Worm Gearings with Internal Worm. Modelling and Manufacture.

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Abstract: The internal worm gear pairs are special ones, which are composed by a helical worm and an internal teeth worm wheel. The paper presents some aspects of construction models, mathematical model and the manufacturing method. Also, it presents the special devices which need for manufacturing.

Keywords: internal worm gear, helical worm hob

1. INTRODUCTION

The internal worm gearings are composed by a worm gear and an internal teeth worm wheel. This type of worm gearing was patented by Pay E. [1]. After the publication of this patent appeared the necessity of the execution of helical worm, essential element of the worm gear pair. Thus in 1987 is patented the “Worm hob for the manufacturing the helical worm” [4]. Two years later, after solve of some technological problems at the I.M.M.U.M. enterprise, had been executed the first helical worm with the devices patented in 1987 (figures 1 and 2).

The results were promising. Were approach aspects regarding the precision, the mating surfaces, and the gearing conditions of these worm gears.

The first recognition of the success was obtained after a Ph.D. theses in this field in 2001 [3]. Also, was realized the first helical worm hob (figure 3) [3,4] and were established the gearing limits in the general case when the angle between the worm’s and worm wheel’s axis is between 0 and 90 degree.

In the paper we will presents the constructive models, the mathematical model and the simulation of the contact between the worm and the internal teeth worm wheel and the execution method of these special worm gear pairs.

2. CONSTRUCTIVE MODELS

A helical worm and an internal teeth worm wheel compose the internal worm gear pairs. At this gear pair the axis can have different positions: parallel, perpendicular or general.

Figure 4 presents an internal worm gearing with perpendicular axes.

Mathematical modeling resembles that of the globoid worm gearing. At this type of gearing, assembling problems occur, as for worm bearing very large worm wheels are to be used.

Figure 5 represents the general case, which is the one when the angle between the worm’s axes and that of the worm wheel encloses an angle between 0° and 90°.

Though mathematical modeling is more difficult, we can state that it is the most favorable case for an internal gearing, as worm bearing faces no problems and we can reach reasonable dimension, along with high efficiency.

At the same time, the driving elements can be fixed in the interior of the worm wheel so as to obtain a reduction of the necessary space also. The determining of the gearing field and the computer simulation of this type of gearing represent the research at present.
As we can observe from the facts above, at internal worm gearings it is not necessary for the angle between axes to be of 90°, even any angle between the axes being favorable, contrary to the cylindrical or globoid worm gearings, where the angle between the axes is of 90°.

3. THE MATHEMATICAL MODELING OF INTERNAL WORM GEAR PAIRS

The kinematical generation can be a vectorial mathematical model or an analytical mathematical model.

Fig. 4. Internal worm gear pair with perpendicular axis

Fig. 5. Internal worm gearing with any axes

In this paper we will present an analytical generation method in general case when the angle between the axes is between 0 and 90 degree [3] [4], [6]. This method is an analogy with the globoid worm gears [3].

The used coordinate systems in figure 6 are:
- O₁x₁y₁z₁ - the worm related reference system; the worm rotation axis is the Z₁ axis; the relative position of the technological reference system is given by the φ₁ parameter - the worm rotation angle;
- O₀x₀y₀z₀ - the functional reference system; it is the reference system considers to be fixed;
- O',x',y',z' - a fix system, which is rotate to O₀x₀y₀z₀ system with γ = constant angle, where γ = (0°, 90°);
- O₂x₂y₂z₂ - intermediary fix system which is translate to O₀x₀y₀z₀ system with the distance between the axis “a” on the direction of O₀z₀ ax;
- O₂x₂y₂z₂ - the wheel related reference system; the wheel rotation axis Z₂ is parallel to Z₁ and perpendicular on the paper plane; the relative position to the technological reference system is gave by the φ₂ parameter - the wheel rotation angle;

The worm’s flank is generated by “u” straight line, which is in the paper plane, also the division diameter of the wheel. The generate line is always tangent to the profile circle with “r” radius (figure 7.).

The coordinates of motion point from the worm after the transformed of generate line’s coordinate from the worm wheels system into the worm system is the follow:

\[
x₁ = -\cos φ₁ (a - r_0) \sin (ϕ₂ - α_{ax}) + u \cos (ϕ₂ - α_{ax})
\]

\[
y₁ = -\sin γ \sin φ₁ (a - r_0) \sin (ϕ₂ - α_{ax}) + u \cos (ϕ₂ - α_{ax})
\]

\[
z₁ = -\cos γ \sin φ₁ (a - r_0) \sin (ϕ₂ - α_{ax}) + u \sin (ϕ₂ - α_{ax})
\]

(1)

In figure 8 we presents the simulated worm used the relation 1. In the follow, we obtained the gearing equation for this type of worm gear pair.

We can write the equation as a square equation in “u” because the variable both in the normal components
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Fig. 7. The scheme used for generation

and the relative speed components is „u”. The gearing equation will be [5]:

\[ \begin{align*}
M &= a_1 \cdot c_1 + a_2 \cdot c_2 + a_3 \cdot c_3 \\
N &= a_1 \cdot d_1 + b_1 \cdot c_1 + a_2 \cdot d_2 + b_2 \cdot c_2 + a_3 \cdot d_3 + b_3 \cdot c_3 \\
P &= b_1 \cdot d_1 + b_2 \cdot d_2 + b_3 \cdot d_3
\end{align*} \]

(2)

where

- \( a_1, a_2, a_3, b_1, b_2, b_3 \) are the components of the common normal
- \( c_1, c_2, c_3, d_1, d_2, d_3 \) are the relative speed components

The discriminator of this equation is

\[ \Delta = \sqrt{N^2 - 4MP} \geq 0 \]

therefore the equation has real roots.

Figure 9 presents the mating surfaces for different

\[ i_{21} = 40, q = 14, m = 10, \gamma = -10^\circ \]

\[ i_{21} = 40, q = 14, m = 10, \gamma = +10^\circ \]

\[ i_{21} = 40, q = 14, m = 10, \gamma = +20^\circ \]

Fig. 9. Mating surfaces for different angles [3] angles between the axes [3].

4. THE MANUFACTURE OF THE INTERNAL WORM GEAR PAIR ELEMENTS.

Taking into account the advantages of the ruled profile generation, we considered both the helical worm and the helical worm hob with ruled profile. Figure 10 presents the technological scheme of manufacture the

Fig. 8. The simulated worm [3]
elements of this type of drive, and the special devices, which are necessary. The manufacturing method is appropriately to the manufacturing of globoid worms with the CONE method [3].

The helical worm precision is influenced by the fixing precision of the hob’s teeth, of the tool’s edges, and of the devices used.

Since now we achieved only the worm wheel with attached teeth. The teeth were realized by casting, and were finishing with the helical worm hob (figure 11).

In figure 12 we presents the helical worm – internal teeth worm wheel drive.

CONCLUSIONS

- The internal worm gearings are made up of an ellipsoid worm and an internal teething worm wheel. These gearings, especially those with perpendicular axes, can be named reverse globoid worm gearings or anti-globoid, as they have similar characteristics.

- The angle between the worm axes and of the worm wheel can range between 0° and 90°. It is even advantageous for the angle to be other than 90°, thus not considering the problem of worm bearing.

- For the time being we consider both the worm and the helical worm hob with ruled profiles, but theoretically their profile can be generated by any curve. For processing, we used two special devices. By there aid a processing, which we could call of anti Cone type, occurred.

REFERENCES


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