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STUDY OF GENERATION OF THE DOUBLE WORM-FACE WHEEL TEETH'S FLANKS WITH TANGENTIAL ADVANCE METHOD

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Abstract

This paper aims to present the results of a study that has resulted in a matrix-vector mathematical model of the process of machining milling cutter of the double worm-face wheels, which engages with a cylindrical worm, with hob through tangentially advanced.. The mathematical model developed provides determine the coordinates of the points that make up the flanks of the two crowns worm-face gear machined simultaneously. Worm generator was considered a cylindrical worm with flanks asymmetric Archimedean. Coordinates obtained by calculation allow modelling in a graphical environment of the machined wheels

Key words: worm-face gear, double worm-face wheels, hobbing, mathematical model, tangential advance

1. Introduction

Double worm-face gear constitutes an embodiment published in the U.S. Patent[19] who comes to bring an increase in lift front auger gear required for special applications. The only standard that refers to the worm face-gear [21] they appear in two constructive versions: tapered worm and cylindrical worm respectively. The fact that a one worm engage simultaneously two worm-face wheels will determine to grow contacts lines number of the teeth at double what has the consequence that the value of the teeth contact pressure, for the same amount of torque moment transmitted, will be substantially reduced and will produce increasing durability this type gearing [13].

The version of the gearing with tapered worm the double worm-face wheel can be executed compulsory only of two separate wheels, the version of the gearing with cylindrical worm the double worm-face gear wheel can be executed and in one body [2].

This is due to the possibilities of implementing the teeth. Double worm–face wheel engaging the cylindrical worm being able to use the milling method can tangential advance hobbing double worm-face wheels so the piece and simultaneously processing two gears crown wheel will form double.
Method for processing of the teeth's milling tangential feed method provides a cutting process in good condition by hob entrance gradually working tool having a specific nosecone [2].Manufacturing of the worm-face wheel in small series is possible, in good condition, using the fly cutter by hobbing machine [4].

Double worm-face wheels processing by simultaneous milling of the two crowns appears higher load this tool having cutting teeth on both sides. This needs to be taken into account in the choice of hobbing cutting data used [2,3,18,20]/

In a previous paper presented kinematic generate double worm-face gear [2,3,15,16,17]. In this paper we present a mathematical model of worm-face wheel machining process through tangential advanced of the hob realizing worm gear mathematical model of the technology that make up the gear on the machine during processing.

2. Definition of matrix-vector coordinates of the points double worm-face wheel tooth flanks

Processing the teeth by hob feed method tangential advance is the only way processing double worm-face wheel in one body, Figure 1.

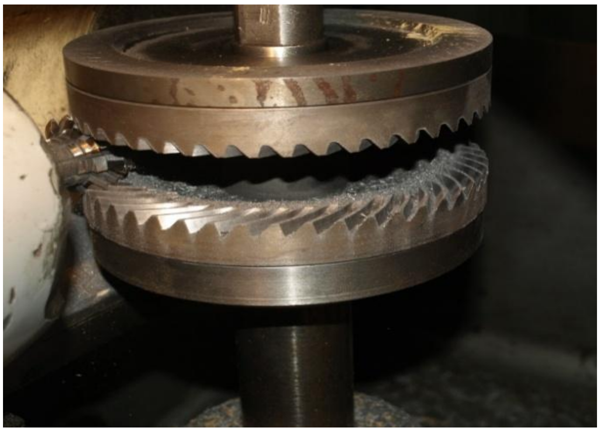

Fig. 1: Milling double worm-face wheel teeth through tangential advanced method with hob

To apply this method required the development, through the gear linkages machine, synchronized movements of the following:

- rotation of the hob its axis with angular velocity w_1;
- the rotational movement of the wheel about its axis with angular velocity w_2;
- advance movement tangential worm size s_T (tangential advance the hob in mm/rotation of the worm wheel). This movement is performed along the axis hob is defined by parameter

$$b = s_T \cdot \frac{z_1}{z_2} \cdot \frac{1}{2\pi} \quad \left[\frac{\text{mm}}{\text{rad}}\right] \tag{1}$$

- further rotational movement of the wheel provided to ensure there is provided the rolling mill of the tangential advance of the hob.

Highlighting relative position of the hob and double worm-face wheel the processing is made tangential advance method in Figure 2. In order to write mathematical expressions using matrix-vector reference systems shown in the same image.

The transfer matrices for writing the coordinates of points to be used notations and expressions that are valid in [.2,6,14,15,16,17].

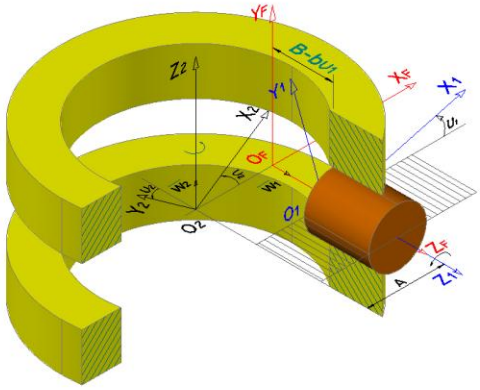

Fig. 2: Systems of reference for the study of processing double worm-face wheel with tangential advance method

The gear ratio and parameter u1 i_{12} will have the values:

$$i_{12} = \frac{z_2}{z_1} \quad \text{si} \quad u_1 = \left(i_{12} - \frac{s_T}{\pi \cdot m_a z_1}\right) u_2 \tag{2}$$

Transfer matrices of the systems used are:

$$M_{F1} = \begin{Vmatrix} \cos u_1 & -\sin u_1 & 0 & 0 \\ \sin u_1 & \cos u_1 & 0 & 0 \\ 0 & 0 & 1 & B - bu_1 \\ 0 & 0 & 0 & 1 \end{Vmatrix} \tag{3}$$

$$M_{1F} = \begin{Vmatrix} \cos u_1 & \sin u_1 & 0 & 0 \\ -\sin u_1 & \cos u_1 & 0 & 0 \\ 0 & 0 & 1 & -B + bu_1 \\ 0 & 0 & 0 & 1 \end{Vmatrix} \tag{4}$$

$$M_{F2} = \begin{Vmatrix} \cos u_2 & -\sin u_2 & 0 & -A \\ 0 & 0 & 1 & 0 \\ -\sin u_2 & -\cos u_2 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{Vmatrix} \tag{5}$$

$$M_{2F} = \begin{Vmatrix} \cos u_2 & 0 & -\sin u_2 & A\cos u_2 \\ -\sin u_2 & 0 & -\cos u_2 & -A\sin u_2 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{Vmatrix} \tag{6}$$

$$M_{12} = M_{1F} \cdot M_{F2}$$

$$\mathrm{M}_{12} = \begin{Vmatrix} \cos u_1 \cos u_2 & -\cos u_1 \sin u_2 & \sin u_1 & -A\cos u_1 \\ -\sin u_1 \cos u_2 & \sin u_1 \sin u_2 & \cos u_1 & A\cos u_1 \\ -\sin u_2 & -\cos u_2 & 0 & -B + bu_1 \\ 0 & 0 & 0 & 0 \end{Vmatrix} \tag{7}$$

$$M_{21} = M_{2F} \cdot M_{F1}$$

$$M_{21} = \begin{Vmatrix} \cos u_1 \cos u_2 & -\sin u_1 \cos u_2 & -\sin u_2 & A\cos u_2 - (B - bu_1)\sin u_2 \\ -\cos u_1 \sin u_2 & \sin u_1 \sin u_2 & -\cos u_2 & -A\sin u_2 - (B - bu_1)\cos u_2 \\ \sin u_1 & \cos u_1 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{Vmatrix} \tag{8}$$

The operator matrix expressed relative speed of the reference system of the worm is given by:

$$P_{12}^{(1)} = M_{12} \cdot \frac{\partial \mathrm{M}_{21}}{\partial \mathrm{u}_2} \cdot \frac{\partial \mathrm{u}_2}{\partial \mathrm{t}}$$

$$P_{12}^{(1)} = \begin{Vmatrix} 0 & -(i_{12} - S_T/\pi \cdot \mathrm{m_a} \cdot \mathrm{z}_1) & -\cos u_1 & (bu_1 - B)\cos u_1 \\ (i_{12} - S_T/\pi \cdot \mathrm{m_a} \cdot z_1) & 0 & \sin u_1 & (B - bu_1)\sin u_1 \\ \cos u_1 & -\sin u_1 & 0 & A - (i_{12} - S_T/\pi \cdot \mathrm{m_a} \cdot \mathrm{z}_1) \cdot b \\ 0 & 0 & 0 & 0 \end{Vmatrix} \cdot W_2 \tag{9}$$

From now appears necessary to take into account the fact that we have two crowns gear one lower and one upper and we must take this into account by introducing notation index k for the lower crown and crown index j for upper

The relative speed of the two gear cases is:

$$\overline{V}_{12}^{(1)} = P_{12}^{(1)} \cdot \overline{X}_{1k\,j}$$

$$\overline{V}_{12}^{(1)} = \begin{Vmatrix} -(i_{12} - S_T/\pi \cdot m_a \cdot z_1)y_{1k\,j} - \cos u_1 \cdot z_{1k_j} + (bu_1 - B)\cos u_1 \\ (i_{12} - S_T/\pi \cdot m_a \cdot z_1)x_{1k\,j} + \sin u_1 \cdot z_{1k\,j} + (B - bu_1)\sin u_1 \\ \cos u_1 \cdot x_{1k\,j} - \sin u_1 \cdot y_{1k\,j} + A - (i_{12} - S_T/\pi \cdot m_a \cdot z_1) \cdot b \\ 0 \end{Vmatrix} \cdot W_2 = \begin{Vmatrix} V_x \\ V_y \\ V_z \\ 0 \end{Vmatrix} \tag{10}$$

Defining relations flanks wheel surface points is obtained from the condition of engagement :

$$\overline{N}_{1k} \cdot \overline{V}_{12}^{(1)} = 0$$

:

$$\begin{Vmatrix} n_{1xk_j} \\ n_{1yk\,j} \\ n_{1zk_j} \\ 0 \end{Vmatrix} \cdot \begin{Vmatrix} -(i_{12} - S_T/\pi \cdot m_a \cdot z_1)y_{1k_j} - \cos u_1 \cdot z_{1k\,j} + (bu_1 - B)\cos u_1 \\ (i_{12} - S_T/\pi \cdot m_a \cdot z_1)x_{1k_j} + \sin u_1 \cdot z_{1k\,j} + (B - bu_1)\sin u_1 \\ \cos u_1 \cdot x_{1k_j} - \sin u_1 \cdot y_{1k_j} + A - (i_{12} - S_T/\pi \cdot m_a \cdot z_1) \cdot b \\ 0 \end{Vmatrix} \cdot W_2 = 0 \tag{11}$$

The work with the method of [2] to make appropriate notations to the new situation

$$K_1 = n_{1yk\,j} \cdot z_{1k\,j} - n_{1zk\,j} \cdot y_{1k\,j} \tag{12}$$

$$K_2 = n_{1yk\,j} \tag{13}$$

$$K_3 = n_{1xk\,j} \cdot z_{1k\,j} - n_{1zk\,j} \cdot x_{1k_j} \tag{14}$$

$$K_4 = n_{1xk\,j} \tag{15}$$

$$K_5 = n_{1xk\,j}(i_{12} - S_\mathrm{T}/\pi \cdot m_a \cdot z_1)y_{1k\,j} + n_{1yk\,j}(i_{12} - S_\mathrm{T}/\pi \cdot m_a \cdot z_1)x_{1k\,j} + + n_{1zk\,j}(i_{12} - S_\mathrm{T}/\pi \cdot m_a \cdot z_1)b - n_{1zk\,j}A \tag{16}$$

By solving equation (17) by a numerical method, the parameter is determined u_1.

$$[K_1 + K_2(B - bu_1)]\sin u_1 - [K_3 - K_4(bu_1 - B)]\cdot \cos u_1 - K_5 = 0 \tag{17}$$

Worm-face wheel joint surfaces, the two crowns (upper and lower) are obtained from the expression: $\overline{X}_{2k\,j} = M_{21}\cdot \overline{X}_{1k\,j}$

$$\overline{X}_{2k\,j} = \left\| \begin{matrix} \cos u_1 \cos u_2 x_{1k\,j} - \sin u_1 \cos u_2 y_{1k\,j} - \sin u_2 z_{1k\,j} - \\ - \sin u_2 (B - bu_1) + A\cos u_2 \\ -\cos u_1 \sin u_2 x_{1k\,j} + \sin u_1 \sin u_2 y_{1k\,j} - \cos u_2 z_{1k\,j} - \\ - \cos u_2 (B - bu_1) - A \sin u_2 \\ \sin u_1 x_{1k\,j} + \cos u_1 y_{1k\,j} \\ 1 \end{matrix} \right\| = \left\| \begin{matrix} x_{2k\,j} \\ y_{2k\,j} \\ z_{2k\,j} \\ 1 \end{matrix} \right\| = \overline{X}_{2k_j}(p, v, u_2) \tag{18}$$

For a complete definition flanks wheel surface expression is necessary and the normal vector to the tooth flank is:

$$\overline{N}_{2k\,j} = \left\| \begin{matrix} \cos u_1 \cos u_2 \cdot n_{1xk_j} - \sin u_1 \cos u_2 \cdot n_{1yk\,j} - \sin u_2 \cdot n_{1zk\,j} \\ -\cos u_1 \sin u_2 \cdot n_{1xk_j} + \sin u_1 \sin u_2 \cdot n_{1yk\,j} - \cos u_2 \cdot n_{1zk_j} \\ \sin u_1 \cdot n_{1xk\,j} + \cos u_1 n_{1yk_j} \\ 0 \end{matrix} \right\| = \left\| \begin{matrix} n_{2xk_j} \\ n_{2y_jk} \\ n_{j\,2zk} \\ 0 \end{matrix} \right\| = \overline{N}_{2k_j}(p, v) \tag{19}$$

Having available the two expressions (18) and (19) double worm–face wheel tooth flank surfaces machined are completely determined if you know the size of the tangential advance of the hob generators.

2. Numerical study of the generation double worm-face wheel teeth's flanks

Validation of the accuracy of the mathematical model developed above can be done by applying numerical methods to allow calculation of the actual teeth flanks coordinates points to a case of gear and choosing a suitable tangential advance processing[1,9,10,11].

As computing flowchart for achieving program scheme used in [2,5,7,8,12,14.] specific for simple worm-face wheels that has added additional year sequence for calculating points higher gear ring

For the calculation was considered a double worm-face gear with the following characteristic: worm with z_1=1, worm-face wheel with z_2=47 teeth, module axial m_a=2,5, axial distance A=56mm, worm Archimedean. Method of calculating the geometrical parameters is presented in [2]

Calculation program in AutoLISP assured determining coordinates of the points flanks double worm-face wheel which allowed then plotting the flanks and shaping wheels in Autodesk Inventor Professional 2008 (Figure 3).

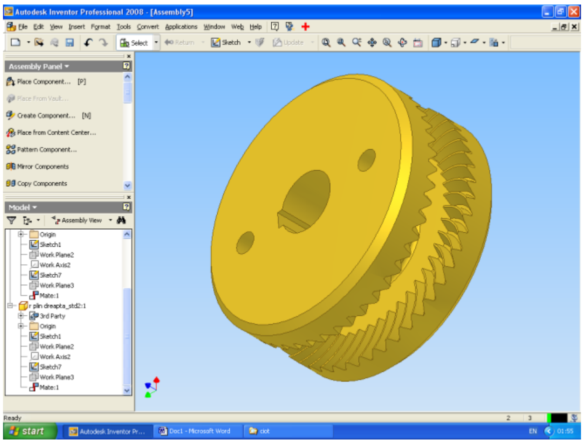

Fig.3. Numerical model double worm-face wheel

4. Conclusions

Mathematical and numerical study conducted above, allows highlighting a set of conclusions among which should be mentioned the following:

- matrix-vector mathematical model of technological gear hobbing formed at operation presented in this paper is proven correct by numerical study conducted;
- proposed mathematical model could form the basis of achievement in the future by

modelling techniques of wheel that is then analyzed FEM;

- proposed mathematical model could form the basis of future achievement of physical wheel through the techniques of modelling and prototyping;
- achieving double worm-face wheel through tangentially advanced of the hob is a process for industrially applicable through clear advantages that it has both in terms of quality and productivity obtained wheel hobbing given the simultaneous processing of the two crowns gear;
- For small series manufacturing the double worm-face wheels can be hobbing with tangential advance method using a fly cutter choosing an appropriate cutting regime;

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