Automation of the inner design of the aircraft

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Abstract: *The task of forming the wind-swept surface according to the results of the aircraft's inner design is described. The approach of the integration of natural and virtual prototyping in the design of equipment compartments is substantiated. Such approaches open up new possibilities for creating intelligent composition algorithms that eliminate the "blind search". For the practical implementation of these approaches, it is necessary to link the appropriate software to standard geometric modeling systems in the form of additional computational modules. Preparing the aircraft for design automation complicates the mathematical description of geometric models of placed objects, increases the complexity of their visualization in modern computer graphics systems and the need to create an additional interface between new geometric models and common CAD systems (SolidWorks, AutoCAD, COMPAS, etc.).*

Key Words: *automation, design, model, inner compartment, aircraft, restriction, placement; geometric models; physical design, virtual design*

1. INTRODUCTION

Design objectives arise at all design stages of an aircraft. At the stage of the technical proposal, when the results of the technical task are used to form the preliminary look of the aircraft, on the basis of the statistical data an assessment is made of the possibility of accommodating the required composition of the installed units. At this stage schematic design data for compositing is limited to a degree of accuracy, which allows to calculate the different design options depending on which option is selected, a model is made. This option also serves as the basis for further design studies, carrying out strength calculations and clarifying management system requirements. Detailed design composition implies updating the composition considering the results of its design study.

All listed sequence of operations is repeated at refinement step of product at which the composition change occurs in geometric shapes, or in physical characteristics of linkable objects that lead to the need to redesign all compartments. In practice, to verify the three-dimensional inner design a full-scale models made of plywood and cardboard is used. Even more complicated and many iterative histories with the formation of the washed surface. The more complicated the contour, the longer it takes to make the aerodynamic and constructive-technical preparation. To meet these conflicting requirements, they usually follow the path of simplifying the model (linearization of forms). The contradiction between the complex geometric forms of the aerodynamic surface of the aircraft and the simple geometry caused by the constructive-technological preparation can be resolved through the use of modern information technologies.

2. METHODOLOGY

When assembling equipment and mechanisms, the following considerations are used as guidelines [1], [2], [3], [4], [5], [6]:

1. Placement is carried out in certain strictly limited volumes of complex geometric shapes, which are generally unrelated to each other and also there are areas where placement is not allowed (partitions and other force elements).

2. There are a number of placed objects, the placement of which in the aircraft is strictly defined (control panels, antennas, photographic equipment, etc.). In some cases, there is the problem of mutual compatibility of placed equipment and compartments (according to the conditions of vibration, temperature, pressure, etc.). For some added placed objects it is necessary to take into account the direction of flight when placing them.

3. For some placed objects when they are assembled we should take into account their mutual influence on each other. So the closest arrangement of placed objects to each other is desirable in cases where, for example, it allows reducing the mass of the connecting cable network or increasing their noise immunity); in some cases, placed objects may be incompatible with each other (to reduce their thermal, electromagnetic, and other influence on each other).

4. It is necessary to provide service areas for the assembled objects (i.e. to provide opportunities for their installation, replacement and maintenance). Requirements for access to these objects can be divided into 2 categories – “For flight” and “For ground service”.

It should be noted that at present there is a tendency to centralize the placement of placed objects on an aircraft (i.e., such an arrangement in which all or most of the objects assembled as part of any aircraft system are located in one specific area of the aircraft, called the technical compartment). Placing objects in technical compartments allows reducing the length and mass of connecting networks, simplifies the task of placing, setting up, ensuring the conditions of work and technical operation of the placed objects (Figure 1).

Fig. 1 – Equipment located in the technical compartment of the aircraft

3. RESULTS AND DISCUSSIONS

When composing the aircraft, the following requirements must be met:

1. Ensuring a given centering of the aircraft (i.e., a given position of the center of mass (CM) of the assembled objects) relative to the selected coordinate system of the aircraft. Requirements to ensure alignment is essential to ensure the stability and controllability of the aircraft. In some cases, additional restrictions are imposed on the moment of inertia of the assembled objects, the value of which affects the dynamic characteristics of the aircraft.

2. Reducing the weight of the aircraft (which can significantly improve the efficiency of the aircraft). The main reserve for reducing the mass of an aircraft due to a rational design is a reduction in length and, as a consequence, a reduction in the mass of the communication network (on modern aircraft, the communication network has a mass comparable to the weight of the equipment being serviced). Rational placement also allows the designer to reduce the mass of the power elements needed to install the assembled objects on board the aircraft. The requirement to reduce the mass of the aircraft is organically combined with the above requirement to ensure centering of the aircraft. This is due to the fact that when the position of the CM oversteps the established limits, in order to ensure centering, installation of additional centering weights, which are the “mass penalty” that must be paid in this design version, is necessary.

3. Increased use of aircraft compartment volume, which also affects its efficiency have sharply limited the scope of the aircraft compartment. An increase in the volume of compartments caused by an irrational arrangement leads to both an increase in the drag of the aircraft and an increase in the mass of the compartment.

4. Ensuring a given reliability of operation of assembled objects, which is one of the most important components of the efficiency of the aircraft. The reliability of the assembled equipment largely depends on the operating conditions of this equipment (vibration levels, pressure drop, temperature, etc.), which in turn is determined by the location of this equipment in the aircraft compartments.

5. Reduced labor costs for installation and maintenance of equipment. This is achieved by ensuring the zones of reach of the assembled objects, taking into account the required frequency of routine maintenance (or reliability) of the assembled objects, the laboriousness of their installation and dismantling.

6. Ensuring the ergonomic characteristics of the interaction of the crew with the assembled objects allows to reduce the physical and psychological stress for the crew of the aircraft and thereby increase flight safety. Basically, this requirement applies to the location in the cockpit of instrumentation equipment and controls.

Obviously, these requirements are contradictory (for example, the desire to reduce labor costs during installation and maintenance will require the creation of less dense arrangements, which will worsen the use of compartment volumes and lead to an increase in its mass).

Therefore, obtaining rational arrangements is associated with finding reasonable trade-offs between the listed requirements. Traditionally, the problem of design in the design of equipment was solved in several stages:

1. Using design drawings, where at the design stage, the required dimensions for the equipment to be placed and ergonomically justified spaces for personnel were determined (Figure 2). At the dawn of aviation, the design was based on the experience of manufacturing and operating previous aircraft models, but the introduction of a drawing design method allowed us to search for acceptable design solutions on the drawings and thereby separate the

aircraft design process from its production [1], [7], [8], [9], [10], [11], [12], [13], [14], [15], [16], [17], [18], [19], [20], [21], [22], [23], [24], [25], [26], [27], [28].

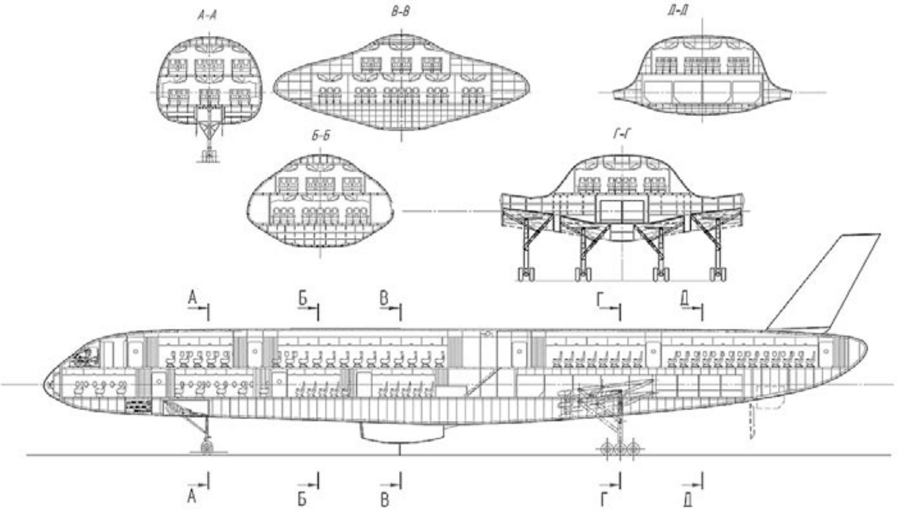

Fig. 2 – Sample 2D design drawing of an airplane

2. Physical models on which design solutions were worked out on a scale or life-size. With high density design of modern technology, even the most careful execution of drawings of placed objects does not exclude the possibility of cases of mutual intersection of placed objects. These design collisions allow to eliminate the physical models of the designs. The big advantage of physical designs is a high degree of clarity, fundamentally inaccessible in flat drawings.

It is clear that with all the attractiveness of physical models, their production is long, expensive, and most importantly – does not provide the required accuracy of modeling. So if the model is made on a scale of 1:10, then the inevitable error in the manufacture of a physical model (for example, ± 1 mm) will grow, taking into account the scale, into an unacceptable ± 10 mm on a real product. Physical life-size modeling (Fig. 3), made of easily to use materials (wood, plywood, foam, light alloys), makes it possible to most fully assess the quality of the design, but their production of full-scale models significantly lengthens and increases the cost of designing aerospace equipment.

Fig. 3 – Making a model of a modern aircraft in full size

Using solid-state and parametric modeling allows us to create models of standard units and systems (chairs, containers, engines, etc.). Using formal heuristic methods [1], [7], [8], [9], [10], [11], [12], [13], [14], [15], [16], [17], [18], [19], [20], [21], [22], [23], [24], [25], [26], [27], [28] based on the results of the functional positioning of aggregates and systems (Figs. 1 and 3), the aircraft's wind-swept surface is formed.

It seems to us extremely important to develop ideas and methods that allow if not to completely avoid, then at least to minimize the “bad” search of placement options. Such tasks add an additional requirement of composability, which must correspond to the geometric model. By suitability of a geometric model for composability, we understand its suitability for the implementation of the following tasks – the possibility of finding a rational position in the design and determining the condition of mutual nonintersecting. At the same time, it is necessary to be prepared for adding these properties to either complicate the model or worsen its other, less important characteristics. Figure 4 shows the plane's air-swept surface by the results of the inner 3D design of the main-line aircraft

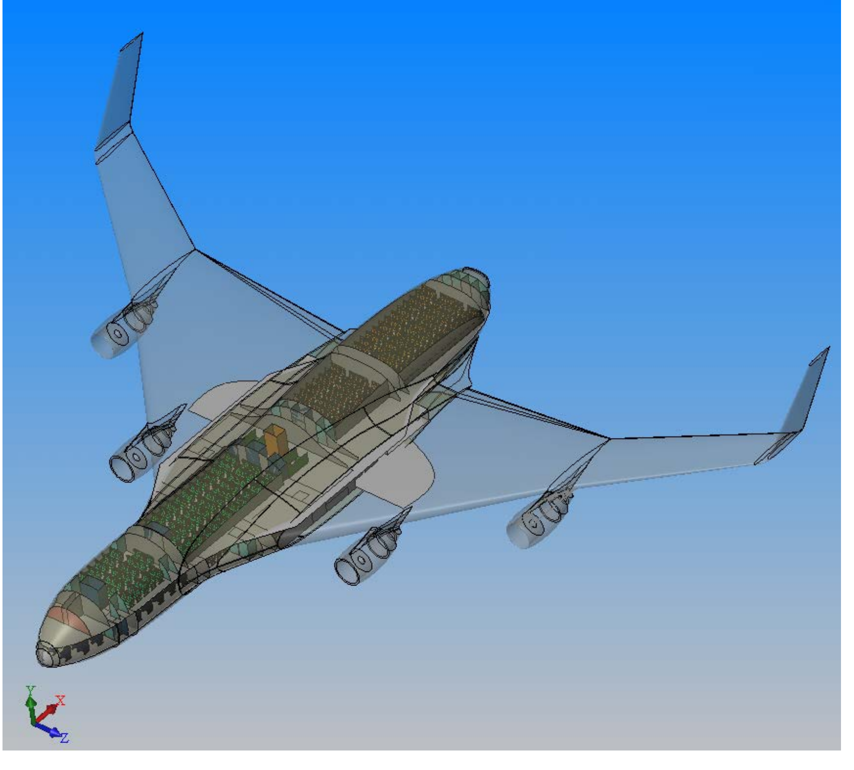

Fig. 4 – Getting the air-swept surface of the aircraft by the results of the inner 3D design of the main-line aircraft

One of these methods, focused exclusively on solving design problems, is the use of the apparatus of normal equations. Their use in the tasks of automated design is extremely interesting – the object described by them, as it were, determines the distance and direction to our point of interest. Thus, algorithms based on the use of this method acquire elements of artificial intelligence, which determines the rational direction of movement of an object to obtain the densest design. The algorithm itself determines the minimum distance to another placed object and the direction in which it should move before contact with this object.

Although such approaches open up new opportunities for creating intelligent compositional algorithms [1], [18], [19], [29], [30], [31], [32], the authors do not need to use the “blind search” to realize that the practical implementation of these approaches requires the connection of appropriate software to standard geometric modeling systems as additional calculation modules. However, the requirement to prepare the aircraft for design automation complicates the mathematical description of geometric models of placed objects, increases the complexity of their visualization in modern computer graphics systems, and make the need to create a supplementary interface between new geometric models and common CAD systems (SolidWorks, AutoCAD, COMPAS, etc.).

4. CONCLUSIONS

1. Preparing the aircraft for design automation complicates the mathematical description of geometric models of placed objects, increases the complexity of their visualization in modern computer graphics systems and makes the need to create an additional interface between new geometric models and common CAD systems (SolidWorks, AutoCAD, COMPAS, etc.).
2. The developed method of forming the air-swept surface according to the results of the inner design made it possible to reduce the time by 7-9 times and improve the quality of designing a long-distance aircraft.
3. The conversion from full-scale prototyping, first to modeling of a plane, and then to a three-dimensional virtual modeling, made it possible to reveal the connection between the inner and external designs.

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