EQUIDISTANT TOOTH GENERATION ON NONCYLINDRICAL SURFACES FOR TWO-PARAMETER GEARING

Senior Staff Scientist Yuriy GUTSALENKO, Associate Professor Alexander MIRONENKO, Associate Professor Tatyana TRETYAK
National Technical University “Kharkov Polytechnic Institute”, Ukraine

Abstract: The questions of design research of noncylindrical tooth surfaces for two-parameter gearing on example of bevel gears with constant normal pitch for gearing variators are been considered. Engineering is based on the special applied development of the mathematical theory of multiparametric mappings of space.

Keywords: gear-shaping cutter, bevel gear, constant normal pitch, two-parameter gearing, gearing variator

1. Introduction

Certain results of researches and designs in the network of this approach supporting design research development of engineering and conversion for a full-scale realization of technical ideology of the two-parametertoothed variators with use of the noncylindrical gears with constant normal pitch [1, 2] are considered here.

Theoretical fundamentals of the two-parameter gears mesh and wheelworks based on the special gear wheels with constant normal pitch inclusive of variators are developed by Ukrainian Soviet scientist V.R.Kovalyukhand primarilywere to develop goods for special technicsat the expense of overall advantages uppermost. Wheels with "equal-high-broad teeth andgashes" [1] have equidistant helix line of teeth which are situated at kinematic pitch surface of rotation of generating profile with variable radius of generatrix. Two-parameter character of gearing consist in independence of running-in parameters and alteration of wheel relative position. Equidistant toothgeometrical come out as result of implementationof dual one-parametric motion of particle: about axis ofkinematic pitch surface and in the line of it generatrix [1].

Unified approach to theoretical and practical developments of objects, tools and processes of machining founded by B. A. Perepelitsa on multiparametric affine mappings of space [3] and accepted at the NTU “KhPI” Scientific and Technical School of Physics of Cutting Processes allows to consider different kinematical and geometric aspects and interactions over a period of product life cycle on the unified mathematical elemental platform.

Considered approach and experience of its consistent theoretical development [4, 5]; supporting by software [6] and generalization in the line of developing of theoretical bases of generation of unified multiparametric information for CAD/CAM systems of gearing, tools and gear processing [7-10] are identify oneself with trend dominance in industrially developed countries of world a so-called CALS-technologies associated with paradigm of use of interconnect information space (integrated infomedia) on the base of international standards for uniform information interaction of all participants of product life cycle: customers and suppliers, exploiting and maintenance personnel.

2. Model of shaping

Workable approach allows considerably simplify accounts and reduce of timetable formaking of geared variators of new generation about double- and three-link two-parameter transmission gears using advanced bevel or spherical gears with constant normal pitch (equidistant helix line of teeth).
The main difficulties of design and practical implementation of gear-shaping technologies of the two-parameter gears mesh and wheelworks based on the special gear wheels with constant normal pitch are tied with shape-generation complexity of noncylindrical gears. Comparative analysis of toothline placement on the bevel and spherical kinematic pitch surfaces (Fig. 1) on example with similar geometrics (Table 1) illustrate comparative comparatives of considered geometrical variants of noncylindrical gear:

- Toothline on spherical kinematic pitch surface is more lengthy, and this disparity increases with increase of radius of lateral generatrix that makes possible to change the angles of skew axes in greater range, and thereby it is possible to increase functionality of gear on the base of spherical wheels;
- Mass of bevel wheel is less and so gears on the base of such wheels will be prime mass-overall data.

**Table 1:** Comparison macrocharacteristics of noncylindrical gear geometrical variants with equidistant helix line of teeth equal-tilted initially for initial work material with height of 60 mm, diameters of base and vertex of 80 mm and 40 mm, respectively

<table>
<thead>
<tr>
<th>Work material form</th>
<th>Length of lateral generatrix, mm</th>
<th>Length of tooth line, mm</th>
<th>Mass of steel block, kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Truncated cone</td>
<td>63.25</td>
<td>80.80</td>
<td>1.371</td>
</tr>
<tr>
<td>Layer of sphere</td>
<td>68.47</td>
<td>93.57</td>
<td>2.195</td>
</tr>
</tbody>
</table>

Unified technical approach [3, 8] can be used in simulation for research of gears with different degree of complexity. Three main forming methods in gear treatment are marked out and investigated [10] with use of mathematical model generalizations [7, 9]. Model on principle of copying includes two methodical variants of treatment, there are by generating line and tool surface; and model of revolving is based on point contact of gear-shaping tool and workpiece, in this connection machine and working gearing are completely identical. Hereitwill be considered in application to bevel gears, Table 2.

Omitting here subsequent consideration of the first two models respectively supported on the use of pencil and disk shaping cutters (milling cutters) we will consider third scheme of shaping (Table 2) remembering that permanent meshing of kinematics by rise of movement number is taken placed when conversion from the first to the third shaping method [10].

According to the third scheme of shaping a gear production is realized by revolving than with indexing movement such as by the first two schemes. In generalized structural formulation:

\[ \overrightarrow{r} = \varphi_2 \overrightarrow{\beta} \overrightarrow{R_1} + \varphi_1 \overrightarrow{\psi} \overrightarrow{R_2} + \overrightarrow{\varphi_1} \overrightarrow{u} \overrightarrow{R_2} \].

Tool makes additional turn \( \overrightarrow{\beta} \) and at the same time translational movement \( \overrightarrow{u} \) along pitch element which commits rotary \( \overrightarrow{\psi} \) and reverse \( \overrightarrow{\varphi_1} \) motions about proper axis. Parameters of broadened matrix notation [9] are possessed the value: \( \varphi_1 = 0; m_{\varphi_1} = 1; \varphi_2 = 0; m_{\varphi_2} = 1 \).
Table 2: Gear cutting technique for bevel gear wheels with constant normal pitch

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Copying (with dividing)</th>
<th>Running-in with a point contact</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>by generating line</td>
<td></td>
</tr>
<tr>
<td>Kinematic scheme</td>
<td>by tool surface</td>
<td></td>
</tr>
<tr>
<td>Concise description</td>
<td>The tool is end-mill type gear cutter with shaped profile making linear motion along one conegenerating line, and conic workpiece makes re-rotary motion from independent drive</td>
<td>The tool is disk cutter with shaped profile making linear motion in the line of cone generating line, spinning motion and rotary motion of additional turn. Conic workpiece turns from independent drive</td>
</tr>
</tbody>
</table>

Shaping by the first two methods does not reproduce the kinematics of real gearing in full; necessity of divider application is leading to accumulation of error on every next tooth. The first method (with point contact of tool surface) can be considered as scheme of preprocessing. The second one (with more accurate line shape-generating contact) can be used for making of gears with mean quality indexes. Examined here the third method excludes all listed shortcomings, but needs in high-value equipment. Realization of this processing technique by running-in method allows to obtain theoretically accurate tooth surface profiles and make bevel gears with high quality metrics. Model of forming by copying technique with dividing can be used on production for gears of average and low degree of accuracy or like preliminary, and model of forming by running-in technique can be used in treatment of gears with fine precision.

3. Software
At the NTU “KhPI” [9] it has been worked the complex of modules for execution of computing experiments and obtaining of visual images for verification of direct motions as inverse ones and characteristics of rounding which in the aggregate are accountable for accuracy of shaping of gearing.
Software of complex of modules for geometric simulation of objects, tools and processes of gear treating involute and noninvolute shaping based on their systematization and multiparametric mappings consist of application programs of detached judgment of particular tasks and the main program protective conformity of solutions of particular tasks, required compatibility of conditions of working and generating gearings.

The soft complex can be used at the different stage of life cycle for objects and tools of gear treatment (design, production, manufacturing and field inspection, culling). It is recommended for applicability checking calculation of serially producible tool in specific gear treating intents as well as for performing calculations and visualization of geometry of special purpose tool if standard tool application is found impossible.

Table 3: Calculating-graphic modules for simulation of detail (D), tool (T) and kinematics (K) in special gearing design

<table>
<thead>
<tr>
<th>Module</th>
<th>Object</th>
<th>Objective</th>
<th>Mathematical kernel</th>
<th>Development resource</th>
<th>Formalization of information</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>Involute</td>
<td>D</td>
<td>Calculation of tooth surface in normal section</td>
<td>Synthesis of known tooth shaping calculations in united complex</td>
<td>Delphi</td>
<td>Module, tooth number, gear-pitch angle, type of tooth surface</td>
<td>Graphics and table of 2D coordinate arrays</td>
</tr>
<tr>
<td>Profile</td>
<td>T</td>
<td>Calculation of tool profile in normal section</td>
<td>Own product on the base of theory of mappings</td>
<td>Fortran</td>
<td>Output information of Involute module, tool type and parameters</td>
<td>Table of 2D coordinate arrays of tool profile in normal section</td>
</tr>
<tr>
<td>Kromka (Edge)</td>
<td>T</td>
<td>Tool visualization</td>
<td>Developing of the Institute of Applied Mathematics of the Russian Academy of Science</td>
<td>Grafor</td>
<td>Output information of Profile module</td>
<td>Vector graphics</td>
</tr>
<tr>
<td>Helix</td>
<td>K</td>
<td>Calculation of equidistant tooth lengthwise curves</td>
<td>Own product on the base of theory of mappings</td>
<td>C++, Csape</td>
<td>Geometric and technical wheel parameters</td>
<td>Table of 3D coordinate arrays of tooth lengthwise curves</td>
</tr>
<tr>
<td>Spiral Surface</td>
<td>K</td>
<td>Vizualization of equidistant tooth lengthwise curves</td>
<td>Application of library of algorithical language</td>
<td>C++, Csape</td>
<td>Output information of Helix module</td>
<td>Imagery of equidistant tooth lengthwise curves on kinematic pitch surface</td>
</tr>
<tr>
<td>Zub (Tooth)</td>
<td>D</td>
<td>Vizualization of tooth surface lengthwise of equidistant curves</td>
<td>Own product on the base of theory of mappings</td>
<td>Delphi</td>
<td>Output information of Helix, Kromka, Spiral Surface modules</td>
<td>Imagery of tooth surface on kinematic pitch surface</td>
</tr>
</tbody>
</table>

Complex (Table 3) is organized under principle of openness and may be completed by a new modules (programs) and internal modules (subprograms), as previously developed modules are exchanged for more perfect, and besides nonconflictingly. This makes it possible to maximum efficiently operate whole complex when there are taken place improvement of certain calculated procedures and their completion, appropriate compliant software engineering.

General idea of realized in complex modular approaches to algorithmic and software-based solutions of gearing profiling tasks on the base of its tipification with use the system of unified parameters and space mappings specially adapted to shaping by cutting is belonged to prof. B.A. Perepelitsa [3, 7, 8].
Processing results of complex program modules are used for stocking of CAD/CAM databased library, as well as for analysis and decision-making in tabular and graphic forms.

4. Special purpose shaper tool

In fulfilled engineering of gear cutting tools for shaping of noninvolute gears with constant normal pitch it is provided for exclusion of distorted profiling after tool regrinds. There are proposed constructive approaches; procedure for estimate of influence of bevel gear’s with constant normal pitch shaping parameters on quality metrics of two-parameter toothed gearing [9]; generalized and particular calculation algorithms [10], which may be used in dataware of respective CAD/CAM systems of maintenance for tooling backup. Among developed tools there are assembled shaping cutters [10] with prismatic and round cutters. Compensatory possibilities of proposed assembled shaping cutters are ensured by repositioning of shaped cutting edges after their regrindings by linear displacement of prismatic shaper cutters and angular displacement round ones respectively.

5. Bevel gears in double- and three-link variators with two-parameter gearing

Thanks to constancy of normal pitch gearing with equidistant helix line of teeth have improved functional properties, serviceability and fabricability as compared with constructions of two-parameter gearings with variable module et al. [7]. In advanced industrial practical application in different branches such vary-drives make it possible to synthesize a new adaptive resource-saving compact mechanisms and machines. Transformation of double-link two-parameter gearing on the base of bevel gear with constant normal pitch in tooth variable speed unit with variable (regulable) gear-contact ratio is made [2] by imposition of compound wheel in place of affiliate disk wheel with narrow gear ring (fig. 2).

Three-link cylinder-conic gear variators working with double complementary use of the same principle of controlled displacement of movable teeth of spur gear are completed by two such spur gears and central bevel gear with constant normal pitch of teeth.

Bevel gears withequidistanthelix line of teethalso [2] are pair entities of interaction with central gear in a form of spherical layer with constant normal pitch of teeth (fig. 1b) in three-link spherico-conical advanced variators.
6. Conclusions

Work executed with any given design accuracy allows to implement a design of tool and technologies of bevel gear forming with equidistant helix line of teeth including for special gear variators; as well as to achieve of labor saving, rise of level of theoretical justification and effectiveness in solution of current engineering tasks.

References


