Determining the structure of an automated system to optimize the design process

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Abstract. This article presents the current process of designing automated systems assigned for computer-aided design. The basic mission of constructing such systems depending on the type of design tasks is described. An example of the problem of designing the upper level of the primary look of the aircraft avionics complex is given. The main tasks for which automation is identified are allocated and the need for the optimization process is defined. The affiliation of the presented problem to the type of existing optimization problems is determined. Criteria for optimizing the design of complexes taking into account the main requirements of customers are given. The possible result of the automated design system to optimize the process is presented. Conclusions on optimization are made, and the prospects for developing such an automated system during the design work on the development of aircraft avionics complexes are justified.

1. Introduction

Automated systems are a separate type of products that are developed in accordance with standards and design guidelines. This article will focus on computer-aided design (CAD), which are aimed at improving the design process of the object as a whole. Improvement refers to any decision that has been reached and adopted as a result of the work of such CAD. Improvement in general is achieved precisely by transferring any stage of the design process, previously performed manually by man, to computer-aided processing and calculation of information. The implementation of such a transition entails a lot of advantages and eliminates the obvious disadvantages of the human factor. That is why CAD systems are widely used in engineering and industry in general [1].

In Russia CAD systems are classified according to state standards. The classification is based on the following criteria:

- kind/type of design object;
- design complexity;
- level of design automation;
- integrity of design automation;
- type and number of output documents;
- number of CAD software levels.
In international circulation, generally applied to CAD there are three main groups of such systems: light, medium and heavy. Despite this qualitative assessment, there are more specific features that allow for a quantitative assessment. These features include:

- type, genus and complexity of the designed object;
- number of hierarchical levels and level of required automation;
- kind and type of output;
- complexity and multilevel in the technical structure of CAD.

As can be seen from the two concepts of CAD in Russia and the world, there is a clear similarity, which indicates the prospects for the implementation of CAD systems and the similarity of design concepts. Currently, all CAD systems are divided by purpose and have the following abbreviations: CAD, CADD, CAGD, CAE, CAA, CAM, CAPP. After analyzing these CAD systems, CAE (computer-aided engineering) systems are of most interest. They are designed to analyze and simulate various processes based on any source data, which allows for modeling and analysis in real time. The scale of application of CAE in industry is very wide [2, 3]. Such CAD systems are applied for design and pre-design work. This type of CAD allowed designing to be more thorough in many aspects, which in turn required developers to use different design approaches, as opposed to those used when using CAD for a different purpose. As a result, this positively affected the possibility of a deeper and farsighted design of the upper levels of objects [4].

This opportunity is expressed in changing the design approach from partially functional to fully functional design of the entire system, taking into account changes in its individual parts. This kind of design led to the emergence of a different CAD structure that was able to cope with this task. Such CAD systems are called design systems (DS) [5]. In general terms, DSs do not differ much in structure from other CAD systems and are based on the same types of software: mathematical, linguistic, informational, software, technical, methodological and organizational. But in view of the need for DS operation at different design levels, there was a need to expand information support (IS). Now the structure of the IS represents not only a set of library components with the described parameters and their values, but various combinatorial variations of these parameters with the possibility of their adaptation for any design level. Undoubtedly, the changes apply to other parts of the CAD structure.

Considering as an example the task of designing complexes of onboard equipment (avionics complexes) of aircraft [6], the new IS concept of DS structure is indispensable. This is expressed in the presence of multi-level and functionally identical devices on the avionics market, i.e. functionality implemented on complex or simple nodes. About the high level of avionics complexity, it is worth noting that a promising direction is precisely increasing the functionality of one node and the elimination of other low-functional ones. Such a conceptual approach is called integrated modular avionics (IMA) [7]. But ideologically, the tasks of integration for the federal concept and integration for the IMA have the same stage of functional design. The described stage of designing the primary look of the avionics complex is very time-consuming. Therefore, the implementation of CAD already at the very first stages of design [8] greatly simplifies this process and reduces its final cost.

The key tasks that can be solved by the described DS are:

- decomposition of primary global functions into lower ones in level,
- selection of equipment for functional purpose at different levels,
- modeling the general functionality and composition of the avionics complex to optimize the process of choosing the final structure of the complex,
- identification of new functionalities obtained from the various composition of avionics complex.

2. Mathematical model of design system

Based on the above, the CAD design task of avionics complex has clear requirements for the look of the DS itself. In general, the structure of design systems is very universal and monotonous. It consists of designing and servicing subsystems. As applied to the designated CAD task, figure 1 shows the structure of such DS.
The key module in such a structure is the “Functional-Hardware Look Module”. Focusing on the aspect of its mathematical support, as the most significant, it is advisable to determine whether the design problem of avionics complex refers to a certain type of mathematical problem. The essence of the application of mathematical methods actually consists in discarding deliberately bad decisions. For this, it is initially required to carry out a model parameterization (of an object) of avionics complex and its parts. In the process of parameterization, many system parameters are to be processed.

The next important step is to develop a research method. Today, two design approaches are applied: simulation and analytical. Depending on the type of task, a suitable one is applied. Simulation is suitable for tasks in which a ready-made option is selected from a variety of options, this approach is applicable when choosing the final model of the structure. Analytical, suitable for designing the best version of the system according to a given efficiency criterion. Since analytical methods make it possible to obtain the dependences of the characteristics of functioning on the parameters of objects and the organization of the structural and functional look. It is advisable to use the analytical approach to complete the design task. Thus, a model of the designed DS is obtained. Further, in the process of analyzing the properties and characteristics of the system, the most influential factors affecting the system are identified. External factors must be taken into account when constructing the objective function. They can have a specific meaning, but can be described by restrictions in a general way.

The key point of DS mathematical software designing is its ability to optimize for a variety of criteria [9] optimization of the set of parameters of the design object. It follows that the problem of optimization of the upper look of avionics complex is multi-criteria, which will significantly bring the mathematical model of the complex to the real one. And also that the software of DS should be able to carry out multi-criteria optimization. Previously, optimization was carried out according to the dominant criterion. This approach reduces the effectiveness of decisions. In essence, multi-objective optimization problems
differ from single-objective optimization problems only in the presence of several objective functions. Multi-criteria optimization problems are widely used in engineering-in complex technical systems. Taking into account the practical implementation of optimization, it turns out that the existence of a solution that maximizes several objective functions is a rare exception, so from a mathematical point of view, multi-criteria optimization problems are uncertain, and the solution can only be a compromise solution [10].

For the first time multiobjective optimization problems considered Vilfredo Pareto in 1904. He described the need to find a compromise between the conflicting criteria, so multicriteria optimization problem imply the presence of multiple solutions. Proceeding from the main works of Pareto it becomes clear that if the optimal solutions for different objective functions differ significantly, it is impossible to talk about the optimal solution of the problem as a whole. In this case, we obtain a set of optimal solutions, none of which is optimal in comparison with others in all senses, i.e. by all criteria. This set has a name: the set of Pareto optimal solutions. As a result, after the optimization process, solutions are obtained that are not necessarily the best, but they are not the worst. Further, to choose a specific solution from the Pareto optimal set, you need to enter additional data. In this case, the problem can have an ideal solution if all functions reach a maximum at the same point.

The optimization criteria, which must be satisfied by the solution of the problem, are extremums. The criteria are selected based on those aspects of the design that are most important to the developer. As practice shows, today the criteria of consumers and customers have a very standard composition, namely: the purchase price of the product, development time, cost and safety of operation, functionality. These are the main criteria that can be disclosed to lower levels and it is on them that the optimization of the design process is carried out. This, in turn, proves the need to use methods for solving multicriteria optimization problems.

The most interesting is the result of such DS and that it can be used in the further development of a new product. The main task was to optimize the design process. That certainly leads to a reduction in labor costs. Due to design system of avionics complex we have obtained many solutions, models of structures, each of which in varying degrees is optimal. Deliberately discarded all unpromising design options, which allows the developer to work only with the best models of avionics complex. In fact, a restriction on the range of parameter values is obtained and the influence of optimization criteria on them is determined. There is a possibility of counter optimization of criteria with values of parameters.

3. Conclusion

The proposed structure of design system has individual features due to the module for the functional-hardware look designing, which emphasizes it as an independent design system. As a result, a significantly facilitated stage of pre-project work was obtained during the development of the new avionics complex. The work of the expert group is reduced in the aspect of initial sketches and ideas about the future design object. But since the design system is automated, not automatic, the decision on the choice of the final option is left to the experts. This approach, the human evaluation of machine computing remains relevant now, despite the high level of automation.

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