The CAD Modeling for Contact Ratio

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Abstract: The investigation of the contact conditions, the effect of errors on them, as well as the optimization of the gears face difficulties because the contact lines continuously move and change their shape during gearing This paper presents a numerical method to determine the contact ratio of cylindrical worm gearing with modified profile. Both profiles, of worm and gear, are obtained numerically by the discreting of helicoidal surface with constant pitch.

Key-Words: - worm gearing, meshing, contact ratio, path of contact, contact points, gear flank profile.

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1 Introduction

In order to pass from 3D in 2D we'll consider a cylindrical worm gearing which has several cross sections perpendicular to worm gear axis [1].

On the basis of the worm modified profile -Σ_H , for example arch profile, which is given by the equations (1), we can determine the gear flank profile, equations (2), using the "minimum distance method" [2], that is a numerical calculus [3], [4].

$$\Sigma_H: \quad \sin\varphi = \frac{H}{-\left[Y_O + R\sin(\alpha - v)\right]} \quad y = \left[Y_O + R\sin(\alpha - v)\right]\cos\varphi \quad z = Z_O + R\cos(\alpha - v) + p\varphi \tag{1}$$

where:
-Y_O and Z_O are the coordinates of the arch profile center and are given by the following relations:

$$\begin{cases} Y_O = R_e - u\cdot\cos\alpha - a\cdot\sin\alpha \\ Z_O = \pm(b + u\cdot\sin\alpha - a\cdot\cos\alpha) \end{cases}$$

- a-constant parameter;

$u = 1{,}25\cdot m/\cos 20^\circ$

$R = \sqrt{a^2 + u^2}$

$b = \frac{\pi\cdot m}{4} - 1{,}25\cdot m\cdot tg20^\circ$

$p = \frac{m}{2}$

- plus + is for right profile;
- minus – is for left profile;
-R_e is tip radius of worm;
-$H=x$ (section plane);
-v is variable parameter of worm flank;

As has been observed in the paper [3], the gear profile is given by the following system:

$$\begin{cases} X = x \\ Y = (y - R_r)\cos(j\cdot\Delta\varphi) + \left[z - R_r(j\cdot\Delta\varphi)\right]\sin(j\cdot\Delta\varphi) \\ Z = -(y - R_r)\sin(j\cdot\Delta\varphi) + \left[z - R_r(j\cdot\Delta\varphi)\right]\cos(j\cdot\Delta\varphi) \end{cases} \tag{2}$$

where:
- R_r is rolling radius of the gear;
- $(j\Delta\varphi)$ is rolling angle;

We have used a numerical calculus method because the analytic methods for determination of envelopes to the surfaces requires the knowledge of enveloped surfaces equations, in parametric or vectorial form with the aim of determining the normals to them (Gohman kinematics method, Willis normals method, Nicolaev method) or with the aim to determining the partial derivatives (Oliver theorems, minimum distance method). The conditions of enveloping are represented, in many cases, by the transcendent equations with a difficult solving.

By means of computer program, the equations of systems (1) and (2) were solved and the figure 1 shows the right profile of the worm in 7 section planes: X=-22,494; X=-14,996; X=-7,498;X=0; X=7,498; X=14,996; X=22,494.

2 Path of Contact Equations

With above elements of the worm gearing we can

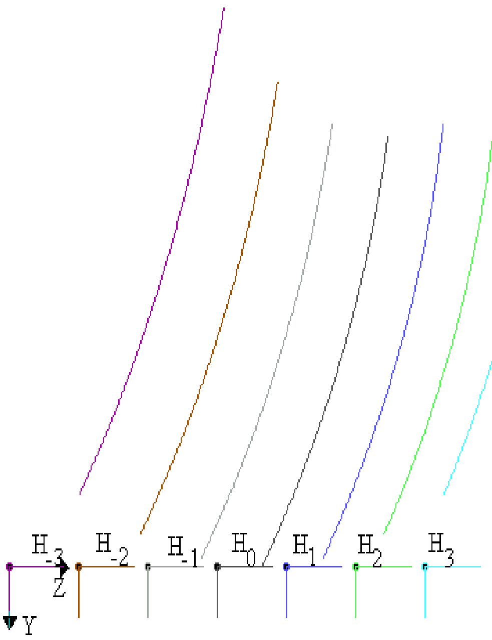

Fig.1 Right flank profile of worm

determine the contact ratio in any section plane perpendicular to gear. The surfaces of contact is defined as geometrical position of the contact points of the two conjugated surfaces, with respect to the coordinate system fixed to the frame, and it is given by the absolute motion equation of the gear flanks profiles:

$$x = \omega_1^T (j \cdot \Delta\varphi) \cdot X \tag{3}$$

or

$$\begin{Vmatrix} x \\ y \\ z \end{Vmatrix} = \begin{Vmatrix} 1 & 0 & 0 \\ 0 & \cos(j \cdot \Delta\varphi) & -\sin(j \cdot \Delta\varphi) \\ 0 & \sin(j \cdot \Delta\varphi) & \cos(j \cdot \Delta\varphi) \end{Vmatrix} \cdot \begin{Vmatrix} X \\ Y \\ Z \end{Vmatrix}$$

where:

-*x* is matrix of a point coordinates with respect to the coordinate system fixed to the frame (xyz);

-*X* is matrix of a point coordinates with respect to the mobile coordinates system (XYZ);

-$\omega_1(j \cdot \Delta\varphi)$ is matrix of rotating transformation, $\Delta\varphi$ being angular increment.

In the section plane x=H, the path of contact is given by :

$$\begin{cases} y = Y \cdot \cos(j \cdot \Delta\varphi) - Z \cdot \sin(j \cdot \Delta\varphi) \\ z = Y \cdot \sin(j \cdot \Delta\varphi) + Z \cdot \cos(j \cdot \Delta\varphi) \end{cases} \tag{4}$$

where:

Y and *Z* are the contact points coordinates, which, in reality, form the gear profile.

2.1 Numerical results

On the basis of equations (4) we have performed a computer program. By means of it we have obtained the path of contact for each section plane (figures 2…8) of the worm gearing with the following parameters:

- number of worm threads z_1=1;
- number of gear teeth z_2=53;
- axial module m_x=10mm;
- diametral quotient q=10;
- constructive parameter a=70;
- angular increment $\Delta\varphi = \pi/3420$.

In the tables 1…7 we have presented the coordinates of points there are on the path of contact from the figures 2…8.

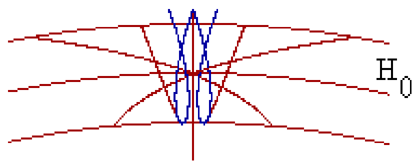

Fig. 2 Path of contact in the section plane H_0

Table 1

	Nr.	y_{la}	z_{la}
X=0	1	-252,5	21,033
	25	-256,243	16,945
	50	-259,504	12,102
	150	-268,147	-10,329
	200	-270,862	-22,407
	283	-274,128	-42,959

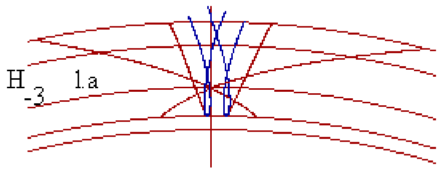

Fig. 3 Path of contact in the section plane H_{-3}

Table 2

	Nr.	y_{la}	z_{la}
X=-22,494	1	-256,688	14,395
	25	-259,764	9,935
	50	-262,632	4,950
	150	-271,099	-17,246
	200	-274,166	-29,068
	300	-279,013	-53,364
	310	-279,433	-55,824

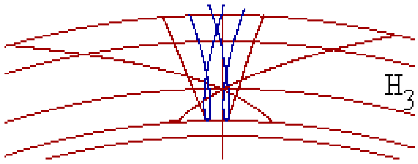

Fig. 4 Path of contact in the section plane H_3

Table 3

	Nr.	y_{la}	z_{la}
X=22,494	1	-256,688	15,852
	25	-259,810	11,228
	50	-262,537	5,993
	150	-269,840	-17,184
	200	-272,164	-29,421
	300	-275,450	-54,399
	354	-276,723	-68,043

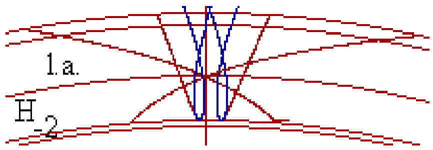

Fig. 5 Path of contact in the section plane H_{-2}

Table 4

	Nr.	y_{la}	z_{la}
X=-14,996	1	-254,325	17,877
	25	-257,787	13,656
	50	-260,857	8,769
	150	-269,535	-13,424
	200	-272,540	-25,318
	300	-276,621	-47,078

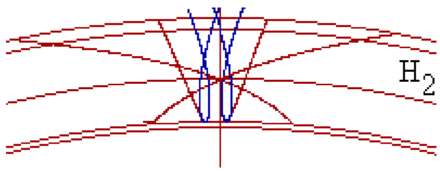

Fig. 6 Path of contact in the section plane H_2

Table 5

	Nr.	y_{la}	z_{la}
X=14,996	1	-254,325	19,308
	25	-257,742	14,925
	50	-260,766	9,833
	150	-268,708	-12,987
	200	-271,178	-25,178
	300	-274,567	-50,134
	354	-275,097	-55,431

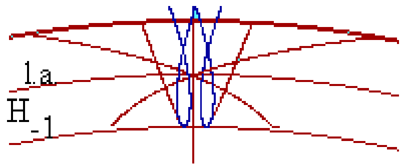

Fig. 7 Path of contact in the section plane H_{-1}

Table 6

	Nr.	y_{la}	z_{la}
X=-7,498	1	-252,951	20,093
	25	-256,592	15,974
	50	-259,812	11,145
	150	-268,562	-11,127
	200	-271,432	-23,115
	280	-274,870	-42,796

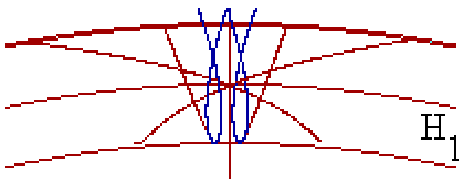

Fig. 8 Path of contact in the section plane H_1

Table 7

	Nr.	y_{la}	z_{la}
X=7,498	1	-253,141	20,542
	25	-256,832	16,359
	50	-260,013	11,424
	150	-268,28	-11,268
	200	-270,860	-23,418
	295	-274,217	-47,080

3 Contact Ratio

In order to determine the gearing contact ratio for each section plane, we have traced the worm gear profile corresponding to one pitch and two pitches, by using the transformation of coordinates given by relation (5):

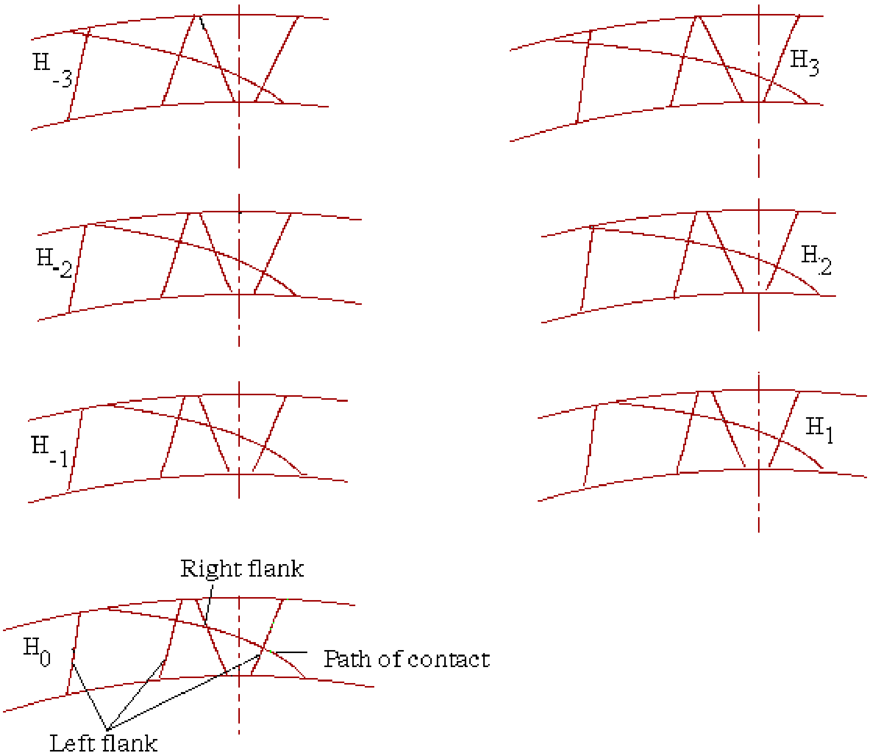

Fig. 9 Contact ratio in the section planes of the worm gear

$$X' = \omega_1^T(k \cdot \delta) \quad (5)$$

So that, the worm gear profile over "k" pitches is given by the equations:

$$\begin{cases} X' = X = H \\ Y' = Y \cdot cos\frac{k \cdot 2 \cdot \pi}{z_2} - Z \cdot sin\frac{k \cdot 2 \cdot \pi}{z_2} \\ Z' = Y \cdot sin\frac{k \cdot 2 \cdot \pi}{z_2} + Z \cdot cos\frac{k \cdot 2 \cdot \pi}{z_2} \end{cases} \quad (6)$$

where: X and Y are the coordinates of the worm gear profile determinated with the relations (2).

Also, by drawing the path of contact for each section plane, we can have a picture of the contact ratio of the worm gearing (figure 9). As may be seen in the figure 9, the contact ratio is 2 or 3, that is also indicated in the literature [3], [5].

4 Conclusion

As the result of investigation above, we can make the following conclusions:

1. On the basis of methodology presented in this paper we can determine the path of contact and the contact ratio in every sectional plane .
2. Determining the gearing contact ratio we can also study another problems such as: the contact forces, tooth rigidity.
3. The numerical method permits the geometry optimization and study of the meshing for different geometrical characteristics of the worm gearing, being in fact a simulation of meshing that leads to important saving in time and costs.

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