CAD-SYSTEMS FOR OPTIMIZATION MODELING OF LARGE EQUIPMENT

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Abstract. Agriculture engineers face the task of developing projects of large-sized agricultural equipment (combines, tractors, etc.). This equipment should work in quite difficult conditions with high loads as well as providing the interaction of individual components and assemblies of this equipment. It is often not possible to create prototypes of the designed model in full size because the created machines have large sizes. Therefore, computer simulation is important for engineers. The process of simulation has the added value of optimizing the parameters of the equipment. The technique of optimization is using simulation calculation and optimization of parameters of agricultural equipment by converting the three-dimensional geometric models of computer equipment, developed in CAD-systems, specialized software package. The purpose of the research is to analyse the tools and methods of automatic construction of three-dimensional computer geometric models and optimization of the parameters of the simulated equipment.

Keywords: agricultural equipment, computer modeling, three-dimensional models.

Introduction

Three-dimensional printing technology is very actively developed and today it can work with a wide range of materials (plastics, metals, some fabric and so on.). But the speed of manufacturing of the product on the 3D-printer is low.

In the past few years, developments in computer, sensor, and printer capabilities have improved the areas related to three-dimensional (3D) technologies. These technologies enable us to create or reconstruct 3D models of environments, objects, or even humans. Furthermore, 3D sensing technologies have become more practical with the development and public availability of 3D printers and 3D printing services, which make the transition from digital models to physical objects easier [1].

This new technology has incredible potential to change different industries, such as architecture, production, medicine, etc. 3D printers allow users to do things that would never have been possible before now. While the basic process has existed for 30 years, 3D printing has exploded in capability and availability to become one of the most revolutionary manufacturing processes in the world [2].

3D printing is a manufacturing process in which material is laid down, layer by layer, to form a three-dimensional object. (This is deemed an additive process because the object is built from scratch, as opposed to subtractive processes in which the material is cut, drilled, milled, or machined off.) Although 3D printers employ a variety of materials (such as plastic, metal, or other) and techniques, they share the ability to turn digital files containing three-dimensional data – whether created on a CAD (computer-aided design) or CAM (computer-aided manufacturing) program or from a 3D scanner – into physical objects [3].

According to Hoffman [3] with 3D printing, designers have the ability to quickly turn concepts into 3D models or prototypes (aka rapid prototyping), and implement rapid design changes; it lets manufacturers produce products on demand rather than in large runs, improving the inventory management and reducing the warehouse space; people in remote locations can fabricate objects that would otherwise be inaccessible to them; from a practical standpoint, 3D printing can save money and materials over subtractive techniques, as very little raw material is wasted.

Samuels and Flowers [4], as well as Martin, Bowden, and Merrill [5] investigated 3D printers used in the educational process.

Chia and Wu [6] gave an overview of recent advances in 3D printing of biomaterials. Chen, Liu and Shum [7] demonstrate the use of stereolithographic 3D printing to fabricate millifluidic devices, which are used to engineer particles with multiple compartments. Jenkins [8] discusses the potential use of the 3D printing technology in the chemical process industry.

Lou et al. [9] gave the mathematical expressions with the parameters of frequency modulation structure, analysed the principles of consecutive spatial frequency modulation and deduced the frequency modulation rules.

Alapan et al. [10] developed a new way to fabricate stand-alone microfluidic devices with integrated manifolds and embedded micro channels by utilizing a 3D printing and laser micro machined lamination based hybrid manufacturing approach. In this new fabrication method, the authors exploit the minimized fabrication steps enabled by 3D printing, and reduced assembly complexities facilitated by the laser micro machined lamination method.

So at the moment it can be argued that the 3D-printing technology is more suitable for prototyping various processes, such as production of different layouts or exclusive production (small-scale production). Additive technologies at the present stage of development do not allow to create the 3D-printer (3D-scanner) prototypes of complex engineering products (equipment, materials), which have threaded connections, pipes, cables with a small cross-section, electric coils in their composition. The expediency of additive prototyping technologies for reduction of the time of creation of a three-dimensional digital model of the object depends on the characteristics and complexity of the construction of the collected product. However, this approach in relation to complex technical devices is not always expedient, since it is difficult to implement threaded connections, electric coils and complex assembly connections in the plastic fittings. Technologies of 3D-scanning that help you create the digital three-dimensional model, also have limited use for the above reason.

Problems of designing large-sized agricultural equipment

Agriculture engineers face the task of developing projects of large-sized agricultural equipment (combines, tractors, etc.). This equipment should work in quite difficult conditions with high loads as well as provide the interaction of individual components and assemblies of this equipment. It is often not possible to create prototypes of the designed model in full size because the created machines have large sizes. Therefore, computer simulation is important for engineers. It is necessary for the first metal model to comply with the requirements of the customer. The process of simulation has the added value of optimizing the parameters of the equipment.

Optimization models are used for solving the tasks of optimal control and simulation of the object and are based on the use of linear and dynamic programming or the use of game theory [11-13].

Linear programming is applicable for mathematical models of the processes which are based on the hypothesis of a linear representation of the real world. It is used to solve economic tasks, management tasks and planning, the optimal placement of equipment, and so forth. Soviet mathematician L.V. Kantorovich was awarded the Nobel Prize in economics for development of linear programming.

Dynamic programming is primarily used in the control theory and in the theory of computing systems, basically for solving complex problems by dividing them into smaller sub-tasks. Bellman has made a large contribution to dynamic programming. The Bellman equation transforms the optimization task in recursive sequence of simpler sub-tasks. It allows the movement from the multi-step solution of the original optimization problem to the number of tasks with a one-step solution. Regardless of the initial state and the initial solution of the first sub-tasks, subsequent solutions should form an optimal course of action, which depends on the values obtained in the first solution. As such, dynamic programming requires a lot of computational work.

Game theory does not attempt to find any particular numerical solution. It is necessary to outline the range of possible decisions or provide additional information about the possible developments and recommend the rules of conduct. In exceptional cases the game is determined by the quantification of models or indicating the optimal solution. Reduction from the game theory task to the task of linear programming is also possible.

In the process of modeling components and assemblies of agricultural equipment the following problems occur:

- lack of information about the equipment,
- the requirement of significant simplifications,
- the problem of dimension and step of numerical simulation.

Optimization models can be divided into control models and models in their design stage. When it comes to optimization models of technical objects and devices, specific numerical solutions are necessary. There are a number of technical devices that are basically three-dimensional, for which there are no effective methods of calculation. During the development of the theory of optimization modeling for complex large-sized equipment, it must be considered that the simulated real technical devices are three-dimensional and, as a rule, heterogeneous in their characteristics (the electrical and magnetic properties, etc.). Therefore, to obtain valid results it is often necessary to solve the three-dimensional problems through information technologies of analyzing the data from the geometry of the CAD (Computer Aided Design) construction.

The question for discussion – how to evaluate the effectiveness of introduction of CAD-systems for optimization modeling of large equipment?

Methodology

To evaluate the efficiency of applying of information technologies for assembly process visualization and technology inconsistencies detecting in the modeling stage, sets of documents on technological processes of assembly have been considered, developed under the proposed approaches, using methods of optimizing the parameters of the simulated devices. The sample data include more than 650 sets of documents that are processed in a single information system of the CD 2014 and are derived from the system of the electronic archive and technical document management.

Results of discussion

In the process of generating a three-dimensional model (3D-models) there are a range of simplifications. These lie in the creation of the basic models in accordance with the reference information about the object of the research (its geometrical dimensions, the curved surfaces of the joints, etc.). Widely used methods for simplifying the development of 3D-models and reducing the design time are extracting the basic models of the pre-created database (DB) to change the values of the parameters in accordance with the geometry data of devices or a predetermined method [14], as well as a means of improving the efficiency of three-dimensional modeling for presentation purposes. [15]. However, these methods do not provide a solution to problems of parameter optimization and increasing the efficiency of devices in the modeling stage.

To solve these problems it is proposed to use specialized software packages for transmission of the equipment geometry (equipment components and assemblies) to the external design applications or development packages of control programs.

The most common CAD-systems for displaying equipment data using three-dimensional simulation software are: 3D-compass, Pro/ENGINEER, CorelDRAW, AutoCAD, SolidWorks, HyperWorks.

In Fig. 1, a method of automatic construction of three-dimensional computer geometric models (TCGM) and optimization of the parameters of the simulated equipment by converting from one medium to another simulation are schematically illustrated [16].

Based on the basic models, you can perform simulations of a unit or units in the assembly to define the shape of the object of the research and layout of components and assemblies.

The method of constructing and converting three-dimensional computer geometric models and parameter optimization of the simulated hardware implemented in different 3D-environments such as Compass and Maxwell is used in the design of complex technical systems, for example, recirculation control of exhaust gases for agriculture vehicles: recirculation valve, magnetic, electric.

The practical application of this technique for the recycling system devices enabled: reducing the terms of preliminary design, improving the weight and size parameters, calculating the transient electromagnetic processes for further optimization of the parameters of system recirculation devices, improving environmental performance, which is clearly very important for agriculture.

To test the adequacy of the 3D-models a verification is performed. The output from the calculation on your computer is compared with the available statistics on the simulated equipment (system).

In the simulation process the adequacy of the properties of the model is verified, which are formulated in the research problem. Adequacy of the model can be verified by testing [17; 18].

If, with the results of the obtained model, optimization settings cannot be determined, you should go back to one of the previous steps of building TCGM and subsequent conversion. If the simulation results allow the optimization parameters to be calculated, the developed model can be used to solve the real problems of optimization.

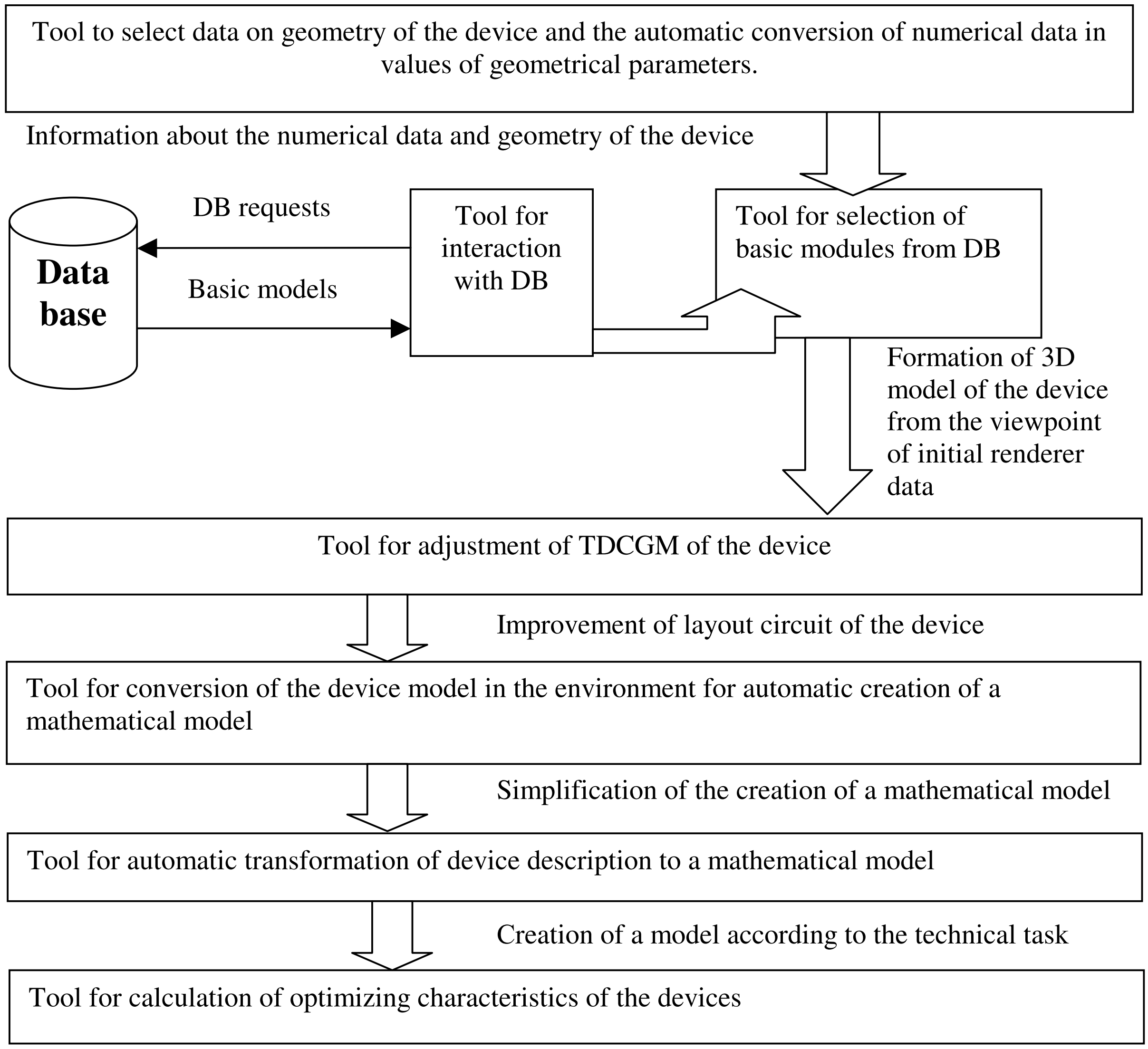

Fig. 1. **Construction TCGM and optimizing the parameters of the simulated equipment**

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Quantitative measures of shortening the terms of work with assembly documents are presented in Fig. 2, on the horizontal axis the numbers of sets of documentation (in ascending order) are shown, on the vertical axis – the time (in days) spent on the work. The uneven shape of the graphic shown in Fig. 2 (in the range of 1 to 400 sets of documents) illustrates the process of improving the assembly process with the use of three-dimensional visualization technologies. During this time the proposed method was implemented and approaches were based on the data of practical experience in e-CD to make configuration changes, analyze the statistics. During this time the proposed method was implemented and approaches were based on the data of practical experience, in e-CD were made configuration changes, the statistics was analyzed. Since the adoption of the proposed approaches into plant engineering the situation has stabilized, the number of changes in the settings of systems has declined. Conducted studies [16] have shown that the real picture of the process of developing e-CD for the process of assembly and testing allows to minimize the share of manual labor for building the electronic structure of products (devices). Complex application of information technologies of three-dimensional modeling and additive technologies reduces the product (unit) development time, compared to the traditional organization methods of assembly and testing processes, on more than 40 %. The amount of changes, made in the testing and assembly at various stages of the product (device) design because of technological deficiencies and inconsistencies of the construction, is reduced by 2-2.5 times.

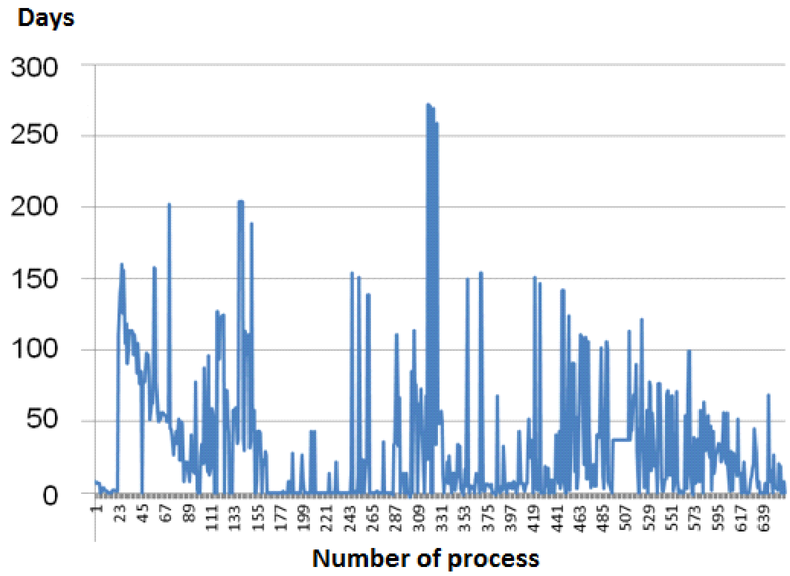

Fig. 2. **Reduction of the terms of testing and assembly of products**

The use of modern technologies of data processing in three-dimensional environments is applicable not only to the technology of assembly and testing of products (devices) and optimization calculations, but full transition to the new standards of CD using rendering methods with the applying of standard 3D-images is also possible.

Conclusions

The proposed method of constructing optimization models using three-dimensional modeling in CAD-systems and conversion into a specialized software package allows various options for the layout of components and assemblies of agricultural machinery to be analysed, to implement a systematic analysis at any level of complexity, as well as to select device parameters and operating characteristics.

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