3D Software Technology for Practical Realization of Special Hyperboloid Gear Mechanisms

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1. Scientific importance of the problem

The wide application of the different types gear transmissions in different engineering machines, devices and robots define the necessity of forming an appropriate strategy for choosing the right type motion transformers from a functional view point with their effective realization and also from technological point of view. The choice of the optimal type gear mechanisms is connected with determining the common section of the above defined two groups of requirements. This is realized by comparison between the exploitation properties of mechanical transmissions with their technological characteristics and with the manufacturing cost.

The science of the gear mechanisms together with the above problem is necessary to create the preconditions for finding out and studying new and little known characteristics of multibody systems transforming motions in accordance with preliminary given laws. This is a premise for development of scientific studies serving the synthesis and design of new types gear transmissions that would satisfy concrete industrial requirements. The solution of the second task is based on development of adequate mathematical models. These models describe the physics of the processes of motion transformation and based on them approaches to the synthesis and design of the corresponding transmissions.
2. Usefulness and applicability of the obtained results

The study presents description of physical prototyping and technical realization of specialized miniature spatial gears. A feature of these gears is the necessity to realize a smooth transformation of rotations with constant values of the velocity ratio for the entire work. They are hyperboloid gears with linear contacting active tooth surfaces at the maximum coincidence of the theoretical and the actual realization of their geometric and kinematic conjugation. The defined goal is achieved by application of 3D software technology.

The application of the 3D technology gives a certain impetus in development of the innovation in the elaboration of spatial gears. The result is shortening of the cycle of the gear’s realization; an elimination of teeth generation errors; a sharp increase of accuracy in gears manufacture and etc.

In the study solutions of some of the tasks included in the 3D technology for the creation of the physical prototypes of two class skew-axes gears of type Spiroid and Helicon are illustrated. These gears are dedicated for incorporation into the drive of the fingers of the robot-hand.
3D software technology oriented towards elaboration of special small module, small size hyperboloid gear drives include the following stages:

- **Mathematical modeling for optimization synthesis of skew-axes gears upon a „pitch contact point“**;

- **Development of a mathematical model for synthesis upon a „mesh region“ (development of a 3D CAD model)**;

- **3D printing of the synthesized gear drives.**
3. Mathematical model for synthesis upon a pitch contact point

Two basic tasks are solved, when:

\[ i_{12} = \frac{\omega_1}{\omega_2} = \text{constant} \]

- Synthesis of pitch configurations;
- Synthesis of active tooth surfaces.

**Figure.** Geometric – kinematic scheme of spatial gear pair with linear or pitch contact between tooth surfaces \( \Sigma_1 \) and \( \Sigma_2 \);

- \( H_i \) \((i = 1,2)\) - pitch configurations: pitch circles; \( \Sigma_i \) \((i = 1,2)\) – active tooth surfaces;
- \( L_i \) - longitudinal line of \( \Sigma_i \); \( \vec{w}_i \) \((i = 1,2)\) – angular velocity; \( \vec{V}_{12} \) - sliding velocity at pitch point \( P \);
4. Synthesis of the Pitch Configurations

Synthesis of Pitch Configurations

\[ r_1 \cos \theta_1 = r_2 \cos \theta_2 \cos \delta + a_2 \sin \delta, \]
\[ r_1 \sin \theta_1 = a_w - r_2 \sin \theta_2, \]
\[ a_1 = r_2 \cos \theta_2 \sin \delta - a_2 \cos \delta, \]  \hspace{1cm} (1)
\[ \cos \delta_1 \sin \theta_1 = \cos \delta_2 \sin \theta_2, \]
\[ \sin \delta_1 = \sin \delta_2 \cos \delta + \cos \delta_2 \cos \theta_2 \sin \delta. \]

We examine (1) having in mind that
\[ \theta_1 \in (0, \pi/2], \quad \theta_2 \in (0, \pi/2], \quad \delta_1 \in [0, \pi/2), \]
\[ \delta_2 \in [0, \pi/2], \quad a_i \geq 0. \]

Fig. Externally contacting pitch circles \( H_i^c \) \( (i = 1, 2) \) and pitch surfaces \( H_i^s \) \( (i = 1, 2) \) with a normal orientation, corresponding to hyperboloid gears with external meshing.
5. 3D software realization of spatial gear pairs

Fig. Computer design of spatial gear drives of type Helicon and Spiroid: a) geometric pitch configurations, b) CAD model
Fig. Helicon gear drive with offset 4 mm, gear ratio 40/10 (axial module 0.5 mm): a) 3D CAD model; b) 3D printed model (the shown scale is in mm)
Fig. Spiroid gear drive with offset 4 mm, gear ratio 40/10 (axial module 0.5 mm): a) 3D CAD model; b) 3D printed model (the shown scale is in mm)
Fig. Helicon gear drive with offset 3,25 mm, gear ratio 32/8 (axial module 0.5 mm): a) 3D CAD model; b) 3D printed model (the shown scale is in mm)
4. 3D software realization of spatial gear pairs

Fig. Spiroid gear set with offset 3.25 mm, gear ratio 32/8 (axial module 0.5 mm): a) 3D CAD model; b) 3D printed model (the shown scale is in mm)
6. Technical Application

Figure. Model of robot hand: a) whole hand; b) forefinger - 1-bevel gear; c) bevel gear with straight teeth with $i_{12} = 4$; $z_1 = 10 ; z_2 = 40 ; m = 0.5 \text{ mm}$
Conclusion

In this study is shown the 3D software technology which is realized on the basis of:
-model for optimization synthesis of skew-axes gears upon a „pitch contact point“;
-model for synthesis upon a „mesh region“ (development of a 3D CAD model);
-3D printing of the synthesized gear drives.

The main idea of the application of 3D software technology is the elaboration of physical prototypes of spatial hyperboloid gear sets. They are dedicated for integration into transmission of special medical robot systems; into micro robots designed for rescue operations and into special military devices. This technology can serve the manufacturing of a small series complicated mechanical systems, requiring an expensive technology for production.
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Thank you for your attention!