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AUTOMATION OF SPUR GEAR PROFILE PREPROCESSING IN CAM SOFTWARE

Master's Program Automation of design and engineering

The abstract of the Master's Thesis

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The thesis work is done at the Federal State Autonomous Educational Institution of Higher Education «Siberian Federal University»

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GENERAL DESCRIPTION OF THE THESIS WORK

Significance of the work: Traditional methods of manufacturing gears require the availability of special equipment and tools for the manufacture of each type of gear, while if any firm is engaged in the manufacture of gears, it needs large investments in equipment to carry out its activities.

However, nowadays universal milling equipment with CNC is becoming more and more widely used, where it would be possible to produce gears with a universal tool. But there are problems associated with the preparation of control programs for such equipment.

If this issue is solved, then for small manufacturers engaged in piece production, repair of products or the manufacture of prototypes, it would be possible to significantly save on equipment, tools and, as a consequence, at the time of manufacturing gears.

The object of the thesis is the automation of the production of cylindrical gears with the use of universal CNC milling machines.

The aim: reduction of processing time and costs for the development of control programs for machining cylindrical gears for universal CNC milling machines.

The objectives of the research are the following:

1. Perform an information review and search for patents on the topic of the thesis
2. To develop numerical methods for obtaining the geometry of the profiles of cylindrical gears based on the theory of envelope curves
3. Develop algorithms for automating the receipt of control programs for CNC milling machines for obtaining cylindrical gears
4. Develop a software tool for obtaining control programs for cylindrical gears machining.

Scientific novelty of this word:

1. Using the theory of envelope curves to obtain the profile of cylindrical gears on CNC milling machines.
2. Application of the system-engineering approach in the development of a software tool for obtaining control programs for cylindrical gears machining.

Practical significance is the following: the developed software tool allows to produce cylindrical gears on universal CNC milling machines without the use of special tools for manufacturing gear wheels.

Personal contribution of the author is the development of numerical methods for obtaining the geometry of cylindrical gears based on the theory of envelope curves, the development of methods for automating the receipt of control programs for CNC milling machines and the development of software tools performed in the thesis work.

Place of the thesis implementation. Department of «Design - engineering support of machinery production» of Polytechnic Institute of Federal State Autonomous Educational Institution of Higher Education «Siberian Federal University».

Place of international internship. CADFEM GmbH, г. Мюнхен, Германия.

Work approbation. Basic provisions of the thesis are presented at the following conferences: International conference of students, graduate students and young scientists «Prospekt Svobodny-2016» (sections «Implementation of CAD/CAM/CAE Systems» и «Automated machine-building»), International conference of students, graduate students and young scientists «Prospekt Svobodny-2017» (section «Digital technology of machine-building production »).

Publications. The results of the dissertation work are reflected in 4 printed works and 1 certificate of registration of the computer program.

THE CONTENT OF THE WORK

In the introduction, the significance of the topic is substantiated and the purpose of the work is formulated, its novelty and practical significance is noted.

The chapter 1 provides an overview of technologies, equipment and tools for making gears on CNC machines. As a result of this information review it is established that in the modern machine-building industry an increasing share of equipment is replaced by CNC equipment. In this regard, there is a replacement technology for designing new products, developing technological documentation, which goes into digital form.

Technological documentation for a modern CNC machine is mainly transformed into programs composed of g-code and a small set of instructions to the machine operator. This leads to the fact that the determining factor in the success of production of these or other products is the use of means for obtaining control programs for the processing of parts.

The analysis of CAM-environments of universal and specialized purpose for obtaining control programs for CNC machines for obtaining gears revealed the advantages and disadvantages of modern products for obtaining control programs, summarized in Table 1.

Table 1 - Advantages and disadvantages of universal and specialized CAM-environments for manufacturing gear wheels

Universal CAM-environments		Specialized CAM-environments	
-	High price	+	Inexpensive
-	There are no specialized trajectories for processing gears	+	There are specialized trajectories for processing gears
+/-	Built-in geometry generators	+	Built-in geometry generators
+	It can process the entire part	-	There is no way to process anything other than the gear profile

Chapter 2 of the work is devoted to the development of algorithms for the synthesis of geometric parameters of spur gear transmission.

As a mathematical model for describing the profile of a cylindrical gear wheel, a model based on the theory of envelope curves was used, and consisted of the following curves: the cavity circle, the fillet (the transition curve), the curve describing the working surface and the circumference of the tooth tip. These curves have the following description:

1. The cavity circle of gear:

$$\begin{cases} x_d = ((r+\varepsilon) - h_a - c)\sin(t) \\ y_d = ((r+\varepsilon) - h_a - c)\cos(t) \end{cases}$$

2. The curve describing the working surface:

$$\begin{cases} x_э = (r+\varepsilon)\sin(t) - (rt - \frac{\pi m}{4})\cos(t) + P_1(t)\sin(\alpha + t) \\ y_э = (r+\varepsilon)\cos(t) + (rt + \frac{\pi m}{4})\sin(t) + P_1(t)\cos(\alpha + t) \end{cases},$$

where $P_1(t) = \left(rt - \frac{\pi m}{4}\right)\sin\alpha - \varepsilon\cdot\cos\alpha$.

3. The fillet:

$$\begin{cases} x_в = ((r+\varepsilon) + y_n)\sin(t) - (rt - x_n)\cos(t) \mp \rho\dfrac{(-(\varepsilon + y_n)\sin(t) + (rt - x_n)\cos(t))}{\sqrt{((\varepsilon + y_n)^2 + (rt - x_n)^2)}} \\ y_в = ((r+\varepsilon) + y_n)\cos(t) + (rt - x_n)\sin(t) \pm \rho\dfrac{((\varepsilon + y_n)\cos(t) + (rt - x_n)\sin(t))}{\sqrt{((\varepsilon + y_n)^2 + (rt - x_n)^2)}} \end{cases},$$

where

$$\begin{cases} x_n = \frac{\pi m}{4} - h_a \cdot tg(\alpha) - \rho\frac{(1 - \sin\alpha)}{\cos\alpha} \\ y_n = \rho - h_a \end{cases}.$$

4. The tooth tip:

$$\begin{cases} x_a = ((r+\varepsilon)+h_a)\sin(t) \\ y_a = ((r+\varepsilon)+h_a)\cos(t) \end{cases},$$

where r - pitch radius of wheel,
ε - displacement of the tool,
h_a - height of tool tooth tip,
t – angle of rolling,
α - profile tooth angle,
m – module,
ρ - radius of arc of the edge of the tooth edge of the instrument.

In order to obtain the profile of the gear wheel on the basis of the given curves, it was necessary to obtain the boundary conditions for these curves by numerical methods, which are, as a rule, the places of contact of the curves with each other. Figure 1 shows the image of the tooth cavity, consisting of a set of curves: 1 - the circumference of the depressions, 2 - fillet, 3 - the curve of the working surface, 4 - the circumference of the vertices.

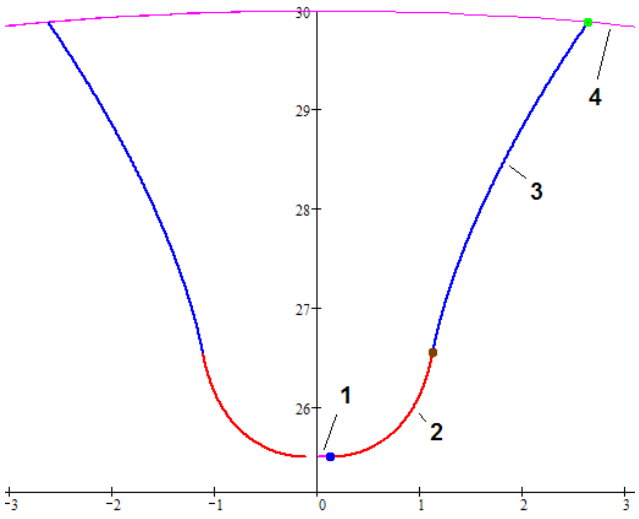

Fig. 1 – Curves describing spur gear

The calculation of the boundary values of the curves describing the tooth profile in this paper was realized using numerical methods and consists of three stages. At the first stage, the boundary values of the circumference of the depression and the transition curve are calculated at the point of their tangency. The second stage is the calculation of the boundary values of the functions describing the transition curve and the profile curve of the working surface in the places where they touch. At the last stage, the calculation of the boundary values of the functions describing the profile of the working surface and the circumference of the tip of the tooth at the

point of their intersection. The result of the work of the set of obtained algorithms is a set of values of the parameters of functions at points that limit the curves, which makes it possible to construct a profile of the gear.

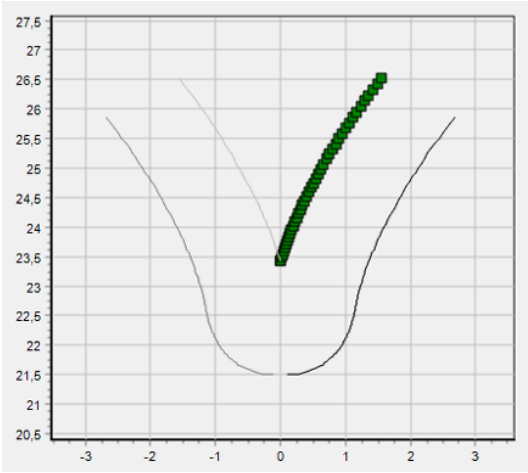

Fig. 2 – Toolpath

To realize the calculation of toolpaths describing the profile of the gear wheel, the development of an algorithm for selecting the maximum diameter of the tool describing the tooth profile based on calculating the minimum radius of curvature of the gear tooth profile was developed. And also an algorithm for calculating the trajectory of the tool, describing the profile of the tooth, the result of which is shown in figure 2.

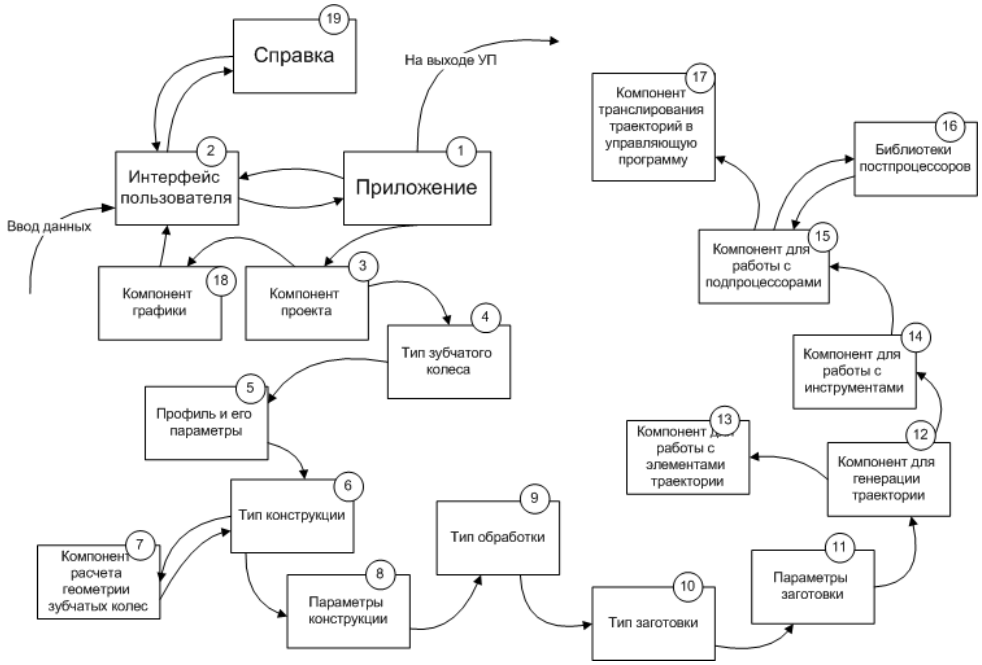

Fig. 3 – Component diagram of the program

In addition, in this section, the development of the architecture of the developed system has been performed, including the component architecture (figure 3) and the modular diagrams, as well as layouts and layout of the system.

Chapter 3 of the work presents a description of the development of a software tool for solving the problem of generating control programs for obtaining toothed cylindrical wheels.

The resulting software product is presented in figure 4, consisting of a project tree through which you can specify the basic settings for creating a control program, and a window to visualize the result.

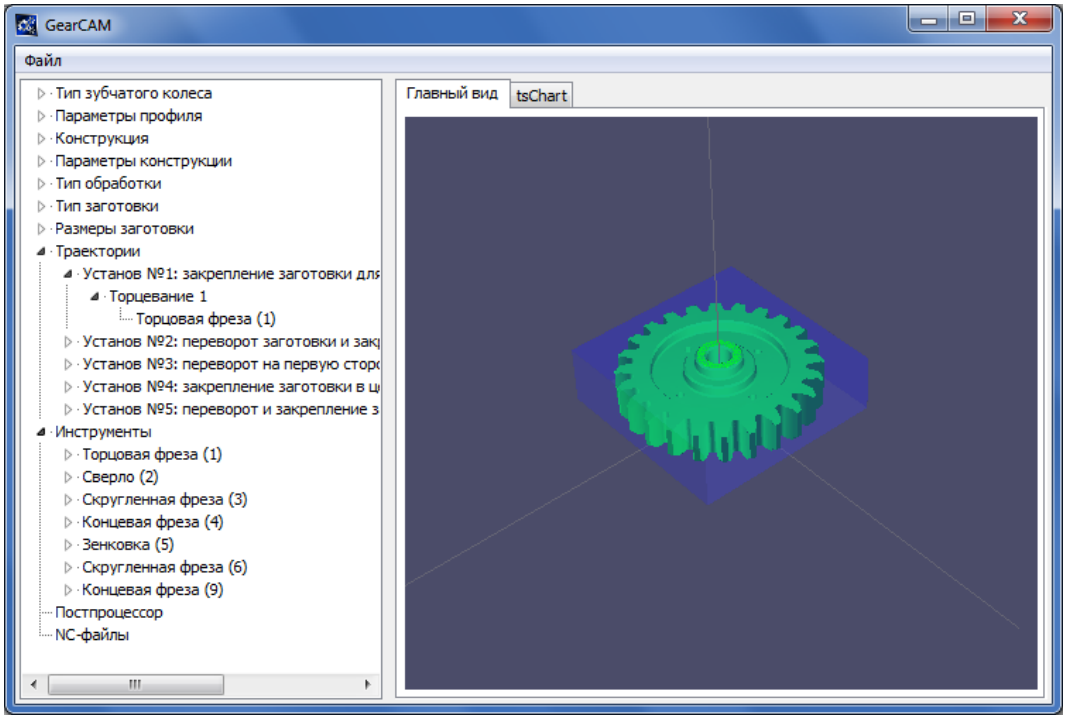

Fig. 4 – User interface of the program

In the section 4, the experiments on machining the workpiece on a CNC milling machine are described. The workpiece processing was performed using the control program obtained in the developed software product.

In conclusion, the main conclusions and results of the work are presented.

KEY RESULTS AND CONCLUSIONS

In the course of the thesis, the following results were obtained:

- the analysis of existing CAM-systems is carried out and their advantages and disadvantages are revealed at generation of control programs for processing of cogwheels.

- algorithms for numerical determination of the boundary values of functions describing the profile of the gear wheel according to the theory of envelope curves
- algorithms for determining the diameter and trajectory of the tool for the processing of spur gears with external engagement
- a software product has been developed with the help of which it is possible to generate control programs for obtaining cylindrical gears on CNC milling machines with 3-axis machining of the workpiece.

CONCLUSION

The developed software product allows to significantly reduce the generation time of control programs by means of which it is possible to obtain cylindrical gears on a CNC machine with three axial machining, in comparison with universal CAM-environments.

BASIC PROVISIONS OF THE THESIS ARE PUBLISHED IN THE FOLLOWING WORKS:

1. A program complex for the synthesis of geometry and interaction of multimodular gear pairs of external and internal gearing GearAnalysis / **A.P. Smirnov**, D.V. Vavilov, A.A. Iptyshev, A.V. Shigina // Certificate of state registration of the computer program № 2012612189. Registration date: 28 february 2012.
2. **Smirnov A.P.** A new technology of gear manufacturing invomill // Collection of materials of the International Conference of students, graduate students and young scientists «Prospect Svobodny-2016», section «Implementation of CAD/CAM/CAE Systems», p.27-28, Krasnoyarsk, 2016
3. **Smirnov A.P.** Modern technologies of manufacturing gear drives by cutting // Collection of materials of the International Conference of students, graduate students and young scientists «Prospect Svobodny-2016», section «Automated machine-building», p.131-134, Krasnoyarsk, 2016
4. Hudoley I.S., **Smirnov A.P.** Development of a dynamic library for obtaining the geometry of a cylindrical gear // Collection of materials of the International Conference of students, graduate students and young scientists «Prospect Svobodny-2017», section «Digital technology of machine-building production», Krasnoyarsk, 2017
5. **Smirnov A.P.** Development of a CAM-system for generating control programs for obtaining gears // Collection of materials of the International Conference of students, graduate students and young scientists «Prospect Svobodny-2017», section «Digital technology of machine-building production», Krasnoyarsk, 2017