18th International Research/Expert Conference
”Trends in the Development of Machinery and Associated Technology”
TMT 2014, Budapest, Hungary 10-12 September, 2014

SOME SPECIFIC ASPECTS REGARDING THE MANUFACTURING OF SPECIAL WORM GEAR DRIVES

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ABSTRACT
The purpose of this paper is twofold, firstly it will go through the geometrical and functional particularities of concave transmissions, and secondly it will present the theoretical and experimental findings regarding the production of high quality special worm gears. The developed methodology is oriented for use with point cloud surfacing construction and CNC machining of the gear. This method has been tested and proven, having good results in real production.

1. WORM GEARS WITH A CONCAVE – CONVEX PROFILE

Because of their superior characteristics, beginning with the last century, worm gears have been the main subject for some complex researches in the area of transmissions. The contact between the special concave shape of the tooth of the worm and convex shape of the worm wheel results in a instantaneous contact surface which gives the gear special properties [3] [4] in forming the lubricant film.

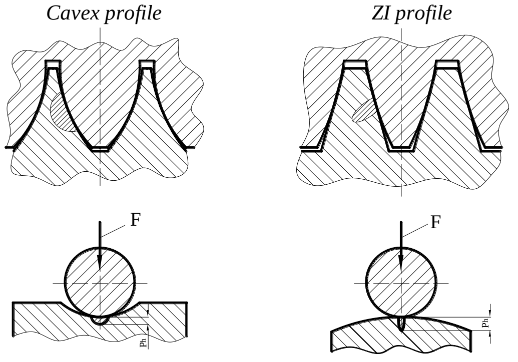

Fig.1. CAVEX gear and ZI gear [1]

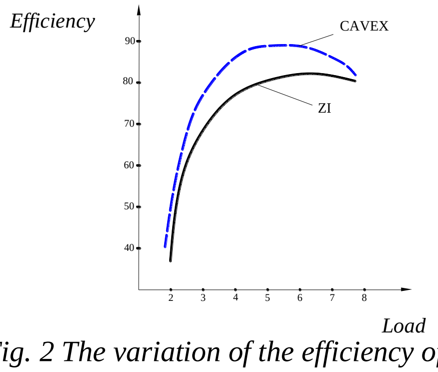

Fig. 2 The variation of the efficiency of type ZI and CAVEX worms in relation with the load in the transmission [1]

Next in this article we will present a recommended production method of these worms, on high performance and high precision CNC machines.

2. A NEW MACHINING TECHNOLOGY OR GENERATION OF THE CONCAV PROFILE OF THE WORM WITH A FINGER TYPE TOOL

2.1. The Definition of the worm profile and of the work surface of the milling tool.

We assume that the axial profile of the worm is described by a point on the milling tool in the X_z coordinate system which is depicted in figure 3.

$$\bar{\mathbf{x}}_z(t) = \left[x_z^1(t), \quad x_z^2(t), \quad 0\right]^T \tag{1a}$$

where: t - profile parameter.

$$m_z = tg\alpha_z \tag{1b}$$

Where: m_z - axial module

α_z - angle of the tangent with the axial profile of the tool in the given point.

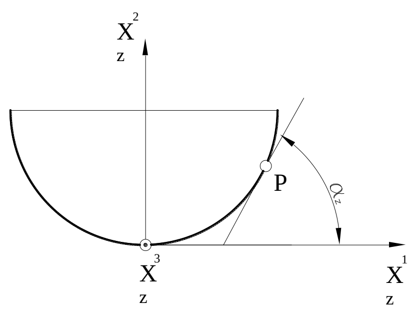

Fig. 3. Description of the active axial profile of the tool [7]

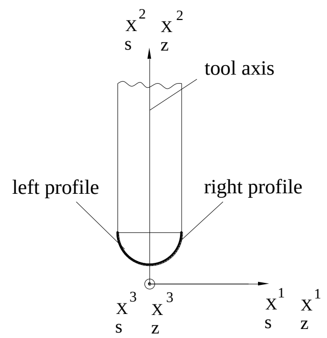

Fig. 4. Finger type milling tool [7]

The active finger type tool surface can be described (fig. 4) with the following formula:

$$\bar{\mathbf{x}}_s(t, \quad \varphi) = [2, \quad \varphi]\bar{\mathbf{x}}_z \tag{2}$$

where: φ - the angular parameter (angular parameter in the axial section) of the active section of the tool

2.2. The positioning and the relative movement of the tool in relation with the worm gear.

For every positioning of the tool we need to take into consideration the distance between the tip of the tool and the axis of the worm (fig. 5):

$$\bar{\mathbf{x}}_0 = \bar{\mathbf{x}}_p + [r_0, \quad 0, \quad f]^T \tag{3}$$

where: r_0 - radius of the distance between the axis of the worm and the tool;

f - the positioning of the tool in relation with the worm axis.

The X_0 coordinate system is tied to the tool, and at the beginning of the milling process this coordinate system is in the same position as the worm's coordinate system, which is fixed. After the milling process has started the coordinate system changes its position – figure 6. If we take into consideration the relative helical movement at the beginning of the milling process when the two axes (the one of the worm and the one of the milling tool) are in the same position, the family of equations in a single coordinate system can be deduced accordingly:

$$\bar{\mathbf{x}} = [3, \quad -v]\bar{\mathbf{x}}_0 + [0, \quad 0, \quad \pm pv]^T \tag{4}$$

where: v - the helical movement parameter between the tool and the worm shaft;

p - the helical surface parameter $\left(p = \dfrac{H}{2\pi}\right)$;

$\pm$ - helix inclination on the right or left.

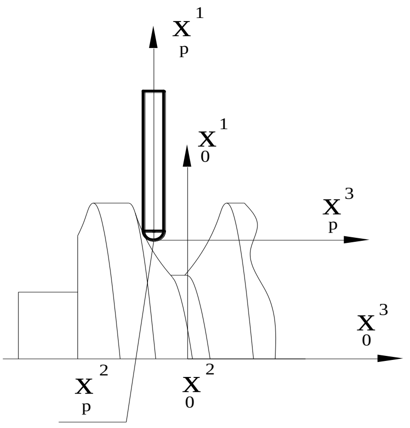

Fig. 5 The positioning of the tool in relation with the worm

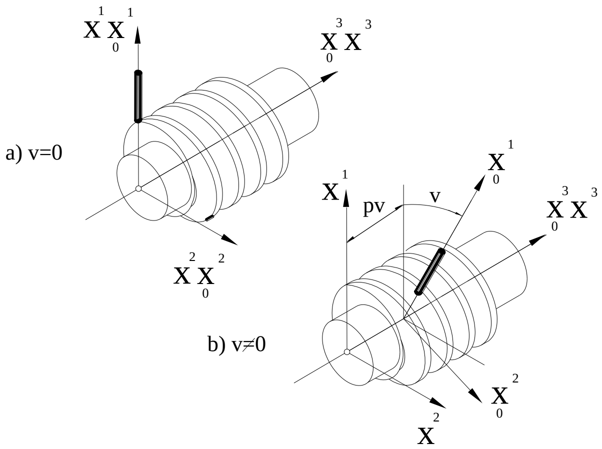

Fig. 6 Finger type tool. The relative coordinate system between the axes:

a) The positioning at the beginning of the relative movement;

b) Helical relative movement [7].

Finally we describe the general formula of the tool generated surface in the worm shaft's coordinate system.

$$\bar{\mathbf{x}} = [3, \quad -v]\left\{\left[3, \quad \frac{\pi}{2}\right]\left[2, \quad \frac{\pi}{2}\right][2, \quad \varphi]\bar{\mathbf{x}}_z + [r_0, \quad 0, \quad f]^T\right\} + [0, \quad 0, \quad \pm pv]^T \quad (5)$$

Equation (5) is the generated surface by the finger type milling tool after one pass. The whole surface of the worm will result after a number of passes as a family of such surfaces with different values for r_0 and f. Therefore it is necessary to describe the values of r_0 and f parameters in the axial section of the worm, for every position of the finger tip tool, in order to obtain the desired axial profile of the worm.

3. THE CALCULUS RESULTS

The machining technology depicted in the above sections was implemented in a program that calculates the axial profile of the worm's tooth in certain points (the profile can be shown in a table as a coordinate set) and the equidistant points of the spherical centre of the tip of the tool. These coordinates can be used as a comparison for the measured values or you can implement them in a CAD software for 3D generation.

The entry data for the calculation are the worm's parameters and the axial section's profile of the tool radius (finger type machining tool or abrasive finger type body) – fig. 7. As depicted in the figure you can choose from three types of profiles: a worm with a circular concave profile, a worm with a circular convex profile or a worm with a linear profile.

The axial profile of the worm and the slope angle correspondent to each point of this profile was described as a set of points (fig. 8.). The main worm parameters are known from the data that has been introduced in the previous window, but in the current window the real form of the worm's gear will appear.

The numerical value of the points of the profile and the numerical value of the correspondent slope angles of the profile of the side of the worm can be found in table from the dialog window. The data from the table can be saved as a text file and can be used for the generation of a 3D model or for comparison with the measurements values form a coordinate measuring machine.

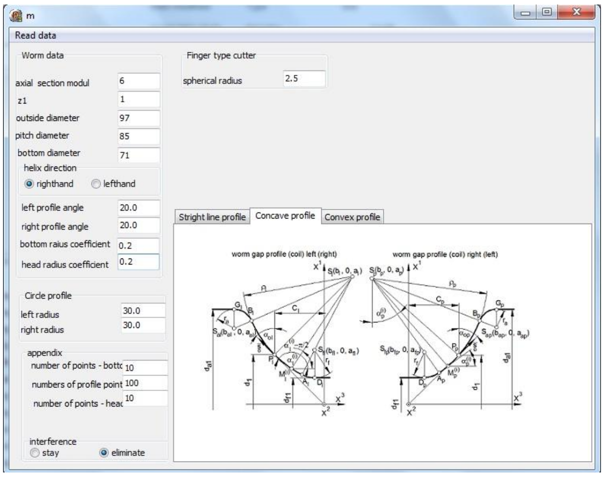

Fig. 7 Entry data for worm profile calculation

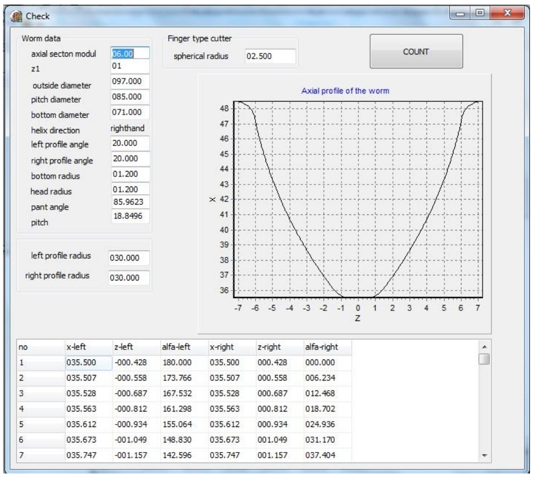

Fig. Axial section of the worm ($r_f = 2.5\,[mm]$)

4. CONCLUSIONS

This is a universal method which can be applied for any type of worm's profile and for any diameter of the tool, because the diameter of the finger type milling tool does not significantly influence the machining precession.

If we have any given profile of the worm which is defined by a number of points for which the tangent to the corresponding points are known, the current method can be applied for any type of worm, not just for the ones with a concave profile.

The tool used for machining the profile is a universal finger type tool. The tip of the tool has a spherical shape, a very popular and common profile. These tools can be made out of new materials, based on metallic carbide, materials that increase the wear resistance and machining speeds of these tools, therefore reducing the required time for machining the worm.

MANUSCRIPT SUBMISSION

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