

**Review Article**

**CAD SYSTEMS AND COMPUTER GRAPHICS IN THE TRAINING OF SPECIALISTS IN THE FIELD OF MECHANICAL ENGINEERING**

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**ABSTRACT**

Modern professional standards in the field of engineering and computer graphics and industrial enterprises require from young specialists not only high level of technical training, but also confident use of modern computer-aided design systems in their work. In standards the changes demanding creation of the design documentation on the basis of three-dimensional models of a product are included. Three-dimensional modeling has become a benchmark for the supply of demonstration materials in the field of mechanical engineering. Computer graphics today has the tools to create almost any object, and for designers to reveal their creative and professional abilities. The article considers a complex approach to the preparation of graduates of specialty 15.05.01 "Design of technological machines and complexes" on the basis of the Magnitogorsk State Technical University named after G.I. Nosov with the use of computer graphics and integration into the educational process of various computer-aided design systems: KOMPAS-3D, AutoCAD, Autodesk Inventor, APM WinMachine.

**Keywords:** Computer Graphics, CAD Systems, 3D Modeling, CAD Engineering Design, Integrated Approach, Design of Technological Machines and Complexes.

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**INTRODUCTION**

Technologies of computer modeling in professional training of specialists come to the first priority. CAD-systems allow to embody a plan of the designer in electronic form and to receive the complete set of the traditional design documentation. Computer design systems (CAD-systems) and modern computing tools stimulate new methods of designing, construction of 3D-models of details, assemblages of units and knots, allows to study interaction between products in the course of modelling of conditions of their operation. The result of designing is an integral set of models, properties or the characteristics described in the form suitable for realisation. Integration of the information between various programs and the analysis of the received results allows to achieve in the shortest terms necessary results of the decision of tasks in view of designing [1].

Qualitative training of the modern expert in mechanical engineering can be realized only on the basis of the complex approach to studying of the modern CAD actively used in the industry. The competences acquired by future specialists in the course of training in higher educational institutions, in many respects determine the ways of their further competitiveness and adaptation in the conditions of industrial activity [2].

**PROFESSIONAL COMPETENCES IN THE FIELD OF ENGINEERING STRUCTURES DESIGN**

According to the order of the Ministry of Education and Science of Russia from October 28, 2016 №1343 the federal state educational standard of higher education in the specialty 15.05.01 "Design of technological machines and complexes" (specialist level), which indicates the mandatory use of modern

methods and means of design, calculation, mathematical, physical and computer modeling. The standard specifies the professional tasks to be solved by the graduate who completed the training programme: production and technological activity - organization of workplaces, their technical equipment with placement of technological equipment; research activity - mathematical modeling of machines, drives, systems, various complexes, processes, equipment and production facilities using standard packages and tools of automated design and scientific research;

design and engineering activity - calculation and designing of details and units of machine-building constructions according to technical tasks and use of standard means of automation of designing; development of working design and technical documentation; development of working design and technical documentation, registration of the finished design and technical works.

The development of these competencies requires comprehensive training of students throughout the entire period of study at a higher education institution using various computer-aided design systems. On the basis of G.I. Nosov Magnitogorsk State Technical University in the training of specialists of the specialty 15.05.01 Design of technological machines and systems are used: KOMPAS-3D, AutoCAD, Autodesk Inventor, APM WinMachine. Mastering of the specified software is carried out on the disciplines included in the training curriculum: descriptive geometry and engineering graphics, applied mechanics, basics of design, design of metal structures, equipment design of steelmaking plants, design of equipment for steelmaking plants,

design of equipment for sinter-making, design of technological lines and complexes of metallurgical plants, design of equipment for rolling and drawing production, design of hydro- and pneumatic drive systems [3].

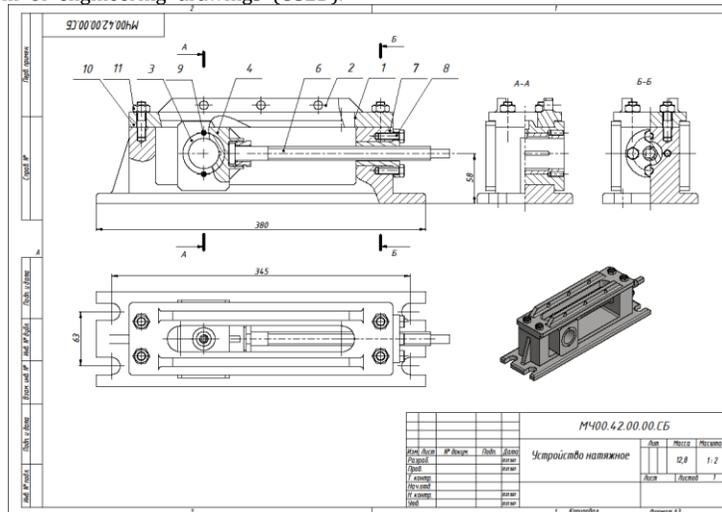
In the field of higher technical education, the teaching process of students should be effectively designed. Modern computer graphics programs allow students to optimally simplify the learning of various subjects and expand their capabilities. In classes on descriptive geometry and engineering graphics students acquire basic knowledge of KOMPAS-3D and Autodesk Inventor. Further the received skills are improved at studying of disciplines at senior courses. The complex approach to preparation of graduates of a speciality 15.05.01 with use of computer graphics and integration in educational process of various CAD allows during training of students of technical specialties to improve understanding, to develop spatial vision, to raise interest to scientific and technical education.

Due to the fact that not all graduates of secondary educational institutions entering the specialist programs have knowledge in drawing, one of the main tasks of teaching descriptive geometry and engineering graphics is visualization of the process of creating images. In descriptive geometry modern computer-aided design (CAD) allow to visualise the task, visually to define kinematics of formation of surfaces, to construct lines of section of surfaces by planes and crossings of various surfaces [4]. In the course of works on projection plotting construction of visual images by means of 3D modelling of details, is a necessary condition for understanding of the form of a product and features of construction of cuts and sections. At a stage of studying of machine-building plotting there is a necessity of definition of various design features of a product, types of connections and performance of drawings of assembly knots according to new standards of unified system of engineering drawings (USED).

Undoubtedly advantage of creation of associative drawings, specifications and other design documentation generated on the basis of 3D-models of details and the assemblage, executed by means of CAD.

**KEY STEPS TO ACHIEVE PROFESSIONAL SKILLS**

At the first year students of a specialty 15.05.01 study 3D modelling of details and tools of preparation of the design documentation in KOMPAS-3D and Autodesk Inventor. In the course on descriptive geometry and the engineering drawing according to GOST 2.052-2015[5], electronic geometrical models of products are created with attributes - requirements to its manufacturing and the control (limiting deviations of the sizes, surface roughness). Geometric models of products are given material properties that allow determining accurately the mass-central characteristics for further calculations. At modelling of details and assembly knots in KOMPAS-3D and Autodesk Inventor parametrization of the sizes that allows to create details with executions, to change geometry during designing without reconstructing model is applied [6, 7]. Based on electronic geometrical models of details and assembly units there is a possibility of preparation of a product for carrying out of the durability analysis and other calculations that are carried out by modern CAD. The acquaintance with application of libraries of standard products, constructive elements begins at a stage of modelling and calculation of connections of standard products: bolt, screw, stud, spline and spline. Also works on frame and surface modelling of products are carried out. While developing the tasks all requirements of modern standards of USCD and federal state educational standard of higher education on a speciality 15.05.01 are taken into account. For maintenance of an educational program textbooks in which the basic principles of work in modern CAD are considered [8-11].



**Figure 1: The work Executed by the First Year Student in CAD Autodesk Inventor on a theme "Simulation of Assembly Units" (The Specification on Fig. 1 is Not Presented)**

The received knowledge and skills of work in modern CAD systems are demonstrated by students on championships of professional skill under standards WorldSkills [12]. The aim of the international non-profit movement Worldskills is to increase the prestige of working professions and develop skills by harmonizing best practices and professional standards worldwide through professional skill contests.

Students of the department annually become participants of national finals in the competence "Mechanical Engineering CAD", which is part of the competence block "Industrial production" and within the framework of Worldskills International on the

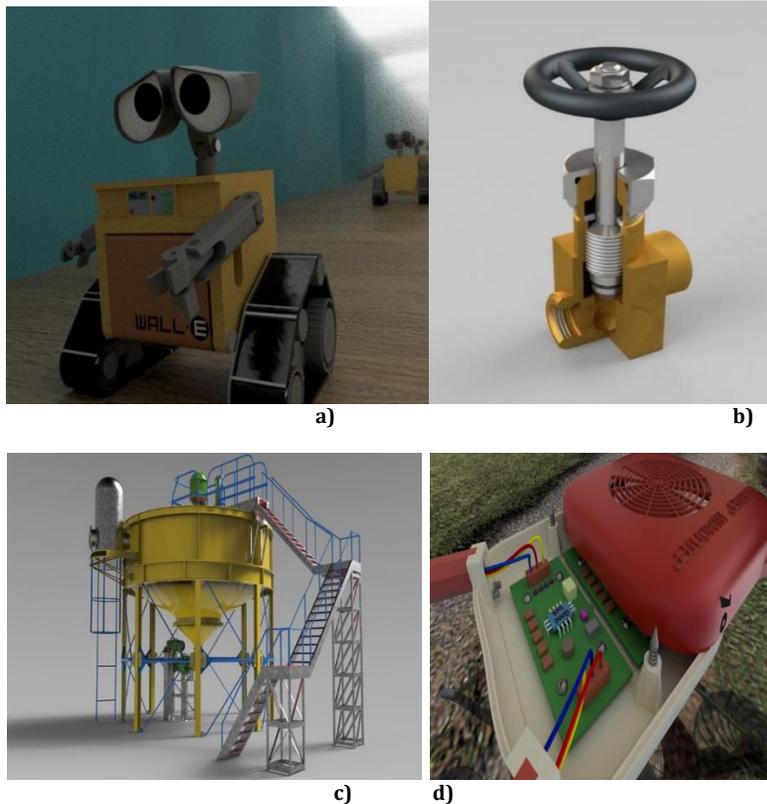
international classifier has #05. The term "Mechanical Engineering CAD" refers to the process of using computer-aided design (CAD) systems in the preparation of electronic models, drawings and files containing all the information necessary for the manufacture and documentation of spare parts and assembly units to solve mechanical engineering problems that are encountered by industry workers. Solutions must be in line with industry standards and the current version of USCD (or ISO) standards [13].

According to the technical description of the competence, the participant, in addition to skills in 3D modeling and work with design documentation, must have design skills:

- Be able to adjust the light, scene or create a background to obtain tinted images of photographs;
- Correctly use the camera installation to demonstrate the project;
- Adjust colors, shadows, and angles to produce clear images;
- Set the color and texture components;
- Create animations to show how individual parts work or assemble.

Using possibilities of the CAD at the championship (KOMPAS-3D or Autodesk Inventor) students make visualisation of objects of machine-building made on drawings and study to modern ways of representation of projects. On Fig. 2 examples of photorealistic images are presented.

Competitive tasks for the championships of higher education institutions are formed on the basis of the tasks of the world championships according to WorldSkills International standards and meet the requirements of world employers in the field of 3D-modeling of mechanisms, machines, metal structures, consumer goods for mechanical engineering design. The quantity of criteria of an estimation of competitive tasks is large, however is a necessary minimum for any expert using CAD in the professional activity. For conformity to any of criteria the importance of qualitative geometrical training which students traditionally receive in junior years of high school is obvious. Level of development of such disciplines as descriptive geometry, the engineering drawing and computer graphics has essential influence on level of possession CAD and quality of the further preparation of the expert.



**(a) Robot Valley project, performed by a school student in preparation for the WorldSkills Junior standards championship;  
 (b) Project "Valli", performed by a first-year student in an engineering graphics class;  
 c, d) samples of the "CAD Engineering Design" competence tasks according to the WorldSkills standards  
 Figure 2: Visualization of the Projects Executed in Autodesk Inventor**

The basic knowledge received in the first year is strengthened and improved at study of disciplines at senior courses: applied mechanics, designing of metal designs, bases of designing. In classes on applied mechanics students perform calculations and determine the geometric parameters of gears. Model building is made with use of tools of KOMPAS - Shaft 3D in which except geometrical calculation calculations on durability and longevity are provided. In KOMPAS-3D the tool for preparation and the subsequent finite element analysis of 3D-solid-state model (details or assemblages) - system APM FEM which allows to

conduct following kinds of calculations static calculation, calculation on stability, calculation of natural frequencies and forms of fluctuations, thermal calculation is integrated. All these types of calculations are made at designing of argegates and units in mechanical engineering. For visualisation of work of the received 3D-model the videoclips with the help of library of animation KOMPAS-3D are created and written down [7]. In Artisan Rendering the electronic model is placed in space and processed for reception of photorealistic images.



**Figure 3: Visualization of the project "Worm gearbox", made by a third year student at the classes on applied mechanics in Autodesk Inventor.**

Between modern CAD there is a possibility of import of electronic files of models, therefore work on designing of shafts and gear wheels of a gearbox students also perform in Autodesk Inventor. Comparison of the results received by carrying out of calculations on the educational literature, in KOMPAS - Shaft 3D and Autodesk Inventor allows to make the correct decision for designing.

At discipline studying designing of metal construction it is applied program complex APM WinMachine - system of the automated calculation and designing of the mechanical equipment and designs in the field of mechanical engineering. With its help students develop a metalwork, make calculation on static durability, receive schedules: stresses, factor of reserve, deformation, efforts, analyze the received results.

Graduates of higher education institutions studying in the specialty 15.05.01 "Design of technological machines and complexes" should have theoretical knowledge and practical skills to solve a complex of issues related to the organization of workplaces, their technical equipment with the installation of technological equipment. Such work is carried out by design organizations, as well as at industrial enterprises in the construction of new units or their reconstruction in connection with changes in the program of production or nomenclature of products, changes in production technology, replacement of equipment to improve technical and economic performance. It is necessary to note importance of the given work as advantages of building of new divisions or their reconstruction cannot be realised without thought over effective lay-out decisions. The questions connected with working out of lay-out decisions are considered at studying of discipline of a basis of designing. Use of means of automation of designing KOMPAS-3D and AutoCAD allows to raise considerably quality of design decisions and to reduce labour input of designing. The workshop lay-out is carried out in the form of drawings according to standards and supplemented with a 3D model. The knowledge received at studying of the given questions, students use at performance of the diploma project [6, 14].

In Nosov Magnitogorsk State Technical University in preparation of graduates of the specialty 15.05.01 an integrated approach is used in teaching disciplines, using modern methods and tools of design, calculation, mathematical, physical and computer modeling. CAD KOMPAS-3D, AutoCAD, Autodesk Inventor, APM WinMachine are mastered by students during all educational process in university within the limits of various disciplines and are applied at performance of term papers and the diploma project. By using the methods of teaching developed at the department, teaching manuals and materials is provided through

the integration of modern CAD in the educational process. Computer graphics are used by students, starting with the study of descriptive geometry and engineering graphics, up to writing the final qualifying work, increasing the level of program knowledge [15-17].

In accordance with the requirements of educational standards, cooperation with leading enterprises and design organizations of the city is implemented in the format of involving leading specialists in the organization of industrial training practices, diploma projecting. At such interaction students show basic skills of possession of CAD and receive knowledge of professional activity. Strengthening of cooperation between high school and industry promotes development of system of engineering education and becomes guarantee of effective development of the enterprises of the Russian Federation in the future. The department annually analyzes the employment of graduates. Young specialists are in demand at leading enterprises and design organizations of the city, such as JSC Magnitogorsk Iron and Steel Works, Gipromez Design Institute, JSC MMK-Metiz and other enterprises.

#### CONCLUSION

One of the urgent tasks of training students of technical disciplines is to improve the technology of teaching technical disciplines using modern computer-aided design systems. The quality of training should meet the level of technology development and new requirements in production.

It is necessary to train specialists:

- To begin studying modern CAD (KOMPAS, Autodesk Inventor) at the first year;
- To provide integration CAD in the disciplines studied at high school with increase of level of knowledge of programs and mastering of engineering calculations;
- prepare students annually for participation in championships on standards of WorldSkills in competence "Engineering design CAD";
- Hold contests, olympiads and other events aimed at developing competition among students and demonstrating the acquired skills;
- Provide communication with leading enterprises and design organizations to apply and improve students' CAD skills in their professional activities.

The complex approach to the implementation of tasks solved by CAD in the training of students of specialty 15.05.01 "Design of technological machines and complexes" provides the output of highly skilled professionals who are able to compete properly in the job market.

## REFERENCES

1. Sakao, T., Shimomura, Y., Sundin, E., & Comstock, M. (2009). Modeling design objects in CAD system for service/product engineering. *Computer-Aided Design*. 41(3). 197-213.
2. Narayan, K. Lalit (2008). *Computer Aided Design and Manufacturing*. New Delhi: Prentice Hall of India. ISBN 812033342X.
3. Savelyeva, I.A., Reshetnikova E.S. (2016). *Computer graphics and geometrical bases of modeling*. Magnitogorsk State Technical University. Magnitogorsk.
4. Gonçalves, J., & Santos, B. (2019). Enhancing Civil Engineering teaching through 3D Computer Aided Design. In IOP Conference Series: Materials Science and Engineering (Vol. 586, No. 1, p. 012045). IOP Publishing.
5. GOST 2.052-2015. (2016). *Unified system of design documentation. Electronic model of the product. General provisions*. Moscow: Standartinform.
6. George, O. (2008). *Mastering Auto CAD*. Sybex.
7. Ganin, N.B. (2010). *Designing in system KOMPAS-3D V11*. 7th edition. Moscow: DMK Press.
8. Svistunova, E.A., Reshetnikova, E.S., Skurikhina, E.B. (2018). *Creation of the design documentation. Part 1: Sketching of the machine parts*. Magnitogorsk State Technical University named after G.I. Nosov, Magnitogorsk.
9. Svistunova, E.A., Reshetnikova, E.S., Skurikhina, E.B. (2016). *Engineering Geometry*. Magnitogorsk State Technical University named after G.I. Nosov, Magnitogorsk.
10. Reshetnikova, E.S., Skurikhina, E.B., Tokareva, T.V. (2011). *Fundamentals of designing of industrial complexes. Features of construction drawings*. Magnitogorsk State Technical University named after G.I. Nosov, Magnitogorsk.
11. Denisyuk, N.A., Tokareva, T.V., Reshetnikova E.S. (2016). *Rules of drawing in engineering geometry*. Magnitogorsk State Technical University named after G.I. Nosov, Magnitogorsk.
12. Reshetnikova, E.S., Svistunova, E.A., Shirokov, V.O., Gudayeva, Yu.A. (2019). *History and prospects of development of the CAD engineering design competence according to WORLDSKILLS standards in Magnitogorsk State Technical University named after G.I. Nosov. Mechanical equipment of metallurgical enterprises*. 1(12). 103-112.
13. Adnan, M. F., Daud, M. F., & Saud, M. S. (2014). *Contextual Knowledge in Three Dimensional Computer Aided Design (3D CAD) Modeling: A Literature Review and Conceptual Framework*. In: 2014 International Conference on Teaching and Learning in Computing and Engineering. IEEE. 176-181.
14. Pozhidaev, Yu.A., Svistunova E.A., Veremey O.M. (2016). *Computer modeling and creation of design documentation in mechanical engineering by CAD. Engineering and computer graphics in Autodesk Inventor, AutoCAD*. Magnitogorsk State Technical University named after G.I. Nosov, Magnitogorsk.
15. Reshetnikova, E.S., Deryabin, L.V., Whiskers, T.V., Svistunova, E.A. (2015). *Computer graphics in mechanical engineering*. Intersectoral Institute of Science and Education. 6. 60-63.
16. Reshetnikova, E.S. (2019). *Implementation of the method of optimal design of belt conveyor in CAD AUTODESK INVENTOR 2019. Actual problems of modern science, technology and education. Theses of reports of the 77th International Scientific and Technical Conference*. 199.
17. Trubilin, E.I., Truflyak, E.V. *Basics of computer design in examples and tasks using the WinMachine APM package*. Krasnodar: Kuban State Agrarian University.
18. Shadab Md, Gourav K. Singh, Alka Ahuja, Roop K. Khar, Sanjula Baboota, Jasjeet K. Sahni, Javed Ali. "Mucoadhesive Microspheres as a Controlled Drug Delivery System for Gastroretention." *Systematic Reviews in Pharmacy* 3.1 (2012), 4-14. Print. doi:10.4103/0975-8453.107130