THE SOLUTION OF PROBLEMS OF DESCRIPTIVE GEOMETRY AS A BASIS FOR THE TRAINING OF ENGINEERS

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The relevance of the investigated problem is caused by the problems caused by the difficulties of representation of geometric objects in the space. When deciding the tasks of descriptive geometry and engineering graphics students have difficulties to imagine in the space a general view of the subject from their images on the main plane of projection. The aim of the article is to form concepts 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 computer-aided design program on 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. The article presents the positive results of the graphic program COMPASS on the example of the construction of the line of intersection, depending on the type of intersecting surfaces. 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.

Keywords: three-dimensional modeling, geometry, descriptive geometry, engineering graphics, information and computer technologies, monitoring studies, the solution of engineering problems.

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 (Merkulova, 2016; Merkulova, 2016; Voronina, *et. al.*, 2016; Valeeva & Shakirova, 2015). 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 (Voronina *et. al.*, 2016; Moroz *et. al.*, 2016; Tretyakova *et. al.*, 2016; Voronina, Moroz & Tretyakova, 2016; Tretyakova & Voronina, 2016; Voronina & Tretyakova, 2017; Khuziakhmetov, Ladoshkin & Esnazarova, 2015; Gabdrakhmanova, Khuziakhmetov & Yesnazarova, 2015; Nasibullov, Konysheva & Ignatovich, 2015). 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 (Merkulova, 2012; Merkulova *et. al.*, 2015; Folomkin *et. al.*, 2016).

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KOMPAS-3D program, created by Russian developers - is an easy program to work in the three-dimensional modeling system for design engineers and designers. 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.

Work on the system allows you to master it, not only for professionals but also for beginners, because the creators have taken care of an accessible interface for a successful development of the system and skills in it. Program developers have built the app "ABC KOMPAS," which allows you to make a drawing and descriptive geometry solution more understandable and accessible (Konakova *et. al.*, 2015; Boreskov, 2016; Mandel, 2015; Muratbakeev *et. al.*, 2016; Merkulova, 2014).

Ways to create three-dimensional models in engineering graphics systems can be divided into two broad classes: solid modeling and surface modeling.

Solid modeling enables to form three-dimensional object by adding or removing (cutting out) a particular piece of material. As a result, the created object is presented as a "solid-state" - the area of three-dimensional space consisting of a homogeneous material, and bounded by a closed surface. It is formed from one or more mating faces. Removal or additions of material are called Boolean operations. In addition to Boolean operations in specialized engineering systems, there is always a large number of various auxiliary commands that let you create a model in a particular design element - rib, bias hole. All these operations are referred to as the forming (or three dimensional).

Forms for adding and removing material can vary, but most often in solid modeling is described by the usual algebraic equations (cube, cylinder, sphere, prism, parallelepiped, cone, every rotation of the body, and so on). Repeated shaping operations with different size and shape of three-dimensional elements allows you to build a fairly complex model.

Possibilities of solid-state modeling allow recreating practically any objects around us (objects created by man). Relative simplicity, the ability to create highly accurate models (full play on the given size), fairly low hardware requirements and a small file size, however great assembly drawings can be attributed to the advantages of solid modeling. These advantages make solid modeling ideal for applications in mechanical engineering, mining industry, civil engineering and other industries.

However, such method of design has also shortcomings. The principal of them is the fact that in nature there are things that are very difficult and sometimes impossible to recreate on a computer by only solid modeling. These are the objects possessing a very complex geometry that cannot be constructed using only one Boolean operations. In this case we apply surface modeling.

The peculiarity of surface modeling is to create a model not as a solid body bounded by smooth faces, but in the form of an arbitrary (both closed and open loop) surface.

Modeling using Boolean operations - this is a common and frequently used technique. Boolean operations are very similar to the traditional methods of sculpting and modeling. Composite Boolean object consists of two objects called operands that represent a Boolean operation. These operands stay in the form of objects for as long as necessary, to permit access to its parameters and to the stacks modifier.

MATERIALS AND METHODS

Research methods

During the study the following methods were used: theoretical (analysis, synthesis, concretization, generalization); diagnostic (questionnaires, interviews, testing, tasks and assignments method); empirical (research of learning experience in educational organizations and in St. Petersburg Mining University, regulatory and instructional documents, pedagogical supervision); experimental (ascertaining method, forming method, control experiments method); method of graphical representation of the results.

Experimental research base

The studies were conducted on the basis of the St. Petersburg Mining University.

RESULTS

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.

Stages of implementation models

The principal stage of the construction of multibody parts is to identify the boundaries of the original elementary surfaces, which the lines of their mutual intersection are. Thus, the task of constructing the line of intersection of two surfaces, quite often encountered in descriptive geometry, has a wide application in the construction of the technical details. The line of intersection of two surfaces in general is a curve in space, which may decay into two parts or more.

The main objective of the mutual intersection of geometric bodies consists in determination of the place of the points belonging simultaneously to both surfaces intersecting bodies. This locus is a data line of intersection of the surfaces. To find the points belonging to the line of intersection of surfaces, use:

– Auxiliary truncated surfaces (private or common position of the plane, curved surfaces);

– Forming the curved surfaces;

– The edges of polygonal surface;

– Auxiliary straight lines lying in the faces of polyhedral surfaces.

Depending on the intersecting surfaces and their mutual location may be a line of intersection:

– Curve line;

– A broken line;

– A straight line.

The line of intersection may be planar or spatial.

Methods of constructing the intersection line defined by the type of intersecting surfaces, thus, they are generally considered separately:

– Mutual intersection polyhedral surfaces;

– The mutual intersection of the curve and the multi-faceted surface;

– Mutual intersection of curved surfaces.

Each point on the line of intersection of the two intersecting surfaces refers to both surfaces, and hence, the construction reduces to finding the row of points.

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. In the case where the shape of the part is the sum of geometric bodies, we can mentally dissect her apart. If the form is combined, begin with an analysis of the major parts then move to smaller. Often there are objects which forms smoothly passes into one another. It is important to learn how to analyze the shape of these parts.

In our case, for example, two bodies have been chosen - a straight rectangular prism and not inclined truncated cone. Prism - polygon, whose two faces (prism base) is a regular polygon with mutually parallel sides, and all the other facets - parallelograms.

Title of the prism depends on whether the polygon is at its base, if a triangle, the prism - triangular, quadrilateral if as in this case, the - quadrilateral. Prism is called direct if its fins perpendicular to the ground plane. Cone - geometric object bounded by a conical surface and a plane, called the base or two planes (truncated cone). The cone can be straight or curved as in our case.

The algorithm for solving this problem is as follows:

1. In the construction of a direct quadrangular prism KOMPAS 3D «squeezing» the program operation has been used at a distance of 100 units. As the main plane on which the horizontal plane is done quadrangle was built. For greater clarity the solution of the problem of squeezing the body, was applied extruding of the shape with a thin wall (fig. 1).

2. In the construction as oblique cone base also adopted horizontal plane. Creating a cone in the program 3D COMPASS possible in several ways. The simplest of them - this operation is "rotation". However, in this case, this operation is not applicable because the cone is inclined. In this case the operation is "on the cross sections" (fig. 2) has been applied.
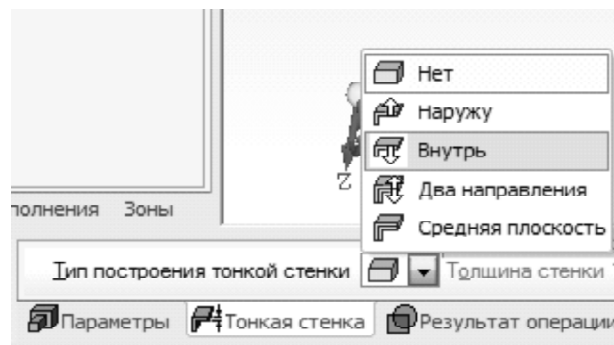

Figure 1: Selection of the thin wall

Figure 2: Selecting the operation of creating a model

In this case, the lower part - the base of the cone (circle) lies on the horizontal plane and the apex of the cone lying on the displaced parallel to the base plane at a distance of 120 units. On the shifted plane with the exact solution of the problem should be the point. However, in such a setting it becomes impossible to create a thin wall in the figure. Therefore, our decision is to replace a point to the infinitely small circle. This assumption does not significantly affect the resulting solution.

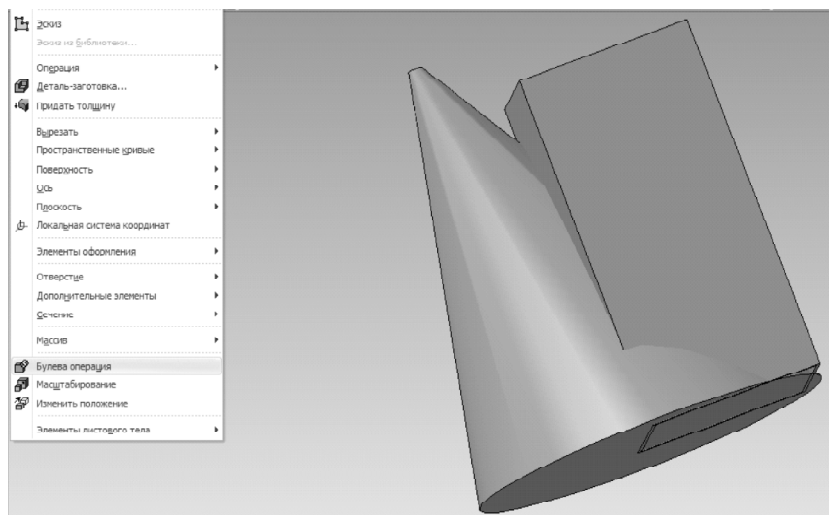The result of the construction of these two figures is shown in Figure 3.

Figure 3:   General view of the confluence of two figures

As can be seen from the figure obtained figures partly penetrate into each other to form a rather complicated intersection line both in form and in the space layout. The solution of this problem by cutting planes will take quite a long stretch of time.

In our case, we give the original form of a thin wall bodies and applying the "Boolean operations" for each body to quickly obtain the solution of the problem. As a result of the Boolean operation has been selected, "subtraction" (fig. 4).
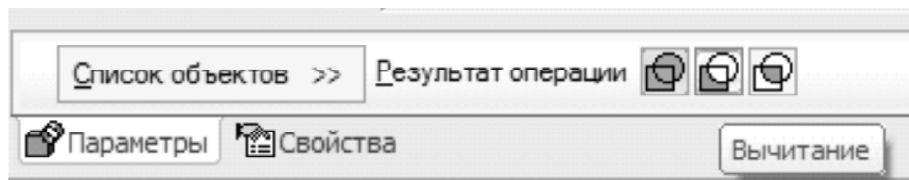

Figure 4:   Selecting the result of the operation

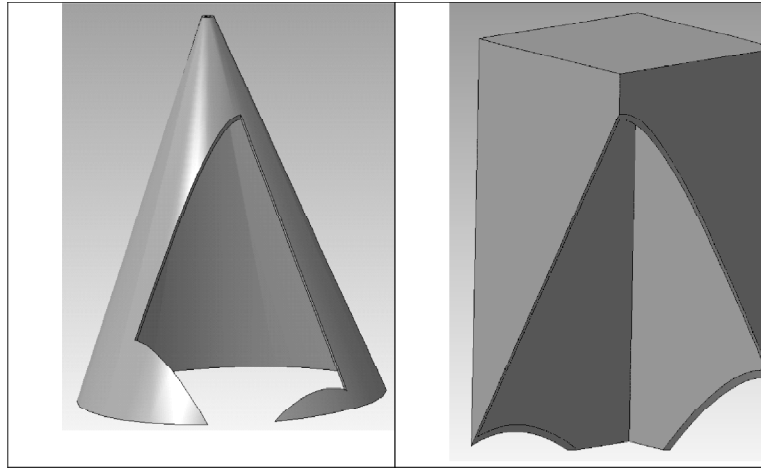Figure 5 shows the intersection of the two figures.

Figure 5: The line of intersection of two figures

DISCUSSION

The mutual intersection of surfaces or composition of the surfaces is one of the fundamental themes of the course of descriptive geometry. This subject defines methods and techniques of creation of lines of mutual intersection of surfaces on drawings, the surfaces on scans and perspective view. This theme is used in the design and construction of machine parts, aerodynamic and hydrodynamic surfaces in the automotive and aircraft construction, hydraulic engineering, hydraulics, mining and other industries.

All machines, devices, any products consist of separate parts joined together. Form of the machine parts mainly are combination of planes and curved surfaces (cylindrical, conical, spherical, torus) arranged in space so that they are relative to each other in a certain ratio. Most often they intersect, forming a common line for them.

Descriptive Geometry solves these issues by means of standard graphics ruler and compass, and consistently goes all the way to the construction of the line of intersection of surfaces generalized algorithm to solve this problem. Such an approach is consistent with the general principle of teaching the subject "Descriptive Geometry", for which the main purpose is to create concepts and graphic geometric foundations of thinking, underlying engineering thinking.

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.

The modern computer technologies of training are considered not only for obtaining necessary volume of knowledge, but also the formation of students' ability to use them for specific production conditions The process of using information technology in higher technical school aims to meet the production needs of the engineering staff with the right skills; determine the conditions, methods of preparation of broad specialists that show not only professionalism, but also creativity, without which no conceivable solution to problems of today.

For organization of computer support education, we can distinguish two directions:

1. The development of computer programs for educational purposes, programs specifically designed for the study of a particular discipline;
2. The use of software designed for professional activities in the relevant field of knowledge.

In the course of the phased monitoring of the educational process it becomes clear that at the present time, any production is impossible without the use of information technology. In the software of modern industrial design automation (CAD) are widely used methods of spatial modeling to generate geometric models of designed objects.

In this regard, there is need for qualified engineers capable of building geometry (surface, line) with the desired characteristics, which imposes special requirements on the training of students of engineering specialties in the course of graphic disciplines.

CONCLUSION

Subjects "The mutual intersection of surfaces" or "Composition of the surfaces" is one of the fundamental discipline of "Descriptive Geometry". The solution of problems of descriptive geometry of the intersection of spatial figures classical methods is time-consuming to carry out constructions and sufficiently skilled artist. All these options increase repeatedly in case of complication of forms of the given bodies. The computer graphics and computer simulation comes to the rescue.

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.

We prepare students to use spatial modeling techniques KOMPAS-3D and Auto CAD design systems and as a consequence, increase professional competences.

The use of modern graphics software packages, including "ABC Compass" 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 Russian company "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.

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