Calculation and design of mechanical transmissions with the help of various computer-aided design in conditions of educational process

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Abstract. The field of application of computer-aided design (CAD) is an integral part of the design of real-world products of construction, lifting-and-transportation, road vehicles, as well as the design of electronic products. Computer-aided design allow you to solve the most time-consuming and time-consuming tasks, carry out calculations, help you to represent the most accurate visualization of an object (3D visualization). The calculation and design of mechanical transmissions using CAD, which form the basis of most working machines, is an important component of the educational process in the training of future specialists in technical areas. In this work, some modules of computer-aided design have been analyzed to apply them to the educational process in the calculation of mechanical transmissions.

1. Introduction
Leading machine-building enterprises successfully operate in modern market conditions thanks to the production of competitive products within a narrow time frame of the production cycle from the project to the finished product. The quality of products depends to a large extent on the level of training of designers and technologists. Traditional «manual» calculations for the stress of mechanical transmissions are time consuming and do not provide high design accuracy for complex assemblies. Modern computer technologies allow to quickly and with high accuracy carry out the necessary calculations of geometric dimensions of parts and assemblies depending on a number of factors: operating conditions, operating modes, selected material, etc. Future specialists should be prepared for modern production conditions. Therefore, when designing machines during standard stress calculations, the development of basic theoretical provisions should be accompanied by the study of computer analysis tools.

In order to facilitate calculation and development of working skills in modern computer-aided design in conditions of educational process, future specialists need to acquire practical skills of ownership of a package of means capable of creating design and technological documentation, 3D models and drawings. Special attention is paid to the convenience of the interface, the ease of development of the software product, the ideal speed of performing the same work on different systems. These packages include the Kompas-3D, APM WinMachine, Mathcad and Excel packages. In each program it is possible to perform calculations of mechanical transmissions. Since cylindrical gear is the most common gearing among mechanical gears, it is useful to show the calculation of this gear to familiarize students with the programs listed.
2. System Kompas-3D
The system developed by the Russian company «Ascon», Kompas-3D [1] allows to perform geometric and design calculations for gears, as well as to check the working ability of the gear and create a working drawing of the gear gearwheel. For this purpose, a fast module for calculation of internal and external gearing gears is built into the system.

To start the calculation, start the system, create a new drawing, open the «Library manager» menu, then open the «Calculation and build» folder and start the «Kompas Shaft 2D» application. In the «Kompas Shaft 2D» program window, the «Mechanical transmission elements» icon must be activated by the mouse cursor. Select the gear of the cylindrical gear train from the menu that appears (figure 1). From the «Gears» mechanical gear calculation program menu that appears (figure 2), you can select the type of gear (for example, external gearing), select «Calculation variant». The «Geometric calculation» menu (figure 3) calculates the basic geometric parameters of the cylindrical gear. After the monitored measuring parameters and quality parameters are normal, it will be possible to form a toothed rim. At the last stage the final working drawing of the gearwheel is formed. After the calculation, there is an opportunity to see the finished three-dimensional detail in any position of interest to us in the «Kompas Shaft 3D».

Thus, the «Kompas Shaft 2D» and «Kompas Shaft 3D» system allows to speed up the process of parts design by tens of times and release the complete documentation of simulated parts at the same time.

![Figure 1. Elements of mechanical transmissions](image1.png)

![Figure 2. «Gears» mechanical gear calculation](image2.png)
3. APM WinMachine

Another Russian engineering package APM WinMachine [2] is available and visible in understanding design and checking calculations by finite element method. APM WinMachine uses APM Trans to calculate and design transmissions. The system allows to perform design calculation and check by moment or endurance. Besides calculations, the system provides simultaneous drawing of the gearwheel.

The APM Trans module must be started to work with the APM WinMachine system. For operation with the module there is a falling, button and graphics menu. In the drop down menu, click the «Type» button to select the transmission type and calculation type (figure 4). Then input of initial data and calculation of parameters in «Results» menu is performed.

The gear drawing is directly generated in the APM Graph. The system automatically starts the module and generates a drawing in it after you click «Save» in the «Drawing» window (figure 5) and specify the name of the gear file. Working drawing of gear reworked in APM Graph module is similar to drawing built with Kompas-3D program.

Figure 3. Geometrical calculation of external gearing cylindrical gear
Figure 4. APM Trans module with selection of transmission or calculation type

Figure 5. Generating mechanical drive feature drawings

4. Systems Mathcad, Excel, SolidWorks and T-FLEX
The most commonly used software complexes in the education process that relate to the mathematical class CAD systems, Mathcad [3] and Excel [4]. The undeniable advantages of using the mentioned programs are automation of calculations, provision of more time during the training process to understand the calculation algorithm and making decisions on selection of the design scheme, applied materials, calculation coefficients, to perform logical transitions. It is possible to perform systematic calculations and solve problems of optimization of the developed design. For example, selecting the material used requires an assessment of its mechanical characteristics and relative cost. For this purpose, the student in the text of the program is offered information in table form, on the basis of which he makes a decision and selects the material.
Mathcad is the most convenient for calculations of mechanical transmissions in the course design of general technical disciplines. It is a computer algebra system from the class of computer-aided design for performing a variety of mathematical and technical calculations, equipped with an easy to master and work graphical interface, convenient for collective work. Mathcad provides you with tools to work with formulas, numbers, graphs, and texts. More than a hundred operators and Boolean functions are available in Mathcad to solve mathematical problems of varying complexity, both numerically and symbolically. When you write formulas in Mathcad, you have the ability to save symbols that are adopted in previously published tutorials and tutorials. If the above-mentioned methodological developments are translated into the Mathcad environment, there is a significant reduction in the time required to perform computational work, the elimination of arithmetic errors, and the possibility of variant calculations.

When you use the Mathcad environment, you need to convert the design and checking algorithm of mechanical transmissions, including gears, into a software environment. In order to achieve the assigned task, programming of the known algorithm [5] of design and checking calculation of mechanical transmissions is performed. The work produced the following results: design and checking programs for cylindrical gear, worm evolute gear, belt and chain gear in Mathcad have been developed; the control calculations for the developed programs were performed and compared with the execution examples.

When solving complex tasks with the help of software products of «middle level», for example SolidWorks [6] and Russian T-FLEX [7], it is necessary to resort to some simplification when drawing calculation diagrams of parts and assemblies. Certain difficulties are caused by an unusual way of displaying results, inability to obtain standard epurs and exact values. Efficiency of application of these software complexes in educational process reduces short time of discipline study and different degree of preparation of students in group for work with similar programs, especially, at the stage of execution of 3-D models.

5. Conclusions
An overview of CAD systems, simple and easy to use in the educational process for engineering training of future specialists, has been carried out. The Mathcad software allows you to significantly reduce the time required to perform calculations as part of a course project for general technical disciplines, provide additional time for students to understand the calculation algorithm, and make reasonable design decisions. It is possible to perform systematic calculations in order to optimize the characteristics of the reduction gear. The teacher is able to quickly check the calculations made by the student and set individual tasks. At the same time, for the complete design and design documentation according to the standards of the unified design documentation system and design documentation system for construction, the Kompas-3D program is most convenient.

References
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