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KINEMATICAL INACCURACIES OF THE SPIROID GEARS

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***Abstract**: There are described the characteristic attributes of spiroid gears in the article. Some kinematical inaccuracies caused by mistakes in gearing assembly are analyzed there. A testing stand is supposed to carry out an experimental research of inaccuracies influence on smooth run of machine aggregate.*
***Key words:** gears, geometry, kinematical inaccuracies, deviations*

1. INTRODUCTION

Gearbox is an important component of energy transmission chain within technical equipments. Dynamic properties of the gearing affect behavior of a machine aggregate as the complete unit and effect also technological process quality to a large degree. They depend mainly on kinematical and geometrical deviations of the gearing.

The spiroid gearing is an intermediate gearing type ranged between hypoid and worm gearing pertaining to gearing group with skew line axes. It consists of spiroid worm with its cylindrical or cone shape and of spiroid disk gear with teeth of arc shape (Goldfarb, 1999).

Fundamental difference between "classical" and spiroid worms lies in the profile asymmetry of the spiroid worm (Fig. 1). The asymmetrical profile is needed so as to ensure approximately equal conditions for meshing and relief of the components being in mesh from both profile sides.

The goal of this contribution paper is to complete information on field of the spiroid gear geometry, kinematics and kinematical inaccuracies (Goldfarb, 2001).

Benefits of the spiroid gears can be summarized as follows:

- high rate of overlap, which means a larger number of teeth in the current mesh (8 through 30),
- favourable distribution of the contact lines and the traction field in terms of liquid friction,
- simple gearings production,
- variety of configuration options of transfer, and compactness as well as, resulting in a wide range of applications,
- variety of materials utilization when different combinations of material pairs can be used,
- low noise, high durability and continuity of operation.

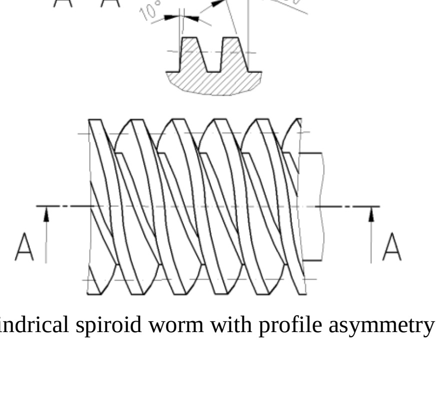


Fig. 1. Cylindrical spiroid worm with profile asymmetry

2. KINEMATICAL INACCURACIES OF THE SPIROID GEARS

A case of utilization of an asymmetrical thread profile of the spiroid worm is shown in Fig. 2. The said worm consists of straight line surface originated by movement of the forming line u on the helix within the unmovable coordinate system $0\ (x,y,z)$ (Majerčák, 1997).

The initial surface of the spiroid gearing with cylindrical worm is rotating cylinder with its radius r_d and the corresponding plane, when they are in mutual contact through line collinear with the axis z of the first member and perpendicular against the axis z_0 of the second member. The basic assumption is that the worm helix has to run through point N of the line and has to be in contact with velocity vector.

Location of the arbitrary point M of the worm surface within coordinate system 0 (x,y,z) is explicitly given by positional vector $\mathbf{r}_M$ which can be declared by its components:

$$\mathbf{r}_M = x_M\mathbf{i} + y_M\mathbf{j} + z_M\mathbf{k}\,, \qquad (1)$$

where the components are those of the vector (1) and they can be expressed by the parameters (ϑ, φ_1, u) as follows:

$$\begin{aligned} \mathbf{x}_M &= u.\cos\alpha.\cos\vartheta + r_d.\sin\theta \\ \mathbf{y}_M &= u.\cos\alpha.\sin\theta - r_d.\sin\theta \\ \mathbf{z}_M &= u.\sin\alpha + p\vartheta + \mathbf{z}_{t1} \end{aligned} \qquad (2)$$

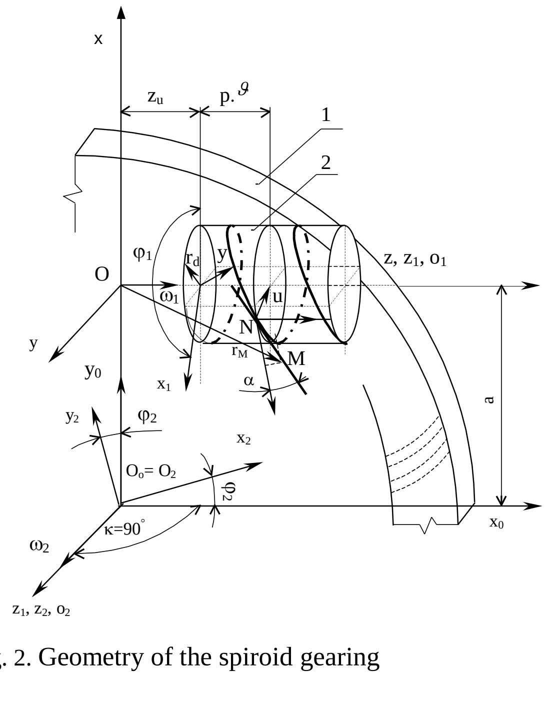


Fig. 2. Geometry of the spiroid gearing

After the components are set into equation (1), the worm surface equation has the form:

$$\mathbf{r}_M = (u.\cos\alpha.\cos\vartheta + r_d.\sin\vartheta)\mathbf{i} + (u.\cos\alpha.\sin\vartheta - r_d.\sin\vartheta)\mathbf{j} + \\ + (u.\sin\alpha + p\vartheta + z_{t1})\mathbf{k}, \quad (3)$$

where:

α angle of the forming line,

$\theta = \vartheta + \varphi_1$ - resultant angle of the helix normal,

ϑ - angle of the helix normal in the point $0_1(x_1,y_1,z_1)$,

$\vartheta = 2\pi.k$, where k is the multiple of the angle 2π,

φ_1 - rotation angle of the auxiliary coordinate system $0_1(x_1,y_1,z_1)$ against system $0(x,y,z)$,

r_d - generating cylinder radius of the spiroid worm,

p - spiroid worm pitch

z_{t1} - distance of spiroid worm front from the point 0.

When taking into account the kinematical and geometrical inaccuracies of the gears and gear backlash, the gear ratio becomes a periodically variable quantity, which depends on angular position against its frequency and is proportional to motor speed. This fact causes parametrical excitation within elastic system and it results in increase of dynamical loading in the machine aggregate.

The kinematical gear inaccuracy is given by position inaccuracy of the driven gear wheel, which is equal to difference between ideal and real seating of the output member as result of the incorrect production and assembly. The initial defects cause incorrect mutual positions of the competent gearing members.

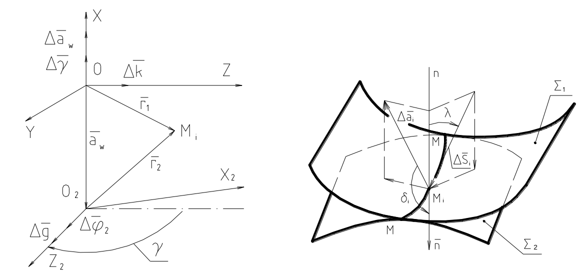
For compensation of the clearance in the normal direction, which is formed as result of the initial defect Δa_i action, it is necessary to ad displacement ΔS_i against the driven member. This relation can be written in the analytical form (4) in accordance with (Kral, 2002), when k means number of the initial defects within gear:

$$\left(\Sigma_{i=1}^{k}\Delta\overline{a_i} + \Delta\overline{S_i}\right)\cdot\overline{n} = 0 \quad (4)$$

The standard initial defects of the spiroid gear are (Fig. 3):

- deviation of the interaxial angle $\Delta\gamma$
- deviation of the axis distance Δa_w
- deviation of the gear wheel axis setting Δg
- deviation of the pinion axis setting Δk

One of the important properties of the spiroid gearings is possibility to gain a large overlap factor. With regard to arrangement (distribution) of the gear mesh zone, to the nature of the contact surfaces being in mutual touch and to the other geometrical and kinematical properties, the spiroid gears are much less sensitive to production and assembly defects as the other gears with skew line axes. There are fewer influences of the production inaccuracies, which could evoke vibration within spiroid gearings.



a b

Fig. 3. a - Depiction of the standard initial defect vectors
b - Depiction of teeth surface contact

Distribution of the contact lines and mesh fields upon the spiroid gears is convenient also with regard to vibration damping. The contact lines are distributed conveniently for oil wedge formation within mesh. This fact makes possible to increase loading capacity and resistance against wear. The distribution of the radiuses of curvature and their high value, which belongs to the spiroid gears, is also one of the reasons that the said gears possess decreased sensitivity to vibration appearance.

3. EXPERIMENTAL RESEARCH

The experimental research of the kinematical inaccuracy of the spiroid gear supposes to choose the way of kinematical inaccuracy evaluation, to product experimental equipment, to elaborate the experiment methodology and results evaluation.

A test stand has been developed for experimental research. This experimental equipment supposed for dynamical loading of the machine aggregates makes possible to observe aggregate parameters influence on the angular speed irregularity $\omega(t)$, on the driving torque $M(t)$ or to obtain dynamic characteristic of the machine aggregates within stable and transitive conditions $M(\omega)$ (Mudrik, 2008).

The said testing equipment makes possible to consider suitability of spiroid gear design with regard to its operational reliability, accuracy and performance within various loading variants. Measurement course of the given quantities can be observed visually within experiment run and the measured values can be processed subsequently into numerical or graphical measurements results outputs.

4. CONCLUSION

The experimental research using the testing equipment makes possible to confront the measured results with the results obtained through analytical solutions.

Thorough vibrations and kinematical inaccuracies study of the spiroid gears, the additional properties of the spiroid gears can be investigated. It allows then to design mechanism with improved accuracy and better vibration-acoustic properties.

Research of various influences on the kinematical accuracy presents starting point for research of the dynamical processes within spiroid gears.

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