Increasing the efficiency of design in CAD CAE systems based on the application of parametrization methods

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Abstract. Modern global trends in green energy indicate a constant increase in the share of energy obtained by burning woody biomass. The volumes of timber harvesting and processing are growing steadily. The Russian Federation is no exception, where logging and wood processing play an important role in economic, social, and environmental terms. Technological operations related to wood processing are predominantly mechanized. Most often, the machinery and equipment used in enterprises are imported. The use of imported products entails a number of consequences related to the dynamics of geopolitical development. It is necessary to minimize the dependence of enterprises on foreign equipment. There is a need to develop and modernize domestic logging machinery and equipment. To ensure the production of high-quality and competitive machines, it is necessary to resort to a set of activities related to design. Ensuring the necessary performance characteristics when developing a project requires financial and time costs, since it is necessary to resort to full-scale prototyping. Minimizing financial costs during design is the most important task of specialists, since the saved resources will allow the enterprise to open up new paths for development.

1 Introduction

Technological equipment is the links in the technological process that perform interconnected work, the result of which is the finished product. Process equipment is selected based on the requirements for the final product. Uninterrupted operation is ensured by design calculations at the design stage.

Design is a process of intellectual work associated with the creation of a product that has a clear goal. Modern design is based on the use of software combined with the experience of individual specialists.

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Software refers to computer-aided design systems. CAD is software packages that implement information technology; they are based on the use of vector and three-dimensional graphics. The idea of using CAD involves automating the design process using the power of a computer. Automation is achieved by cloud-based interaction of programs with each other, as well as a variety of software product tools.

There are many types of CAD systems that individually allow you to implement narrowly focused ideas, namely:

CAD (Computer aided design) is engineering software for designing structures. With the help of CAD systems, conceptual ideas are developed in the form of three-dimensional models, as well as the necessary design documents. CAE (Computer-aided engineering) are software packages that implement engineering tasks such as analysis of calculations of the strength characteristics of a product, simulation of physical processes in a virtual environment. The use of CAE allows you to verify the functionality of the project in the early stages of design, which helps to reduce time and financial resources. Examples of programs for modeling physical processes: Solid Works, Altair Insipre, Ansys. In work [1], using Ansys, an analysis of the stress state of gears was carried out to identify the wear characteristics of agricultural machinery gears.

CAM (English: Computer - aided manufacturing) is a software package necessary for writing control programs for computer numerical control (CNC) machines. CAM systems are often a complement to CAD and CAE.

Russia has significant reserves of forest resources (more than 814 million hectares or 20% of the world's forest area). Theoretically justified logging volumes exceed 500 million m^3 per year, although about 215 million m^3 are actually harvested. The global demand for wood and its processed products is constant. In high-income countries, due to the current environmental agenda of minimizing the carbon footprint, the share of wood fuel will increase, since wood is an ecological and renewable source of energy. The use of wood biomass as an energy source is based on the production of thermal energy when it is burned. The trend of constant growth in prices for liquid hydrocarbons and gas, air pollution caused by emissions from the combustion of oil and coal, is increasingly contributing to the wider use of woody biomass as an energy source [2]. Wood is a renewable source of energy. Compared to fossil fuels, when burning wood there is no unilateral increase in emissions into the atmosphere, but the carbon deposited in the wood is recycled (Figure 1 [3]).

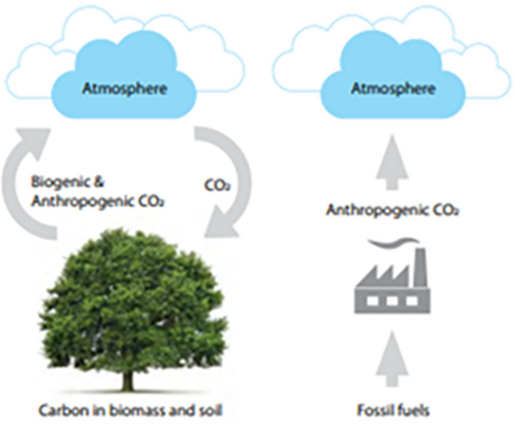

Fig. 1. Scheme of sequestration and carbon turnover of woody biomass.

The use of woody biomass energy provides significant climate benefits using the natural carbon cycle [4]. Thus, ensuring a sustainable process of wood harvesting and processing is an important task for both business and regulatory authorities in the field of ecology. Modern wood harvesting is carried out by machine. Many companies with extensive experience in this field are involved in the production of logging machines. Until recently, machines from such manufacturers as Komatsu, Ponsse, and John Deer were widely represented on the Russian market. The Russian timber industry is largely dependent on foreign equipment. Due to the current geopolitical situation, supplies of imported equipment are difficult or impossible. Possible consequences for industry enterprises are as follows:

1. Violation of the competitiveness of enterprises due to delays in project implementation. Some enterprises directly depend on the supply of foreign parts or equipment.
2. The quality of products directly depends on the equipment on which they are produced; the inability to maintain production contributes to a decrease in the quality of the finished product, which directly affects the reputation of the enterprise.
3. Disruption of business continuity may cause shortages of some goods and services.
4. There is also a need to search for alternative solutions, which entails an additional financial burden.
5. Reduced ability for innovative developments due to a negative impact on the country's economy.

In connection with the above points, it is important to take measures aimed at reducing dependence on imported equipment. To ensure the release of high-quality equipment to the market while minimizing financial costs, it is necessary to pay attention to the design process of forestry machines. Namely, the creation of high-quality, scalable, modular products that incorporate the idea of rapid equipment modernization at minimal cost.

Parameterization in design is the process of creating and using parameters that define various aspects of the design or construction of a product. Parameters are variables that can be adjusted or changed to produce different designs without having to create a new model from scratch. This allows engineers to experiment quickly and flexibly, as well as optimize and adapt their designs to different requirements and conditions.

Work [5] describes the process of creating a library of standard products using parametric modeling in the CATIA V5 software package. The main idea is to create a template model of a nut, which has variable parameters, to effectively form a complete library of products. It is noted that the parameterization method increases the convenience and efficiency of design. Research was also carried out [6] related to the parameterization of the aircraft wing profile. The importance of parameterization when modeling a wing lies in optimizing its technical characteristics by exploring multiple model options to find the optimal option. Research using CAD will ensure the accuracy of the results that will be used in full-scale tests.

Parameterization in the design of forestry processing equipment is an important tool for increasing efficiency and optimizing processes in the forest industry. Our work examines the practical application of parameterization in design using the example of a three-dimensional model of the components of a forestry machine.

2 Goals and objectives of the study

In the context of the need for import substitution and technological sovereignty, it is important to ensure the production of competitive domestic equipment. Since the quality of equipment and resource costs for the design process are directly related to the competence of specialists, it is necessary to identify and justify the most effective tactics for creating projects. Taking into account the above, let us formulate the purpose of the study: to justify the feasibility of using parameterization in design to improve the quality of finished products while minimizing production costs.

Research objectives:

- Construction of a parametric model of the blade and boom of a logging tractor using CAD products;
- Strength calculation of a parametric model in the CAE system;
- Analysis of the interaction of the resulting models with CAD systems;
- Justify the need for parameterization of projects.

3 Objects and methods of research

The object of the study is the influence of parameterization on a three-dimensional model. The research methods are based on qualitative and quantitative data analysis of available research results. The research used freely available sources, observational methods, modeling and experiment. The solid modeling package Compass 3D was used, as well as the CAE package Altair Inspire [6].

4 Results

At the initial stage, models of the blade and boom of a logging tractor were built using parametric functions. Building a model using the example of a dump begins with creating a geometric sketch of the profile, which has dimensional references for each individual element, Figure 2.

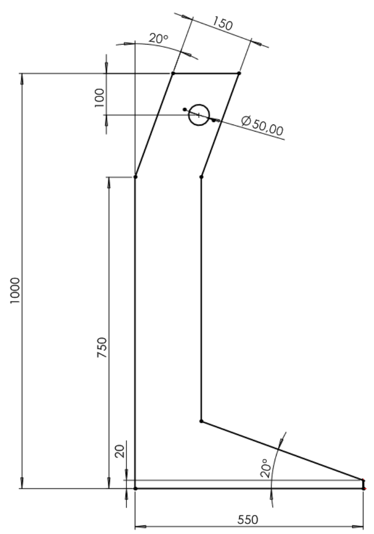

Fig. 2. Basic sketch of the model.

The interrelation of geometry ensures further efficiency of editing the entire structure as a whole. Each subsequent part of the blade has its own geometric sketch; individual sketches have a relationship, which means that editing the first sketch will automatically change all linked sketches and 3D modeling actions. Also, relationships are specified for individual assembly models; as a rule, each individual object has three degrees of freedom. Design documentation in the form of assembly drawings, detailing and specifications is created on the basis of a three-dimensional model, that is, the model and drawings are software interconnected. There is no need to directly correct project drawings; the drawings are made once and then automatically updated based on the 3D model. For example, a prototype blade with an overall size of 2240 mm was built, Figure 3. The overall size was chosen randomly to demonstrate the parameterization capabilities.

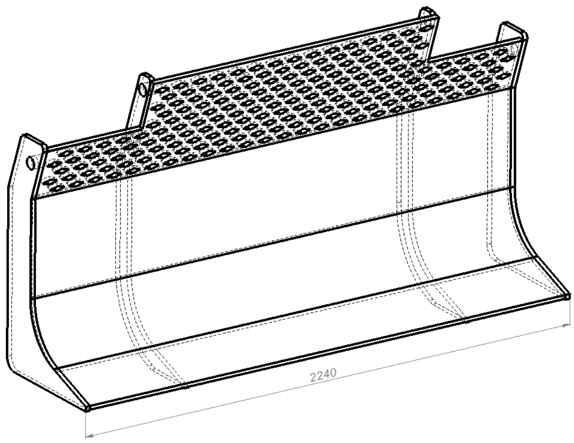

Fig. 3. Three-dimensional model of the dump.

It took 20 minutes to build this model. The time spent on creating a three-dimensional model is individual, since there is a direct relationship with the experience of the specialist and the complexity of the assembly. Since the project was built in a parametric way, when the overall width of the blade changes, for example, to 1540 mm, the entire model is rebuilt.

The time spent rebuilding the entire model takes 1 minute. This results in a blade model that differs from the first model in technical characteristics. The twenty-fold difference in the time it took to build the model lies in the fact that only one size in the model was changed and the configuration of the entire product did not change in any way, Figure 4.

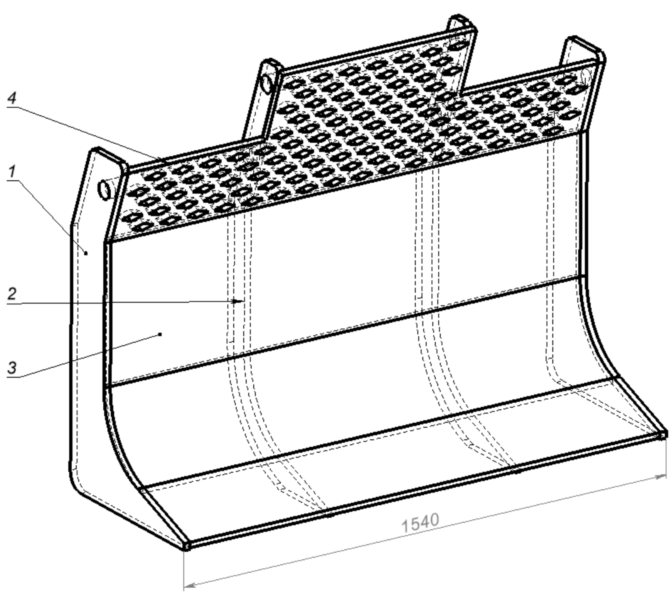

Fig. 4. Modified parameterized 3D model of the blade.

In Figure 4 you can observe changes relative to the original model, namely:

- All assembly positions have a reference that has symmetry properties. When changing the size of a part, all positions are aligned relative to the center of the assembly;
- Pos. 1 and pos. 2 have a connection between the basic sketches, namely, the edges of the model adjacent to pos. 3 are repeated;
- Pos. 3 in the section is linked to pos. 1, so when editing the sketch shown in Figure 1, the basic sketch of pos. 3 is automatically changed;
- Pos. 4 in the section is also tied to pos. 1, but on the plane there are diamond-shaped cutouts that have an array connection, namely a step between each other and a parameter that does not allow the cutouts to go beyond the limits of pos. 4, thus ensuring the correct reconstruction of the model when specifying any necessary size, in this case the width of the product.

In the absence of the above relationships, to obtain a new model configuration, one would have to resort to designing the model from scratch, which requires time and money. The practical application of parameterization using the example of a tractor blade will allow us to solve important problems:

- Determination of the optimal blade height for various types of wood and operating conditions, taking into account the limitations and requirements of the technological process;
- Adjustment of blade width depending on the needs of the harvesting process. For example, the width of the blade can be changed to accommodate different tree sizes or to accommodate woodland conditions;
- Adjusting the blade angle allows you to optimize the slope for better sliding and wood transfer when working on uneven or sloping ground;
- Changing the geometry and shape of the blade to suit specific job requirements, for example to improve the penetration of the blade or to improve the distribution of wood within it.

All of these parameters can be adjusted or changed depending on the type of wood, the size of the harvested trunks, the characteristics of the soil or other factors, which allows you to achieve optimal efficiency and results in the process of harvesting wood with a forest tractor. Paired with the blade, the boom supporting it was modeled, Figure 5 model is built on the same principle, using parameterization. By changing various parameters of assemblies, it is possible to obtain a diverse product line, but in this case it is necessary to concentrate on parameterizing each size and connection, without exception.

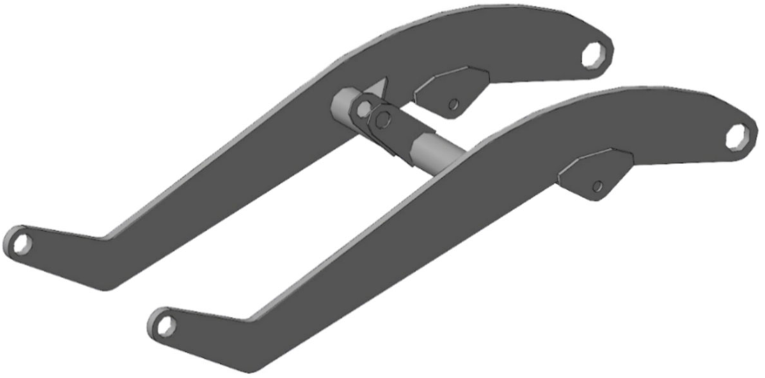

Fig. 5. Boom model.

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The boom performs the function of supporting the blade itself; to ensure the reliability of the structure, it is necessary to resort to modeling of physical processes in a digital environment, namely, to calculate the strength capabilities using the Altair Inspire CAE system. Calculation of strength loads helps to identify weak structural components, this will allow solving a number of technical problems before manufacturing a full-size sample [7]. Previous work with this software package showed its ease of use and high efficiency [8-10].

In Altair Inspire, basic fixing of the three-dimensional model of the boom and its loading was carried out. The estimated load on the boom was 2 tons. The forces are distributed symmetrically between the axes. One axis accounts for 50% of the total loading forces. The CAE system allows you to flexibly customize the material of the future product; the choice of material directly affects the final result. To demonstrate the software calculation of the product, fastening points are created, forces are applied, the material of the product is selected, the calculation results are presented in Figure 6.

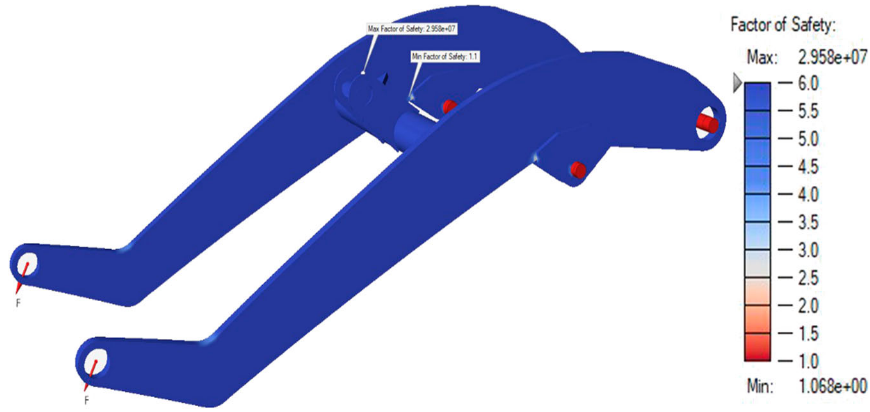

Fig. 6. The result of calculating the safety factor.

The estimated mass of the boom was 250 kg. The calculation results show that its strength is excessive, and there are reserves for reducing weight. Therefore, it is necessary to optimize the boom design. To reduce the weight of the product, it is necessary to resort to topological optimization of the design. The CAE system allows for optimization and more rational distribution of material throughout the structure, Figure 7.

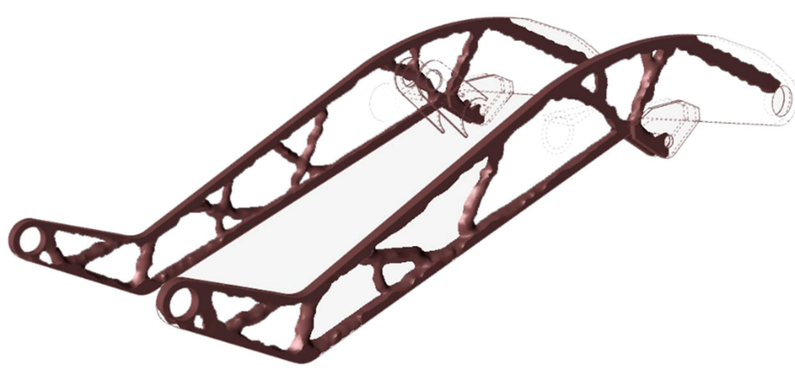

Fig. 7. Altair Inspire optimizer results.

The use of a parameterized model in conjunction with CAE systems will make it possible to quickly explore many design configurations to find the most successful option, for example, if the safety factor is unsatisfactory, the designer will resort to upgrading the design in order to correct the shortcomings; the parametric model will ensure a prompt change in the design for subsequent calculations.

5 Conclusion

Efficiency and speed of design: Parametric models allow engineers to quickly change the value of parameters in the model, allowing studies based on different configurations and design options. This significantly reduces the time spent on product development and optimization, and also helps speed up the process of bringing new products to market. The high efficiency of parameterization has been confirmed by many studies and works [11].

Improved accuracy and reliability: Parametric models help reduce the likelihood of errors and misunderstandings because changes in one parameter automatically lead to corresponding changes in the entire model. This provides more accurate and reliable results of calculations and analyzes, and also allows you to predict and prevent possible problems and defects at the design stage.

Reusability: Parametric models can be easily adapted for different projects and tasks. This allows companies to reduce the time and cost of developing new models, since existing models can be used as the basis for new projects. This approach makes the design process more efficient and flexible.

Visualization and Communication: Parametric models are easily loaded into various visualization programs, allowing engineers and designers to visualize the final product. This allows project participants to better understand and visualize the concept and vision, and also allows for more effective collaboration between different departments and specialists.

Improved control and change management: Parametric models have version control and change management capabilities. This allows you to conveniently track and manage all changes made during the development process, as well as control access to models and their documentation. This approach helps improve the efficiency and reliability of the project management process.

Disadvantages of parametric modeling:

- Learning Difficulty: Parametric modeling requires learning specialized software such as CAD systems. Learning new skills may take time and require additional training;
- Parameter dependence: In parametric modeling, models depend on certain parameters. If these parameters are changed incorrectly or accidentally, it may result in incorrect models or errors. There are methods described in the study [12] that allow minimizing the number of parameterization variables to simplify optimization experiments;
- High system requirements: Parametric modeling requires powerful computer systems and graphics accelerators to perform complex operations and work with large amounts of data.

Enterprises using CAE systems with parametric models can help reduce development time and costs, improve the quality and accuracy of designs, enable more efficient collaboration between different departments and specialists, and increase model flexibility and reuse.

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