Computer-aided design systems for product life cycle stages

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Abstract. The article gives a brief analysis of computer-aided design (CAD) systems and KBE-project, the use of CAD in the design of products at all stages of the life cycle. The result of CAD studies can be used by enterprises when choosing CAD categories of low, medium or higher level.

1. Introduction

Currently, production process in any industry like oil and gas, aircraft, automotive, heavy machinery, architecture, construction, geographic information systems, even small-scale production of consumer goods is impossible to imagine without the use of computer-aided design (CAD) systems. We are talking about the complete product life cycle (PLC), including the period from the idea of its creation to the time of its final use (or its modernization, i.e. the beginning of a new round of the life cycle). In the general case, the PLC is represented by the following main steps, presented in Figure 1: 1) choice of the product layout, 2) design, 3) manufacturing, 4) use, 5) recovery/modernization.

Figure 1. Product life cycle

The main purpose of using CAD is to increase the engineers’ labor productivity, including:

• reduction of design and planning complexity;
• reduction of design time;
• reduction of the costs for design, manufacturing, operation;
• improvement of the quality, technical and economic level of design results;
• reduction of costs for full-scale modeling and testing.

2. Materials and methods
The results obtained in the article are based on analytical methods and literature analysis [1–16].

3. Research and evaluation of their effectiveness
The current state of CAD has reached such a level when the stages of the PLC are not only a closed cycle but also an interconnected one. It is implemented by means of an information aspect, in which each subsequent stage is based on the previous one and vice versa [1]. For example (Figure 1) full information on the appearance, purpose, characteristics of the prototype (fifth stage), and information on technological capabilities of production (third stage), etc. is required for the design of a new product (the second stage of PLC), which has higher operational, ergonomic, aesthetic or other properties, [2]. Here the concept of knowledge-based engineering (KBE), associated with effective methods and software tools designed for their use by design engineers in product development prevails.

State standard R 57321.2-2018 “Knowledge management in the field of engineering. Part 2. Design based on Knowledge management. Knowledge management for engineering. Part 2. Knowledge-based engineering” adopted on 01.01.2019, among other things describes the roles that must be followed at the stages of the project as well as the model of the KBE project implementation process (Figure 2).

Figure 2. Phase model of the KBE project implementation procedure

State standard R 57321.2-2018, the procedure for implementing a KBE project is divided into four stages. At the planning stage, the main attention is paid to organizing KBE-projects, including the required knowledge identification. At the development stage, strategies and methods for collecting, analyzing and structuring knowledge as well as various options for applying knowledge are considered. The testing phase covers validation and release procedures. The operation stage describes the work on the knowledge administration, maintenance and updating. Important and necessary provisions for ensuring safety and protection of knowledge go through all stages.
Assuredly, the procedure of the design with a lot of research and various approaches was the same from the very beginning but until now there is no single and universal description of the industrial environment with which you can implement and use KBE applications. The form they are currently published in, specific solutions implemented by individual companies can be used for other applied tasks with only significant changes and financial costs [13–16].

It is worth noting that the central role within the KBE project belongs to the knowledge engineer (project manager). Let us consider this in a little more detail because the role of a knowledge engineer should be preserved and preferably belong to the same specialist throughout the entire life cycle of a KBE application and we will try to list the competencies that a knowledge engineer should have. They are as follows:

- be a mediator between company strategic goals and business process users;
- control the comprehensive planning, development and operation processes of a KBE system, including conducting preliminary research (for example, developing a feasibility study), selecting suitable tools, gaining knowledge, integrating into the company’s IT environment and then finalizing the KBE application;
- possess knowledge in the field of information technology and communications as well as have completed fundamental education;
- possess fundamental knowledge in the field of logical and system analysis;
- possess programming skills for the development of reliable software, skills in KBE-applications implementation as well as the necessary knowledge in the field of software ergonomics;
- be ready for cooperation and conflict resolution, have the ability to implement the requirements of the customer by combining the knowledge of all experts in one decisions. It is very important for this person to be already familiar with the relevant technical field.

Let us now consider the hardware and software automation of design, engineering, technological and production works, which are conditionally divided into the following three categories with regards to cost and capabilities [3]:

- a low-level CAD, which is a system of traditional design processes automation based on two-dimensional drawings. These include scribers, the brightest representatives of which are AutoCAD LT, T-Flex CAD 2D, KOMPAS-Graph, and others;
- mid-range CAD systems, for example, SolidWorks, Autodesk Mechanical Desktop, T-FLEX CAD, being three-dimensional solid-state design systems that can also build three-dimensional parametric models of parts and assemblies, shorten documentation production time and project development time by automating the design and technological documentation processing, programs for CNC machines. These systems enable to create a product’s three-dimensional model, which determines the inertial mass, strength and other characteristics. It controls the relative position of the parts, simulates all types of CNC processing, works out the layout using photorealistic images, and produces documentation. In addition, project management based on electronic document management is provided. It is economically beneficial due to a multiple increase in labor productivity with a sharp reduction in errors and, accordingly, in improving the quality of products. Currently, mid-level systems are very popular and therefore are developing rapidly, approaching in their capabilities to top-level CAD systems;
- top-level CAD systems have two main differences. Firstly, these systems provide integration of the entire product creation cycle from a product’s conceptual idea, design, calculations, preparation for manufacturing. Additionally, they enable to design parts taking into account the characteristics of the material (plastic, metal sheet), conduct a dynamic analysis of the assembly with imitation of assembly devices and tools, design fittings with simulation of manufacturing processes (bending, stamping, casting), which eliminates defects in fittings and makes the production of full-scale models unnecessary, that is, result in significantly reduced costs and time for the production preparation The mathematical analysis programs of such CAD systems can include strength, kinematic and dynamic analysis. Modeling of machining enables to evaluate the quality of parts in terms of their deformation, etc. Secondly, these CAD systems make it possible to create a design and information environment for
the simultaneous work of all participants in the process, to work on the product from different sides: to solve the problems of style design, product layout and parallel unit development of the product, etc. A new product is created in the design department, which is the central link: groups of specialists of various profiles simultaneously carry out all stages of parts development and assembly, their technological development, etc. At present, KOMPAS-3D, Pro/Engineer and EDS Unigraphics systems meet the most complete requirements for integrated CAD systems of the highest level.

What does design mean? According to the Great Soviet Encyclopedia (4th ed., 1990), design is the process of creating a project being a prototype of a proposed or possible object, condition. State standard 22487 defines design as the process of compiling a description of an object that does not exist yet but is necessary in the given conditions based on the initial description of the object and (or) the algorithm for its functioning ...”.

In modern conditions it is logical to give the following definition of design: a block of work on the research, calculation and design of a new product or a new process based on technical specifications [4]. The following types of design can be distinguished:

- human-made design being a design process performed by a person manually. It is gratifying to note that this type of design is becoming history;

- computer-aided design is carried out by the interaction of man and computers. Today it is the most common, highly employable and successful type, provided with a variety of CAD tools that are developing at high speed;

- automatic designing is a type of designing in which all transformations of object descriptions and its functioning algorithm are carried out without human intervention. Currently, it is already being implemented in some cases for simple objects; a matter of the near future. However, there are a lot of questions and sophisticated problems, for example, the design algorithm of a particular product should not depend on the CAD used to create the part and should easily perceive changes in the product’s geometry [6].

The introduction of any category of CAD into production is impossible without computerization being the totality of efforts necessary to automate the design, technological and production processes aimed at equipping design bureaus and other services with appropriate equipment [5, 6]. The characteristics of the CAD systems are constantly changing, offering a consumer new design possibilities, so the equipment should also be updated in a timely manner.

There are many classifications of CAD. So, according to the industry purpose, the domestic classification is given in State standard 23501.108-85 but the foreign one is used more frequently [11-13], for example, MCAD (mechanical computer-aided design) being a computer-aided design of mechanical devices, i.e. engineering CAD for the development of parts and assemblies using parametric design SolidWorks, Autodesk Inventor, KOMPAS, CATIA. Another one is ECAD or EDA (English electronic computer-aided design) being CAD of electronic devices, electronic components, integrated circuits, printed circuit boards Altium Designer, OrCAD [7, 8].

The most commonly used classification of CAD systems concerns their intended purpose, for example, CAD/CAM/CAE [9, 10]:

- CAD (computer-aided design/drafting) represents CAD tools designed to automate two-dimensional and/or three-dimensional geometric design, create design and/or technological documentation and a product’s digital model. This is a CAD designer provided, for example, by KOMPAS, AutoCAD, T-FLEX;

- CAM (computer-aided manufacturing) is the means of products technological preparation and it provides programming automation and equipment control with CNC (Russian analogue of the term ASTPP, automated system of technological preparation of production); they provide ADEM, GEMMA-3D, SprutCAM, Mastercam, CNC Module. Technologist turning;

- CAE (computer-aided engineering) is a means of automating engineering calculations, analysis and simulation of physical processes. T-FLEX Analysis, APM WinMachine, ABAQUS, ANSYS, Autodesk Simulation provide dynamic modeling, verification and optimization of products, solve the
problems of strength analysis, thermophysical and hydrodynamic calculations, analysis of plastic deformation and mechanical analysis;

- CAPP (Computer Aided Process Planning) is CAD for automating technological processes design (VERTICAL, ADEM CAPP);
- PLM (Product Life Cycle Management) is product lifecycle management, which provides T-FLEX, PLM, PILOT: PLM, etc.

Taking into account a wide range of CAD systems, it should be noted that the use of CALS technology (Continuous Acquisition and Life cycle Support), which is important for ensuring the rhythmic work of a modern enterprise, is continuous information support of deliveries and product life cycle. The implementation of CALS technologies in practical terms involves the organization of a single information space that combines automated systems designed both for the effective solution of engineering tasks, and for planning and managing production and enterprise resources. Data management in a single information space throughout all stages of the life cycle is assigned to the PLM system being a means of CALS practical implementation.

The main condition for the efficient use of CAD at any stage of the life cycle remains the competence of a specialist in various departments and services: production, transportation, financial, marketing and especially design. Automation of routine operations provides a designer with more time for creative work, increases the design productivity during engineering calculations and at the design stages of work. However, automatic design of products based on KBE design is still a matter of the future.

4. Conclusion

The article analyzes the existing computer-aided design systems in terms of their selection and application at the appropriate stages of the product life cycle. Implementation of CAD enables to do the following (1):
• shorten the product creation cycle by 1.5–2 times (from design to production);
• reduce the material consumption of the product by 20–25%;
• reduce production costs by 15–20%;
• improve product quality and increase competitive advantage of an enterprise.

References

[1] Gilmanova A M 2018 Consideration of various factors influencing acoustic logging equipment production accuracy IOP Conference Series: Materials Science and Engineering (13th International Conference on Mechanical Engineering, Automation and Control Systems, MEACS 2018) 560(1) DOI: 10.1088/1757-899X/560/1/012063

[2] Andreev V E, Chizhov A P, Chibisov A V and Mukhametshin V Sh 2019 Forecasting the use of enhanced oil recovery methods in oilfields of Bashkortostan IOP Conference Series: Earth and Environmental Science (International Symposium «Earth sciences: history, contemporary issues and prospects») 350(1) 1–6 DOI: 10.1088/1755-1315/350/1/012025

[3] Gilmanova A M 2019 Metrological support of geophysical equipment for acoustic logging IOP Conference Series: Earth and Environmental Science 378 30-36 DOI:10.1088/1755-1315/378/1/012080

[4] Yagafarova Kh N, Arslanov I G and Teregulov R A 2018 Performance analysis of surface reducing gear of rod driven screw pump with involute gearing and Novikov gearing Advances in Engineering Research (AER) (International conference "Actual issues of mechanical engineering" (AIME 2018)) 157 627-630

[5] Abdyukova R Ya 2018 Improving the design of poppet valve in piston mud pump Advances in Engineering Research (AER) (International conference "Actual issues of mechanical engineering" (AIME 2018)) 157 1-4

[6] Verhagen W J C, Bermell-Garcia P, Van Dijk R E C and Curran R 2012 A critical review of knowledge-based engineering: an identification of research challenges Adv. Eng. Inform. 26(1)
5–15

[7] Shangareev R R 2019 The formula for determining motivation indicators in the occupational risk management system IOP Conference Series: Materials Science and Engineering (13th International Conference on Mechanical Engineering, Automation and Control Systems, MEACS 2018) 560(1) DOI: 10.1088/1757-899X/560/1/012201

[8] Galiullina I F and Kadyrov R R 2018 Technical and economic background for siting production of well-killing liquid at oil fields IOP Conference Series: Earth and Environmental Science 194(8) 1-6

[9] Mukhamadeev E Z and Yagafarova Kh N 2019 Frequency converter power reduction for controlling the hydraulic parameters of the pumping station IOP Conference Series: Materials Science and Engineering (13th International Conference on Mechanical Engineering, Automation and Control Systems, MEACS 2018) 560(1) DOI: 10.1088/1757-899X/560/1/012077

[10] Galeev A S, Suleymanov R N and Filimonov O V 2019 Development of a laser beam to the line in measuring systems IOP Conference Series: Materials Science and Engineering (13th International Conference on Mechanical Engineering, Automation and Control Systems, MEACS 2018) 560(1) DOI: 10.1088/1757-899X/560/1/012125

[11] David Baxter, James Gao, Keith Case, Jenny Harding, Bob Young and Sean Cochrane 2007 An engineering design knowledge reuse methodology using process modelling Res Eng Design 18 37–48 DOI 10.1007/s00163-007-0028-8

[12] Huang X and Zhang Y 2010 Robust tolerance design for function generation mechanisms with joint clearances Mech. Mach. Theory 45(9) 1286–1297

[13] Etienne A, Mirdamadi S, Mohammadi M, Malmiry R B, Antoine J F, Siadat A and Martin P 2017 Cost engineering for variation management during the product and process development Int. J. Interact. Des. Manuf. (IJIDeM) 11(1) 289–300

[14] Khodaygan S and Movahhedy M R 2011 Tolerance analysis of assemblies with asymmetric tolerances by unified uncertainty accumulation model based on fuzzy logic Int. J. Adv. Manuf. Technol. 53(5–8) 777–788

[15] Fischer X, Daidie A, Eynard B and Paredes M 2016 Research in Interactive Design Mechanics, Design Engineering and Advanced Manufacturing 4

[16] Baxter D, Gao J, Case K, Harding J, Young B, Cochrane S and Dani S 2007 An engineering design knowledge reuse methodology using process modelling Research in Engineering Design 18 37–48