CAD-technology is a tool for teaching bachelor students industrial technology

E A Danilova*, T V Antropova, A A Skotnikova and S V Borodulina
Department of Engineering Geometry and Basic CAD, Institute of Mechanical Engineering and Materials Science, Yuri Gagarin State Technical University of Saratov, 77 Politechnicheskaya St., Saratov 410054, Russia

*lenochka240766@ambler.ru

Abstract. The vast majority of special disciplines in technical fields are studied bachelor students over one semester. This time is not enough for developing comprehensive knowledge of industrial technology and product forming processes. In addition, visit to training machine laboratories does not always allow student to fully explore the features of a particular technological process. As a problem solution, students may use CAD-technology in practical classes for computer simulation of various technological processes. Methods for solid body model constructing should correspond to the workpiece forming method in production environment. Such tasks would allow students to understand better the technology and features of manufacturing workpieces on different machines. This is especially important in the conditions of distance learning, when students have no opportunity to personally visit industrial laboratories and perform work on special equipment.

1. The content of the curricula
Teaching bachelor students in technical fields lasts eight semesters. Their curricula include circa 55 disciplines. The vast majority of disciplines are studied over one semester. The exception is represented by general theoretical disciplines, such as mathematics, physics, history, foreign language, physical education, etc. The duration of study for such disciplines may range from two (mathematics, physics) to six (foreign language, physical education) semesters.

An average indicator of training intensity (credit hours per week) for disciplines aimed at formation of general professional (GPC) and professional competencies (PC) is three hours a week: a weekly two-hour practical session (16 classes total per semester), and a bi-weekly two-hour lecture (8 classes total per semester). During this time, students manage to get acquainted with some basics of the discipline; however, one can hardly expect some serious and deep knowledge about the subject. It is well known that any new discipline (especially technical) will be better understood and mastered more deeply if its application is considered via case-studies from the practical field or from future professional activity. However, to conduct all classes in specialized laboratories is not always possible, and sometimes even unjustified. For example, it is not necessary to be always next to the working gear shaper, when you are calculating the parameters of the gear wheel, although it is required to get acquainted with its design and principles of functioning. If university specializes in these fields of study, then students’ visits to such machine-tool laboratory is easy to organize. If university does not have sufficiently well-equipped machine tool lab, then it is necessary to organize visits to enterprises,
for which bachelor students are prepared. This will help students understanding the field and assessing the necessity of their knowledge.

Engineering problems, solved in conditions of industrial production, require extensive theoretical knowledge and practical skills. In addition, students are required to develop spatial thinking. The movements of a workpiece and a tool against each other represent a complex dynamic system. A workpiece shape is often an extremely complex geometric structure that cannot be described analytically. An engineer needs to visualize a workpiece in his, or her, mind before starting to manufacture it. If he, or she, does not visualize how to make it, how to place it inside a certain structure, and how to subsequently operate the resulting product, then he, or she, will not be able to implement the technological process of shaping and/or assembling the product in industrial production.

Demonstration of physical applications of theoretical calculations and problems will contribute to developing constructive and geometric imagination in students. However, students will not be able to witness all technological processes. The reasons can be different: need to comply with safety regulations, small workpiece size, high speed of technological operation or process, process’ incidence in obscure environment, etc. In this case, an adequate alternative is to demonstrate the video of this process with necessary correction: e.g., to slow down the speed of demonstration, or to increase the image scale, etc. However, the video must be available, which is not always feasible. In such situation, a three-dimensional model imitating the process may become a tool for teaching bachelor students.

Contemporary graphic systems allow us implementing the most complex designs, and the methods for their implementation can be very different. This is one aspect of undergraduate education. It presumes teaching a student to use the methods of solid body modeling, so that he could apply various shaping methods to obtain the same geometric model [1]. Having described a certain sequence of actions on the shape-formation of the model, a student can be introduced to the technological process of processing this particular workpiece in specific production situation. The second aspect presumes that, with the help of contemporary systems of three-dimensional modeling, we can create an animation clip that will recreate the technological process on a computer screen at any given speed.

This learning approach is of particular importance when educational institutions use distance learning. In this case, students have no opportunity to personally visit industrial laboratories and have a hands-on experience in studying the production process. Video demonstration of the production process partially eliminates this gap, but it is less informative than a computer simulation performed by a student in person, especially in the form of animated movie.

2. Mastering CAD-technology
Curricula of technical fields of study contain a large number of disciplines aimed at studying software systems for various purposes. Besides, various software products may be used in the course of virtually any discipline. The same product may be differently used for several courses. For example, Informatics, studied in the freshman year, covers the details about working with such software systems as MathCAD. In the disciplines studied in subsequent semesters, MathCAD will be used to solve higher level mathematical problems, as well as to construct analytical curves to import those into 3D-modeling programs.

Graphic applications, such as KOMPAS3D, SolidWorks, Inventor, etc., are even more widely used in educational. These programs allow teaching students to competently and quickly prepare design documentation, which is the main goal of studying such complexes. They also greatly contribute to the development of the volumetric representation of complex geometric models by students and their overall spatial thinking. This is especially important given the situation prevailing in school education: the main emphasis is made on the studying sections of algebra, while geometry, especially its spatial section (stereometry), is deprived of school students’ attention. In their freshman year, university students study such disciplines as Engineering Graphics, Descriptive Geometry and Computer Graphics. They are designed to acquaint them with new information, as well as to fill in the gaps in their Geometry education. In the framework of these disciplines, students can become acquainted with
the interface of the program, its tools, and ways of designing documentation via 2D graphics. At this stage, they make technical drawings of parts, simple assembly drawings and specifications for those. This is a first step towards the formation of students’ spatial visualization in technical fields, because tasks in these disciplines are transformations of axonometric images into orthogonal projections or vice versa: flat images should be represented as spatial images. The construction of orthogonal projections in compliance with all standards, an application of dimensions and designations are major constituents of tasks performed by means of 2D-graphics. It should be noted that freshmen have a difficulty of determining the required dimensions in the technical drawings, because they lack knowledge on technological process on any machine.

The next step in this direction is the construction of 3D models of workpieces and their subsequent connection into an assembly.

The task can be issued in several ways depending on aim of the work. For example, to build a three-dimensional model using a working drawing of a part containing all necessary views and sections with dimensions. This will allow students to improve drawing reading skills.

Also, the task can be issued in the axonometric form with required dimensions. In this case, a student solves another problem: he has to decompose the completed model into separate steps, which would allow obtaining the necessary shape of the workpiece fragments correctly from the point of view of 3D modeling and technology of workpiece processing. This problem ought to be solved in the course of two or more disciplines. The first of those is 3D Modeling and Basic CAD. Others are taught by the departments teaching students industrial technology in their specific fields.

The third case: the task may be issued in the form of assembly drawing and its specifications. In this case, the task for students becomes more complicated. First, they should decompose the assembly drawing into separate workpieces, make a working drawing for each of those, and specify their dimensions. Then it is possible to proceed to constructing three-dimensional models. To simplify the labor and/or to save time, the working drawings of the workpieces can be replaced with their sketches. However, at this stage, assembly drawings (tasks) may consist of different numbers of workpieces of various complexity degrees. Overall, this task is very time- and labor-consuming for the students. One of rational approaches is to split this task into two semesters: students prepare working drawings during one semester, while in the next semester, they move on to building 3D models, bringing together assembly units, creating animation, generating specifications, automatic generation of working drawings, etc. As a result, students can evaluate the complexity and accuracy of each type of design documentation generation and its editing. Such approach has additional advantages: after automatic generation of working drawings, students can see in person the flaws of manually prepared drawings made by them from the assembly drawing; also, they begin to understand an importance of correct application of dimensions on working drawings in industrial production.

The transition from a two-dimensional drawing to a three-dimensional image and vice versa helps students to perceive the connection between a flat orthogonal projection of a workpiece and its three-dimensional shape, which, in fact, serves the goal of developing constructive geometry knowledge and spatial thinking in students.

3. Using CAD-technology for training in technological processes

Let us illustrate the approach, described above, using the case-studies of student projects completed in KOMPAS3D.

The curricula of bachelor students in the fields 15.03.02, 15.03.04, 15.03.05, and five-year degree students (15.05.01) [2] deal with mechanical engineering production and/or engineering technology. These fields of study contain three disciplines that are not directly related to studying industrial technologies, but rather form students’ skills permitting them computer imitation of production processes.

During their freshman year, students are acquainted with drawing design rules, standards, and principles of constructing orthogonal projections and spatial geometric shapes. The courses of the graphics cycle during their sophomore year are designed to teach them how to implement such
geometric images on a computer. At this stage, students learn the techniques of working with graphics systems for the design documentation, as well as consolidate and develop their freshman year skills. Such approach to education of bachelor students has proven its effectiveness over the past few years.

3.1. Design documentation preparation by means of 2D graphics
The third semester is devoted to the acquisition of skills on preparation of 2D documents. Students receive tasks in the form of sufficiently complex and laborious assembly drawing (figure 1) and specification (figure 2) [3].

They carry out working drawings of all non-standard parts included in the product, and apply required dimensions, which they are supposed to measure and calculate on their own (figure 3). At this stage, it is precisely the dimensions that cause the greatest difficulty: which of those should be specified on the working drawing, which are permissible to specify, and which are not. However, this task performs an important function for further understanding of the technological process, since, for building three-dimensional models in the next semester, students would use those dimensions.

After completing all working drawings, students begin building an assembly drawing using previously prepared working drawings and a library of standard fasteners. Also, specification is executed in semi-automated mode by connecting the drawings to it.

By the end of the semester, students are quite clear about each detail shapes. Thus, they are prepared for a fairly quick application of new solid modeling skills in their practical work.

3.2. Using 3D models to form a set of documents
The fourth semester of the graphics training for bachelor students is devoted entirely to solid body modeling.
First, students master 3D modeling without reference to technological operations. For deeper understanding of modeling tools and their differences, students are offered to complete the shaping of the same workpiece by various operations and with a different combination of methods: matching components of the part to each other, removing metal from the workpiece, rotation, etc.

In this semester, according to the working drawings made over last semester, students form spatial models of non-standard workpieces, using the most appropriate modeling methods corresponding to specific technological operations. In this situation, they begin realizing an importance of correct dimensions for workpiece formation: how much easier it is to build a model, when there are all necessary dimensions.

By completing the shaping of all non-standard workpieces, students are prepared for the assembly process. As a rule, this stage does not cause them much difficulty.

![Figure 4. Assembly](image)

Automatic generation process of an assembly drawing from the assembly surprises the students, how little effort is spent on obtaining the most complex assembly drawing (in terms of shapes and number of workpieces), as well as a large number of working drawings with all required views and cross-sections.

![Figure 5. 3D model](image)  ![Figure 6. Working drawing from 3D model](image)

Students often make threaded connections without strict adherence to standard sizes. In this case, the threaded connection is depicted on the assembly drawing in violation of the standard, which indicates an error in a model construction. Such situation clearly demonstrates how easily changes are made to all drawings, both assembly and working, after editing a 3D model.

Automatic generation of assembly specifications, including standard products, is already perceived by the students quite calmly, because to this time, they had already realized the advantages of three-dimensional modeling versus manual preparation of any drawing, especially an assembly.

Building first a decomposed assembly, and then an animated movie with simultaneous movements of two workpieces completes the process of preparing students to the next stage: simulation of a technological process or operation via computer graphics. This stage must be conducted within technological disciplines taught by specialized departments.

From the foregoing, an obvious conclusion follows: the described approach could improve the effectiveness of teaching industrial technology disciplines to bachelor students by including the tasks
that simulate specific technological operations and processes in educational routine, which is especially important in the context of distance learning.

**References**

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