

Development and Application of Computer-Aided Design and Tooth Contact Analysis of Spiral-Type Gears with Cylindrical Worms

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TECHNICAL PAPER

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[The statements and opinions contained herein are those of the author and should not be construed as an official action or opinion of the American Gear Manufacturers Association.]

Abstract

The paper presents the method of step-by-step computer-aided design of spiral-type gears with worms, which involves gear scheme design, geometrical calculation of a gearing, drive design, calculation of machine settings and tooth-contact analysis.

Models of operating and machine-tool gearing have been developed, including models of flank generation and their actual interaction with account of flank modifications, manufacture and assembly errors, force and temperature deformations, and drive element wear as acting in real gearing.

Possibilities of CAD-technique application are shown to solve design and manufacture tasks for gearboxes and gear-motors with spiral-type gears.

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DEVELOPMENT AND APPLICATION OF COMPUTER-AIDED DESIGN AND TOOTH CONTACT ANALYSIS OF SPIRAL-TYPE GEARS WITH CYLINDRICAL WORMS

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Introduction

The design process of any kind of gearing is a complex multi-step procedure; and different directions of the design and choice of parameters are possible with respect to many factors: initial requirements to the gear under design, mode of its operation, the applied technique, specific decisions made by a designer, and others.

The determinacy level of the design procedure depends on the accumulated experience of design, manufacture and application of gears, formalized as standards for the calculation and CAD systems.

Note that the design procedure is not quite determinate even for the most widespread cylindrical gear with its national and international standards and plenty of various computer systems, since there are (and obviously, there will be) many unsolved questions related with the strength evaluation, wear resistance, vibration activity, thermal balance, different degrees of manufacturing accuracy, materials of links, lubricants, modes of loading and so on.

Let's divide conventionally all the variety of gears into two groups depending on the existence or absence of standards (technique stated by law) for the calculation (design) of a gear. The first group is for gears with the worked out standards.

It's interesting to note that CAD systems for a gear design may be also divided conditionally into two groups depending on the same feature - availability of the standard design technique. The bases of first group CAD systems are standards. All the following computer systems (we name them CAI systems - Computer Aided Investigation) - applied to investigate the corresponding gearing - are a kind of subordinate ones and intended to solve special research tasks (influence of errors, stress loading, noise and so on) and modernize the basic standard and its corresponding CAD system.

The second group of CAD systems are in the essence CAI systems. The gear design is

performed in this case when investigating the range of parameter values. The design experience accumulated under such investigation may be formed as some CAD system which is a component of the CAI system and is mostly the information data base of design references for certain ranges of initial parameters.

Spiral-type gears are referred to the second group of gears. They are gears with skew axes with the geometrical features of hypoid type gears but they are related to worm type gears according to the manufacturing technique [1]. The remarkable role in the appearance (1954) and development of such gears was played by ITW Inc., under the trade name spiroid[®], and its representatives O.Saari [2, 3 and others] è W. Nelson [4, 5 and others]. Specific features and advantages of this gear are described in a great number of publications the major of which come from Russia lately [6, 7, 8, 9 and others] where it has been studied for about 40 years (spiroid[®] gears are young compared with others with the age of several centuries). Nowadays many varieties of this gear are known, some of them are shown in Fig.1, and their effective applications in different technical fields are known to be successful within a big range of performance parameters - gear ratio from 4 to 600 in one gear pair and torque from 1 to 50000 Nm and more.

The computer system for spiral-type gear design described in this paper is in the essence a CAI system.

Construction Fundamentals and Structure of Design Process

1. Any kind of gear may have the following sequence of CAD creation:

- the construction fundamentals and the structure of design process are formed;
- methods of task solution at separate stages with account of the designed gear features are chosen and developed;
- the structure of system and its software is worked out.

Let's open some principle aspects of this sequence.

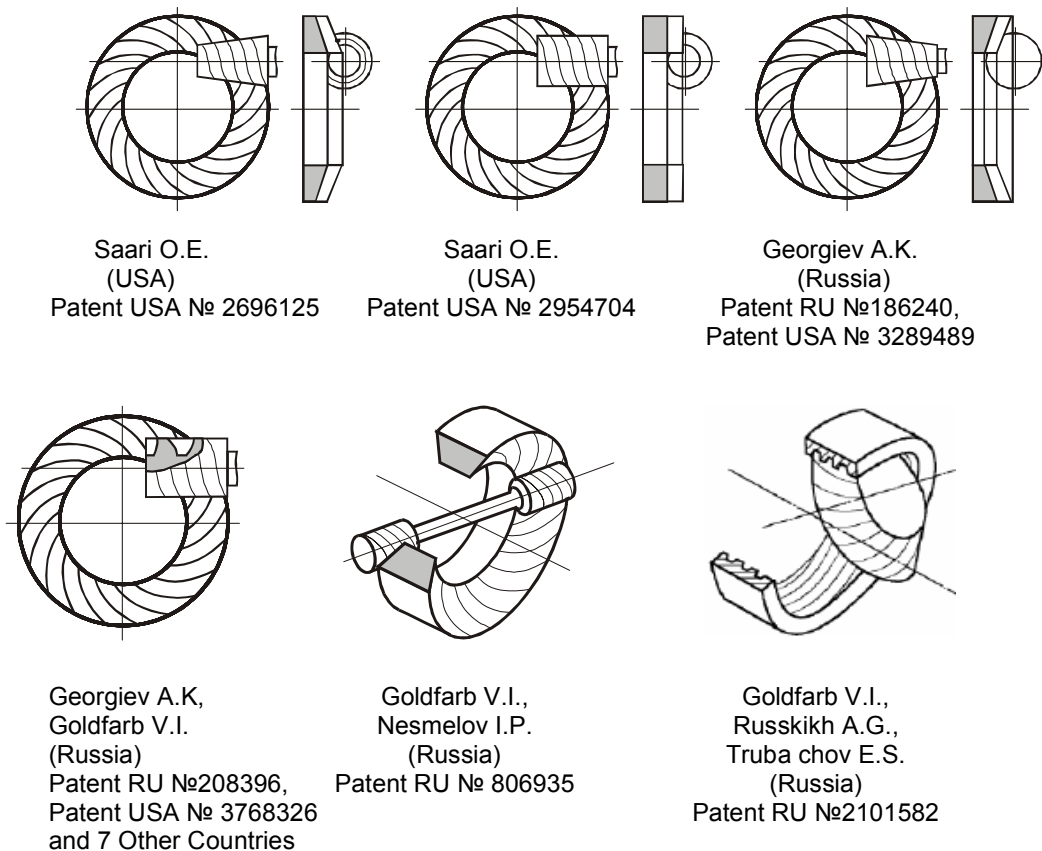


Fig.1. Different kinds of spiral-type gears

The construction fundamentals of the design process are also obvious enough:

- accurate division of the statements of the design tasks, independent and variable groups, input and output parameters, dependent and independent on given design requirements; this principle allows to focus the design purpose and construct informational bonds;
- separation (decomposing) of the design process into stages with corresponding subsets of input and output parameters, which allows to eliminate unacceptable variants at primary stages and accelerate the process of choosing the required design solution;
- setting of the order of parameter definition at each stage depending on the problem statement and design requirements.

Let's discuss briefly another principle item connected with the statement of the design task. The preferable variant of the statement is the following:

$$p = f(g), p \in P, g \in G \quad (1)$$

where p - are the values of gear parameters, P - is the area of possible p , g - are criteria of gear quality evaluation (technical requirements), G - is the area of possible

values g . The sense of (1) is obvious: values of gear parameters are determined for given values of technical requirements by means of some functional f .

As the functional f is difficult, and more often impossible to create for most of gears including spiral-type, the design task is solved as $g = \psi(p)$ - for the chosen set of initial parameters p the criteria g are found by means of the functional ψ to analyze the quality of the design solution. The design process is in this case the iterative one and implies the sequential approximation of the set p to the required (optimal) one according to given design requirements g .

2. The structure of gear design process may be largely presented as the following sequence of stages (Fig.2):

- synthesis of ideal gearing;
- manufacturing synthesis of gearing;
- evaluation of deformation mode of a gear;
- analysis of tooth contact in a real gear;
- prediction (evolutionary) of gear state;

The feedbacks shown in Fig.2 emphasize the iterative character of the design process. The information exchange between stages proceeds here via some controlling area

where the information concerning initial requirements to the gear under design and also data from the primary standard base and reference standardized base are accumulated. Let's consider each of the pointed stages in more details.

2.1. The synthesis of ideal gearing is obviously the first design stage when the main geometrical and evaluation gear parameters are determined. This stage (Fig.3) is also

decomposed into the following separate steps with independent input and output parameters:

- synthesis of gear scheme;
- calculation of parameters which define the geometry of the worm (pinion) and wheel;
- simulation of gearing geometry and kinematics;
- calculation of forces, efficiency and load capacity of the gear.

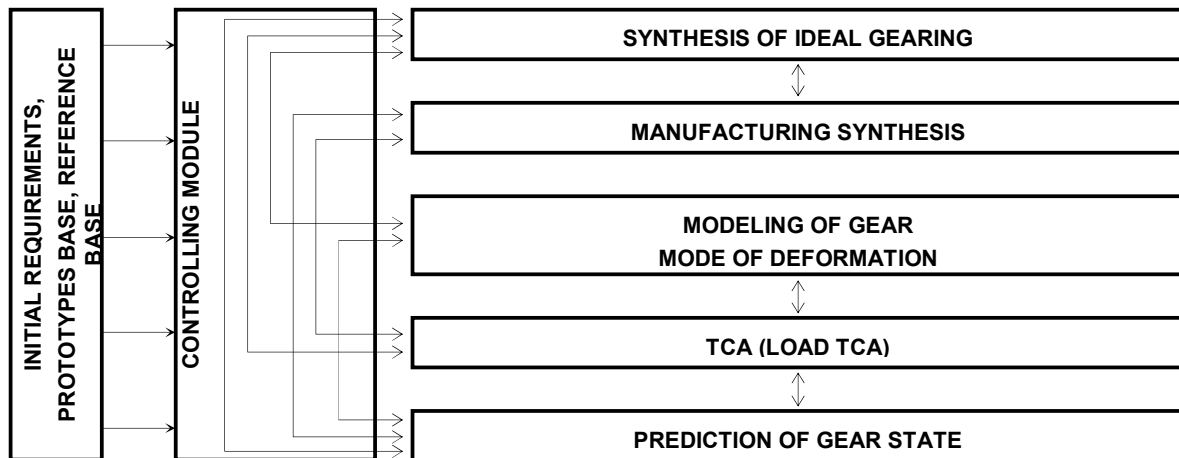


Fig.2. Structure of gear design process

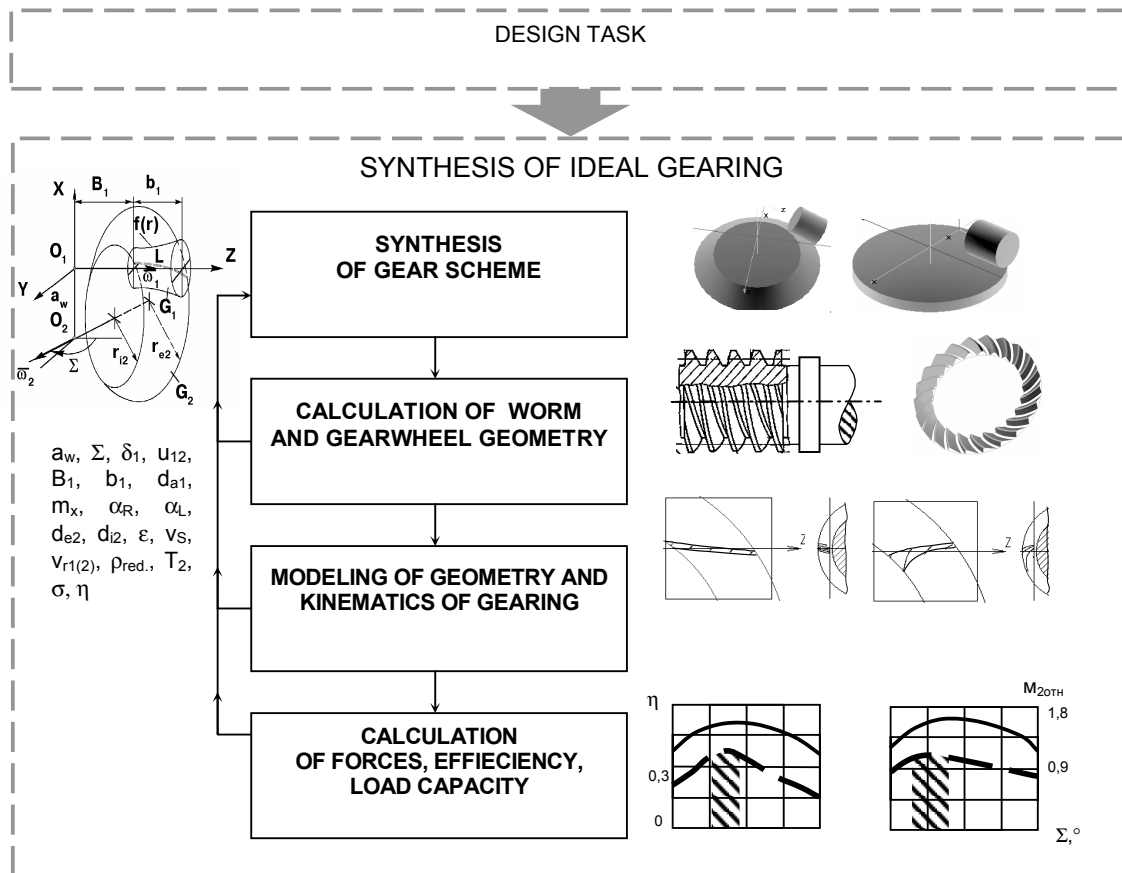


Fig.3. Structure of ideal (conjugate) gearing synthesis