Designing mountain drawings with the help of computer-aided design (CAD)

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Abstract. The relevance of the researched issue is caused by the problems due to the difficulties of the representation of geometric objects in the space. When deciding the tasks of Descriptive Geometry and Engineering Graphics, students find it difficult to imagine a general view of the subject in the space from their images on the main projection plane. The aim of the article is to form concepts for the basics of graphics and justifying the use of spatial modeling techniques to generate geometric models and designed objects in the minds of students with the help of a computer-aided design program by the example of the Russian company ASCON KOMPAS. The leading methods of research of this problem are the information and computer technology, observation, comparison, analysis and monitoring of the above problems, using the experience of working at the university. Results of the study. In the article the positive results of application of the graphic program KOMPAS by the example of construction of an axonometric drawing of mine are presented. Practical significance. The research is aimed at solving problems on Descriptive Geometry and Engineering Graphics, using three-dimensional modeling; the formation of concepts graphic bases of thinking and solving engineering problems of any level.

1. Introduction
Knowledge, skills and abilities during the development cycle of graphic disciplines (descriptive geometry, engineering and computer graphics) are used in all disciplines of the curriculum according to the engineering profession in the Russian Federation. The use of graphic materials and information (diagrams, drawings, charts, nomograms, figures) is the basis for the development of the professional cycle subsequent disciplines in the performance of course and degree projects, as well as in industrial practice. The student must choose a specific program for the tasks. We believe that the most efficient and affordable program for students of the first and subsequent courses is the Russian KOMPAS-3D program [1-4]. A feature of the simulation system is its own mathematical core and parametric technologies and main component of it is the three-dimensional modeling system itself. KOMPAS-Graphic system (computer-aided design) and a text editor - a design specification module greatly simplifies the work of any professional in this field. For Russians, the usability of the system is determined by its orientation to the Russian standards series USDD (Unified system for design documentation) and SDDC (system design documentation for construction) and the presence in it of a variety of industrial applications. According to independent research KOMPAS-3D ASCON program takes more than a quarter of the Russian market. Program developers have built the app "ABC
KOMPAS,” which allows you to make a drawing and descriptive geometry solution more understandable and accessible.

2. Results

2.1. The structure and content of a model

Design of a detail begins with creation of a basic body by creation of the sketch (or several sketches). At the same time the following types of operations are available:

- rotation of sketch around an axis lying in the plane of the sketch;
- squeezing a sketch in a direction perpendicular to the sketch plane;
- kinematic operation - moving a sketch along said guide;
- the construction of the body with use of several cross sections- sketches.

Each operation has an additional option, allowing the body to vary the construction by the rules:

- at the sketch, you can set the rotation angle and rotation direction with respect to the sketch plane, and select the type of body - a toroid or spheroid (if the sketch loop is not closed);
- When you set distance and direction of the extrusion of the sketch with respect to the sketch plane, you can enter the angle of inclination, if necessary;
- When you want to use the kinematic operation, you can specify the orientation of the generator relative to the guide (maintaining the normal inclination or orthogonality);
- you can specify whether you want to close the built body when you make the construction of the body with use of cross sections.

In all types of operations, you can include the creation of a thin-walled shell option and specify the thickness and direction of the construction of the wall - inside, outside or on both sides of the body facing surface of the operation.

After creating a base body you can make "sticking" or "cutting" of additional volumes. Each of them forms a body by using the above-mentioned operations on new sketches. In case of a type selection of operation it is necessary to specify directly, the created body will be subtracted from the main volume or to be added to it. Examples of subtracting the volume of the parts may be a variety of holes, grooves, groove, and examples of adding volume - lugs, flanges and ribs.

For most of the operations on the workpiece due to the emergence of multibody you can choose among several options of the design methods (modes):

1. When you cut (removal of material):
   - subtraction of element - the removal of material parts is going on inside the closed surface formed by a given sketch and the type of operation (extrusion, rotation, etc...);
   - the intersection of the elements - as a result of the operation is going the removal of parts of the material located on the outside surface, which was formed on it.

2. In the "bonding" (adding material):
   - a new body forms a three-dimensional element to be added to a new solid parts, regardless of whether it intersects with existing bodies or not. If you want to create an element which does not cross or does not touch an existing part geometry, this feature is automatically activated;
   - association - added element is connected to the solid body, with which it intersects;
   - self-join - the system automatically combine into one body existing and new elements, if they intersect, or creates a new body, if they do not intersect.

2.2. Stages of model implementation

Mining drawings (underground mine workings) are significantly different from those of other industries. Mountain excavations are not physical bodies, but voids in the thickness of rocks. The objects (workings) projected on mountain drawings are elongated by tens and hundreds of meters with relatively small cross sections.
Building this drawing manually is a rather lengthy and complicated process. KOMPAS allows you to build a drawing and 3D model faster and with higher accuracy, which is very important [5-12].

The algorithm for solving this problem is as follows.

The first stage of work in CAD is the construction of horizontal plans. Using the "New" command, select the document type "Fragment". To specify the horizon parameters (length and width) in meters, use the "Tools" command to select "Parameters", "Unit of measure", "Meters" in sequence. The horizons are drawn with a display scale of 0.0002. Then create a contour of the future production horizon, not including the projections of the inclined and vertical workings, the digitization of the projection axes, all the inscriptions.

At the second stage, the work is created the 3D-fragment. To do this, select and copy the fragment to a document file of the type of the part, select the plane ZX, select the sketch, insert the fragment. Select the sketch in the model tree, then click the "Extrude Operation" button on the left panel. Simultaneously, at the bottom of the screen, the panel is set to Direct extrusion direction to a distance of 15000, incline inwards, at an angle of 9.5°. Then press the key combination "CTRL + ENTER" and a 3D image of the model of our horizon will appear on the screen.

After this, they proceed to construct vertical workings: a ventilation shaft and ore passes. To do this, select the upper or lower working plane, click on the button "Sketch" button. And in the presented plane, outlines the vertical workings (in accordance with the issued task): for the ventilation shaft - a circle with a radius of 25 m, for ore passes - a square with a side of 25 m (the dimensions of the workings are presented according to the variant). Then the Extrusion is performed in two directions so that the distance between the 2-3 horizons is equal to 150 m, between 3-6 horizons 450 m, but in connection with the fact that an associative drawing of the assemblage of three horizons in isometry is carried out, increase this distance for visual the assembly view. Similarly, models 3 and 6 horizons are created (Figure 1, 2).

![Figure 1. Fragment of Horizon 2 (upper level).](image)

![Figure 2. 3D-model of Horizon 2.](image)

A three-dimensional model of the mine fragment is created in a document such as "Build". To do this, create a new document, which is similar to the document type "Detail". Then, in the opened window of creating the assembly on the compact panel, click the "Add from file" button. Sequentially add horizons and place them in the working field of the program. The horizons are arranged relative to each other in such a way that the common vertical workings of the horizons coincide in accordance with their image in the given version. At the last editing stage of the "Assemblage", it is necessary to capture images of the mine fragments.

To create inclined excavations in the "Sketch" mode, the horizons are the points that are the beginning and end of the inclined workings. Then perform the operation "Axis", "Through two vertices", the vertices of which are the points established earlier. After this, to create a sketch of the cross section of the workpiece, create a plane perpendicular to the edge, i.e. axis of the incline. To do this, perform the operation "Plane", "Through the vertex perpendicular to the edge". After completing the sketch, squeeze out the slope (Figure 3, 4).
In order to perform an associative drawing, a file of the "Drawing" type is created. Then, using the command "Service", "Parameters" set the format of the current document A1 and change to the horizontal orientation. Then set the scale to 1: 5000. Open the context menu "Insert", "View from the model", "Free".

Horizon plans are plotted with a coordinate grid, vertical and inclined mine workings and signs them.

In the context menu "Insert" "View from the model" "Custom", specify the scale 1: 5000 and the XYZ isometric view, since all the details and assembly are executed in this orientation. After insertion, axonometries destroy the associative connection for the addition and removal of segments and the drawing of a grid. Add lines at the junctions of the inclined and horizontal workings, and remove at the junctions of the vertical workings (Figure 5). Calculate the distortion coefficients along the axes:

\[ k_{xy} = \frac{h_r}{h_i} = 0.8165 \]
\[ k_z = \frac{h_r}{h_i} = 1.23 \]

where \( h_r \) - is the actual (actual) distance between the horizons, and \( h_i \) - is the theoretical distance between the horizons [2,4].

Apparently from above explained the decision of this task is rather complicated and also requires a lot of time for execution of graphic operations and ultimate accuracy of the executed creations. Besides, it is not always directly possible to see one or another combination of the spatial intersection of complex geometric bodies and their results.

3. Conclusion and recommendations

Educational system is an information field that contains all the information for its development, reflecting the systemic features with the required level of accuracy. The mechanisms of perception of the current information system of higher education and the construction of scenarios of development depend on user-defined boundaries of the study, complexity and specificity of the methods of information processing [13]. The modern information and computer technologies of training allow gaining the new volume of knowledge to the student and ability to use them in specific conditions, namely the design and construction of machine parts, aerodynamic and hydrodynamic surfaces in the automotive and aircraft construction, hydraulic engineering, hydraulics, mining and other industries [14-18].

We prepare students to use spatial modeling techniques KOMPAS-3D and Auto CAD design systems and as a consequence, increase professional competences. Formed in the minds of students a holistic concept of descriptive geometry and graphics, it became possible in the process of learning to...
use computer graphics, theoretical mechanics, machine parts, strength of materials, objects of engineering education. As a result, an engineer, which received an education, can solve engineering tasks at every level, as well as to formulate and solve non-standard problems and generate new ideas.

Figure 5. A fragment of the drawing sheet, the assembly of Horizons.

The use of modern graphics software packages, including "ABC KOMPAS" application allows you to dramatically simplify the decision of the problem, minimizing both times to solve problems and design of solutions in graphic form.

This approach may allow considering as a study not just one but several options for solving spatial problems. By changing the angle and distance, as well as the shape and size of the figures, we allow a clear and easy to develop in the future spatial thinking and understanding of spatial problems of the engineer.

Experience is provided in the system of KOMPAS-3D by ASCON for design engineers and designers. The contents of this article can be useful to teachers, students and in professional activity in mechanical engineering, mining industry, civil engineering and other industries.

References
[1] Boreskov A V, Shikin E V 2016 Computer Graphics: tutorial and workshop for applied bachelor. Series: Bachelor. Applied course (Moscow: YURAYT) p 219
[2] Folomkin A I, Voronina M V, Moroz O N, Tretyakova Z O 2016 Development of training mining and graphic libraries for CAD KOMPAS Proceedings of the X St. Petersburg Congress “Professional education, science and innovation in the XXI century” (Saint-Petersburg, Russia) 2 pp 326–329
[3] Katuntsov E V, Kultan J, Makhovikov A B 2017 Application of Electronic Learning Tools for Training of Specialists in the Field of Information Technologies for Enterprises of Mineral Resources Sector. Zapiski Gornogo intituta 226 pp 503–508 DOI: 10.25515/PMI.2017.4.503
[4] Konakova I P, Pirogov I I 2016 Computer graphics. COMPASS and AutoCAD: a tutorial (Ekaterinburg, Russia: URAL UNIVERSITY) p 148

[5] Merkulova V A, Sudarikov A E 2017 The solution of problems of descriptive geometry as a basis for the training of engineers Man in India 97 (3) pp 431–441

[6] Merkulova V A, Grebenschikova A N, Gribunina K A 2017 Comparison of the drawing of the "Fragment of the mine" by hand and with the help of CAD systems "Scientific community of students of the XXI century. Engineering" Electronic collection of articles on the materials of the XLIX student international scientific and practical conference (Novosibirsk: Sibac-info) 1 (48) pp 59–70 http://www.sibac.info/archive/Technic/1(48).pdf

[7] Merkulova V A 2012 Designing in KOMPAS-3D system. Information technology and technical design in professional education and industry Proceedings of the IV All-Russian scientific-practical conference with international participation (Novosibirsk: NGTU) p 176

[8] Merkulova V A 2015 The modern approach to the development of a culture of thinking and an effective speech in the study of engineering disciplines Proceedings of the V International scientific and methodological conference "Actual problems of the humanitarian knowledge in higher technical educational institution" (Saint-Petersburg, Russia: Saint-Petersburg Mining University) pp 224–226

[9] Merkulova V A, Tretiyakova Z O 2015 Development prospects of computer modeling in teaching engineering drawing course Proceedings of the X International scientific-practical conference "Scientific Perspectives XXI century: new century: achievements and prospects" (Novosibirsk) pp 113–115

[10] Merkulova V A 2014 Creating of the level-matrix model of project of teaching disciplines. Proceedings of the International scientific and methodological conference "Modern educational technology in the teaching of natural sciences and the humanities" (Saint-Petersburg, Russia: Saint-Petersburg Mining University) pp 442–445

[11] Merkulova V A 2016 The impact of ICT on the formation of the information-educational environment of University Proceedings of the III International scientific and methodological conference "Modern educational technology in the teaching of natural sciences and the humanities" (Saint-Petersburg, Russia: Saint-Petersburg Mining University) pp 199–204

[12] Merkulova V A 2016 The modern model of education Modern education: content, technology, quality (Saint-Petersburg, Russia) 1 pp 294–296

[13] Levenina E Y, Voronina M V et al 2016 The Concepts of Informational Approach to the Management of Higher Education’s Development International journal of environmental & science education 11 (17) pp 9913–9922

[14] Tretiyakova Z O, Voronina M V, Moroz O N, Folomkin A I 2016 Computer graphics - an important aspect of the training of engineers Proceedings of the X St. Petersburg Congress "Professional education, science and innovation in the XXI century" 2 pp 257–262

[15] Tretiyakova Z O, Voronina M V 2016 Geometric modeling in descriptive geometry Modern education: content, technology, quality (Saint-Petersburg, Russia: Saint Petersburg State Electrotechnical University named after V. I. Ulyanov (Lenin) ("LETI")) 1 pp 324–326

[16] Voronina M V, Moroz O N, Tretiyakova Z O, Folomkin A I 2016 Descriptive geometry in educational process of Technical University in Russia today International journal of environmental & science education 11 (18) pp 10911–10922

[17] Voronina M V, Moroz O N, Tretiyakova Z O 2016 Descriptive geometry in educational process of modern Technical University of Russia: problems and prospects Proceedings of the X St. Petersburg Congress "Professional education, science and innovation in the XXI century" (Saint-Petersburg, Russia) 1 pp 103–108

[18] Voronina M V, M Muratbakeev E Kh 2017 History and modern interpretations of descriptive geometry in today's Russian engineering university Man In India 97 (15) pp 155–170