Digital support of production small business preparation in engineering

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Abstract. The article summarizes the experience of adapting Russian CAD systems in the working conditions of small enterprises in the engineering sector. Computer-aided design combines the following stages: design, technological and engineering analysis. Each of the sections acts as an independent one, but the transition to the next step is completely based on the previous one. Adaptation of CAD packages in small enterprises includes filling in databases on completed projects, parts, components and components of the engineering sector, the distribution of access rights, the creation of working archives, as well as the available equipment and accessories.

1. Introduction

This academic research [1] formulated the resources, information systems, culture and production engineering policy requirements. Achievements of each stage of the six-level model enable digital enterprises to gain competitive advantages in the production of goods and services. These qualities require to create multi-functional and ever-expanding databases, which defines the vector of enterprise development towards Industrie 4.0 [1].

Industrial automation includes the conversion of design and engineering documentation in the engineering industry into an electronic format. The product market requires to supply products with the documentation carrying interactive elements, including the means of integrated support for all production stages. Marketability of services creates challenges that cannot be met without implementation of the following CALS technologies [2-5]:

- maintenance and exchange of design and technological information in a digital format and development of repair and operational documentation in the form of interactive electronic manuals;
- creation of a digital database of products and designs of illustrated electronic catalogs of spare parts and consumables based on realistic 3D models;
- development of logistics services for consumables and spare parts as well as technical support throughout the product life cycle;
- compliance with the international quality management system standards.

Fulfillment of these conditions increases competitive capacity of enterprises and improves product quality, but requires the personnel retraining to be able to perform the assigned tasks [6].
The machinery production development trend is a complete transition of the product life cycle key stage (design and technological preparation of production) to information technology. Digital manufacturing relies on the technologies involving the computer-integrated manufacturing. Innovative IT solutions are the core of the information space where CAD, PLM and other automated systems of engineering enterprises operate [2-5].

2. Digital CAD Platforms
The information space of a virtual enterprise includes CAD, CAPP, CAM, CAE, and PLM technologies. Choosing technological complexes in the engineering sector and construction and installation companies, Russian manufacturers shifted their preferences towards local developers of innovative technologies. Small enterprises, as a necessary economy sector, also adhere to these waymarks [6, 7], which requires the personnel expertise development. The purpose of this paper is to show the results of CAD systems adaptation in a small engineering business.

Small engineering enterprises feature the production of parts, components and devices of medium complexity using a limited number of machines. In view of this limitation, the manufacturing methods should depend on capabilities of the existing equipment. Small engineering enterprises can ensure production flexibility only through the computer-aided engineering oriented to the specific equipment. In a short time, a small design group must provide the required documentation for all technological processes and the product drawings simultaneously [6, 7].

2.1. 3D Design
We will show the process of CAD systems implementation in small enterprises using an example of preparation of the Mobile Drilling Complex product and metal structures for manufacturing [4, 6]. The software feature set allows us to see the future product in three dimensions and various views, create a realistic image of the product taking into account the given material, and perform preliminary assessment of the design solutions and color scheme.

Computer-aided part design relies on the stage of preliminary classification and coding of the component with subsequent search for a prototype in databases. The addressing and synthesis methods serve as a methodological basis for this stage. Within the framework of the design preparation stage, we create 3D models of all parts, assign materials, and prepare drawings with the necessary views, cross sections and cuts. At the same time, there is still an absolute association between the model and the drawing, which automatically corrects the drawing when the model is changed. After the necessary views are created, the drawing is finalized (dimensions, tolerances, and shape deviations to be defined) and executed according to GOST (technical requirements, unspecified surface irregularity, and the main inscription to be filled in). The process ends with execution of the design specifications. During this stage, certain changes and modifications are made to the project. The assembly units and entire product models can help to expose conflicts and errors. Figure 1 shows 3D models of the Half Coupling part from the assembly unit of the Conical Reduction Gearbox product.

![Figure 1](image_url)

**Figure 1.** Digital models of the Half Coupling part (a) of the Conical Reduction Gearbox product (b).
2.2. Process Engineering
The second stage is the development of parts manufacturing technologies aimed to create a working archive of technology solutions and organize teamwork for the project as well as parallel engineering [3].

The CAPP module allows to get a complete set of engineering documentation in accordance with GOST starting from calculations of cutting modes and other process parameters to maintenance of the shared information space to control the product life cycle at the enterprise.

Functions of the CAPP application are extended by the CAM software package – a control program generation system for processing of parts using multiaxis milling, turning, turn-milling, EDM machines and numerically controlled machining centers. The framework allows to create control programs for machines with various kinematic schemes and can be configured for any types of devices with digital services.

Selecting a cutting tool and assigning cutting modes, the CAM module enables us to simulate cutting modes and identify potential conflicts. Figure 2 shows a simulation of the cutting tool trajectory during machining of the Gear Half Coupling part.

The databases of both software products enable the team to fill the data storages with a wide range of materials, tools, devices and equipment available and used at the enterprise.

![Figure 2. Modeling of the cutting path in the CAM environment in machining of the Gear Half Coupling part.](image)

The CAD systems, using three-dimensional modeling methods, allow us to create the final product layout. Figures 3 and 4 show three-dimensional computer models of the Elastic Pin Half Coupling and Friction Clutch assembly unit and the general assembly of the Mobile Drilling Complex product.

2.3. Engineering Analysis
Force calculation of the structural elements is carried out using the CAE system made as a combination of computer program modules being a part of the development CAD [7].

Automation of the engineering structure force calculation makes it possible to obtain data on the strain-stress state of parts and assembly units. Analysis findings allow us to identify areas with dangerous sections by the following physical values: deformation, shifts and stresses of the structure elements. The result of the force calculation is a part safety factor.

For example, let us consider strength calculation of the Coupling power tool part using the CAE framework [4, 8]. The shaft seat is a through hole in the main body of the coupling with a pad protruding inwardly preventing free rotation of the motor shaft.

We begin calculation of the strain-stress state determining the load application points and amount. The load is applied to the pad ends in the direction of the coupling rotation and represents a torque calculated on the basis of the electric motor parameters. To perform the calculation, we use an average torque rating value, which is 0.21 N×m. The safety factor resulting from the static analysis is 4.5.
Figure 3. 3D model of the Elastic Pin Half Coupling and Friction Clutch assembly unit. Figure 4. 3D model of the Mobile Drilling Complex product.

Figure 5 shows the strain-stress state simulation result for the Coupling part under cyclic loading (10⁶ cycles). Calculation of the fatigue effect involves loading with linearly increasing torque from zero to maximum. The experiment result is the minimum value of the load factor, which is 3.2.

Experiments allow us to select the material of the assembly units according to the criteria of part processing costs, material cost and strength characteristics.

Figure 5. The result of the fatigue analysis of the Coupling product (material: D16t aluminium alloy).

Figure 6 shows the strain-stress state simulation result for a more complex Shaft assembly unit of the Mobile Drilling Complex.
Figure 6. Displacement pattern of the Shaft assembly unit at the shaft torque rating.

3. Structural engineering and design
A significant part of the order volume of small enterprises is occupied by design and manufacture of metal structures. Diverse topology of such structures leads to high labor intensity and, as a result, insufficient productivity [9].

The metal structure being created is the Base assembly unit of the Mobile Drilling Complex. The product parameters and topology depend on location of other structural parts and assembly units as well as on the size of the final engineering product. To develop the metal structure design, we compactly place all the parts and assembly units according to the functions they perform in the product.

The problem is solved by determination of the bearing points of the mounting structural elements obtained with the help of corresponding projections of their models and creation of a layout sketch. Then, the Base metal structure layout is created as a set of generators serving the basis for the design of its parts (channels, profiles, angles, etc.). Based on this layout, a three-dimensional model of the Base metal structure is designed using the CAD system, where variables are assigned to the dimensional parameters allowing to change their numerical values after which the model is automatically modified in rebuilding [4, 9, 10].

Figure 7 shows a 3D model of the drilling complex base with a complete set of the design and engineering documentation.

Figure 7. Digital model of the mobile drilling complex base.

Models of certain metal structure parts can be excluded from the calculation changing its topology. This allows, using a typified product model, to create many other prototypes of metal structures different
in their parameters and form. The resulting metal structure designs can be promptly edited and used both as assembly units for the engineering product structures and as independent products.

CAD capabilities allow us to perform all types of design works, for example: determination of metal structure parameters and selection of the grade, determination of metal structure elements position in space. Technological sections simplify the selection of parts processing methods, parts lengthening or cutting, required cutting of profile ends, design of part end offsets, automated generation of specifications associated with drawing models [10].

4. Conclusion

Introduction of PLM technologies in operations of small enterprises is one of the means to increase their efficiency in multitopic, but limited, production and acts as a logical link of small businesses development [8, 9]. Experts predict the efficiency increase as a whole up to 30%-40% and give the strategic initiative to this area. Introduction of PLM systems involves organizational innovations in the enterprise operation principles, quick and rational accounting of changes as well as data exchange between all participants depending on their access level.

The whole complex of works on creation and maintenance of technical documentation is carried out on the basis of the selected Russian software for design and technological preparation of production. We performed adaptation of the integrated design management system (Pilot: Design Bureau platform) in the setting of small engineering enterprises. We demonstrated that one of the factors of production efficiency and flexibility increase in such enterprises is the CAD usage strategy which ensures growth of labor productivity and, at the same time, is a factor of expertise development.

Introduction of design and engineering works automation in small enterprises results in the lower production preparation time relying on innovative technologies.

References

[1] Schuh G, Anderl R, Gausemeier J, ten Hompel M and Wahlster W 2017 Industrie 4.0Maturity Index. Managing the Digital Transformation of Companies (Munich: acatech STUDY) p 60
[2] Peters D 2016 Digitalization transforms the economy and improves the efficiency of investment projects CAD and graphics 1 4-7
[3] Lovygin A 2016 Future of CAM systems CAD and graphics 1 8-17
[4] Bulavin V F, Bulavina T G and Iakhrichev V V 2017 Validation of CAD products in small enterprises machinery sector Fundamental and applied problems of engineering and technology 5(325) 64-72
[5] Volkov E V, Kuz’mina M S, Pomeschikov V E, Bulavin V F, Grigor’ev N S and Iakhrichev V V 2017 Russian CAD systems in the instrument-making industry Eurasian scientific association 1 10(32) 65-8
[6] Nikiforov A D and Bakiev A V 2011 Product life cycle processes in mechanical engineering (Moscow: Abris publ.) p 688
[7] Iakhrichev V V, Blagovestova M E, Kazakova S A, Nesterova A A, Stoletova A N, Panchenko E N, Gromov A A and Bulavin V F 2018 CAD/CAM-technologies in machine building Eurasian scientific association 1 1(35) 70-3
[8] Bulavin V F, Bulavina T G and Yahrichev V V 2018 Engineering analysis and new technologies in the finite element method Fundamental and Applied Problems of Technics and technology 2(328) 109-20
[9] Bulavin V F and Yahrichev VV 2018 Digital technology in the small business of the engineering industry CAD and Graphics 6 52-5
[10] Bulavin V F, Yahrichev V V and Glazkov V A 2018 PLM-strategy in small-scale production machine-building industry News of higher educational institutions. Engineering 8 37-49