
v^{(2)}_1 = \begin{bmatrix} v^{(2)}_{x1} \\ v^{(2)}_{y1} \\ v^{(2)}_{z1} \end{bmatrix} = \frac{dM'_{2 \cdot 1}}{d\varphi_2} \cdot r^{(1)}_1
$$

(27)

The derivative $\frac{dM'_{2 \cdot 1}}{d\varphi_2}$ in the eq. (27) is calculated by substituting in eq. (24) for $\varphi_1 = \varphi_2$. In the general equation (22) of gear meshing the eq. of surface normal vector $n^{(2)}_1$ (25) and tangent vector $v^{(2)}_1$ (27) are introduced:

$$
n^{(2)}_1 \cdot v^{(2)}_1 = \begin{bmatrix} n^{(2)}_{x1} & n^{(2)}_{y1} & n^{(2)}_{z1} \end{bmatrix} \cdot \begin{bmatrix} v^{(2)}_{x1} \\ v^{(2)}_{y1} \\ v^{(2)}_{z1} \end{bmatrix} = 0
$$

(28)

After solving the eq. (28), for given parameters $u$ the solutions set of $\varphi_1$ is obtained. Substituting the solutions to eq. (21) the lines of contact between worm and worm wheel in $x'_1 y'_1 z'_1$ coordinate system are received (Fig. 7):

$$
r^{(1)}_1 = r^{(1)}_1(\varphi_1, u)
$$

(29)

Worm surface is in tangent with worm wheel surface at every instant of two lines. One contact line lies in the central plane of worm drive. It is constant and straight. The other contact line is curvilinear and is moving to the first on each worm wheel tooth being in mesh with worm. These lines generate that part of worm wheel, which is described as region II. Region II is generated as the envelope to the family of surface $\Sigma_1$. This part of worm wheel $(l^{(1)}_{2_\text{Region.II}})$ can be obtained by rotation the worm with specified value in rotation range from 0 to $2\pi$ ($0 \leq r \leq 2\pi$) and determining the contact lines.
These lines are selected, which are not lying in the axial section of worm. Then the selected contact lines should be brought to the one tooth side of worm wheel, as shown as example in Fig. 8.

![Figure 7: Contact lines shown in $S'_1$ coordinate system.](image)

Region I and III is formed by a first cutting edge of worm hob cutter. It is equivalent with the extreme contact line ($r_{cl,2}^{(1)}$ from Fig. 7), lying in central plane. The alternative is transformation of axial profile of tool $r_{cl,2}^{(1)}$ using the equation (21) and then the next transformation of the profile to central plane:

$$r_{1(\varphi_1=\varphi_{ip})}^{(1)} = M'_{11} \cdot r_{cl,2}^{(1)}$$

In the matrix $M'_{11}$ the expression $\varphi_1' = \varphi_{1_{tool-base}}$ is substituted. The surface generated by the extreme cutting edge represented in coordinate system of tool $S'_1$ is obtained by applying the following equation:

$$r_{2}^{(1)} = M'_{11} \cdot r_{cl,2}^{(1)}$$

where: $r_{cl,2}^{(1)} = \text{contact line } r_{cl,2}^{(1)}$ after taking equation (30) into consideration.

In eq. (33) in the matrix $M'_{11}$ the range of parameter $\varphi_1$ is selected to obtain the worm wheel tooth surface of a given width ($\varphi_{1p} < \varphi_1 < \varphi_{1k}$). In the Fig. 9 the surface generated by extreme cutting edge of tool on the basis of eq. (33) is plotted.

From the surface shown in Fig. 9 region I and III have to be separated. The two contact lines in the area of the extreme cutting edge of the tool are the boundaries of the regions (Fig. 7). For region I there is the contact line, which doesn’t lie in the axial plane of tool ($r_{cl,1}^{(1)} = r_{cl,1}^{(1)} (i, 1)$), marked in Fig. 7. For region III there is the contact line lying in the axial plane ($r_{cl,2}^{(1)} = r_{cl,1}^{(1)} (i, 2)$ marked in Fig. 7). The separated region I and III of the worm wheel tooth surface generated during machining through the extreme cutting edge of the tool is shown in Fig. 10.

![Figure 8: Region II presented in $S'_1$ coordinate system.](image)
The algorithm for selecting the region I \((r_{2,\text{region,I}}^{(1)})\) consists in checking the condition:

\[
r_{2,\text{region,I}}^{(1)}(i,j) < r_{\text{cl},x_i}^{(1)}(i,1)
\]

where: \(r_{2,\text{region,I}}^{(1)}(i,j)\) – element of coordinate table \(x_i\) of worm wheel surface \(r_{2}^{(1)}\) determined on the basis on equation (33), generated during machining through the extreme edge of the tool, \(r_{\text{cl},x_i}^{(1)}(i,1)\) – element of coordinate table \(x_i\) of contact line \(r_{\text{cl},1}^{(1)}\) (Fig. 10), \(i, j\) – natural numbers.

Equation (34) specifies the range of coordinates \((i,j)\) of the table for region I. It can be expressed as:

\[
r_{2,\text{region,I}}^{(1)}(i,j) = r_{\text{cl},x_i}^{(1)}(i,1)
\]

where: \(i, j\) are satisfying the condition (34).

The algorithm for selecting the region III \((r_{2,\text{region,III}}^{(1)})\) is analogous and consists in checking the condition:

\[
r_{2,\text{region,III}}^{(1)}(i,j) > r_{\text{cl},x_i}^{(1)}(i,2)
\]

where: \(r_{\text{cl},x_i}^{(1)}(i,2)\) – element of coordinate table \(x_i\) of contact line \(r_{\text{cl},2}^{(1)}\) (Fig. 10).

Equation (36) specifies the range of coordinates \((i,j)\) of the table for region III. It can be expressed as

\[
r_{2,\text{region,III}}^{(1)}(i,j) = r_{\text{cl},x_i}^{(1)}(i,2)
\]

where: \(i, j\) are satisfying the condition (36).

6 Conclusions

The presented mathematical model can be used in practical application by designing new transmission gear. The double enveloping worm gear drive provides increased load capacity in comparison with the cylindrical worm gear drive. Because of this, it can replace the cylindrical worm gear in the gearbox, when the overall dimensions of the gear can’t be enlarged.

Final conclusions can be formulated by following points:

1. Presented mathematical model of globoidal worm drive with straight axial tooth profile shows that its determination is complex. The theory of gearing and gear generation mechanism was used.

2. The extreme cutting edge of worm hob has a considerable impact by generating the tooth side of worm wheel. It is circa 85% of tooth width of worm wheel.

3. The presented mathematical model of tooth flank of globoidal worm and worm wheel can be used for different analysis, like contact pattern, lubrication condition of the gear, etc.

4. The mathematical representation of tooth flank surface of hourglass worm and worm wheel can be helpful for generation CAD models, which can be used for FEM analysis.
References