Method of assembly and adhesive technological equipment automated design

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Abstract. In the production of modern aviation equipment, special attention is paid to reducing the mass of its components and assemblies. To achieve a reduction in aircraft mass without compromising strength and increasing economic efficiency, various composite materials are often used. The manufacture of components and assemblies from such materials entails the design and use of special assembly and adhesive equipment, which provides the necessary accuracy and rigidity to obtain the desired geometric shape of the aircraft structure. This article is devoted to the process of computer-aided design of assembly and adhesive technological equipment for the manufacture of aircraft cellular metal panels from polymer composite materials, using a Siemens NX CAD system.

1. Introduction
Reducing the mass of the aircraft structure, as mentioned above, is one of the priority tasks in the field of aircraft engineering [1]. The solution to this problem is to introduce polymer composite materials (PCM) into the aircraft structure. PCM have found wide application in the aircraft industry due to their qualities: high specific strength, the ability to control the structure and shaping of products of almost any geometry, the ease of combination with different materials [2]. Up to 50% of the total mass of the airframe from PCM is used on modern airplanes abroad [3]. So the rational use of composite materials in the manufacture of aircraft allows saving from 5 to 30% of the aircraft weight. An example of such PCM products is shown in figure 1.

![Electronic models of aircraft cellular panels from PCM](image)

Figure 1. Electronic models of aircraft cellular panels from PCM.

In the PCM production one of the main roles is performed by equipment. Assembly and adhesive technological equipment (AATE) provides the required geometry of PCM products, uniform heating and cooling of the products during molding and curing, the necessary forming pressure over the entire surface of the products [4]. Based on the importance of AATE, we conclude that the manufacture and design of AATE for PCM products is a complex, high-tech process that requires great responsibility.
and professionalism. At the initial stage of equipment design, together with the customer, a mold model is developed, taking into account many parameters and calculations. The initial data for the manufacture of assembly and adhesive equipment is the design documentation and the mathematical model of the tool. The accuracy and quality of the product outline at the metal processing stage will depend on how accurate the snap model is.

The high specificity and complexity of obtaining PCM products largely affect the design process of AATE for the manufacture of cellular metal panels of aircraft from PCM. Therefore, the design process of AATE takes a large amount of time, which leads to a decrease in the economic efficiency of production. One of the ways to solve this problem is to develop new technologies to reduce the complexity of technological processes, their automation and robotization [5]. To date, there are no described automated methods and design techniques for AATE for the manufacture of cellular metal panels of aircraft from PCM on the Russian market. The results of the study in the article “Methodology of the design process of assembly and gluing equipment for the manufacture of honeycomb metal panels” of the journal “The Matrix of Scientific Knowledge” were taken as the basis for the development of a methodology for automated design of AATE [6].

2. Design methodology for AATE for the manufacture of cellular aircraft metal panels from PCM
When designing fixtures, the following main stages can be distinguished:

- Analysis of the product design.
- Design of the foundation (frame, patterns, if necessary).
- Determination of the basing scheme for the lower skin and the design of basic elements.
- Assignment of installation elements for cellular core and profiles (bends).
- Design and installation of clamping elements for fixing profiles and cellular core.
- Designing clamps and inserts (if necessary) for a tighter closure of adhesive surfaces (in hard-to-reach places) under a vacuum bag.
- Definition and installation of clamp fixation elements.
- Determination of the place for the witness-sample (if necessary).
- Design and installation of vacuum tubes and fittings for pumping air and control (if necessary).
- Definition and installation of standard elements.

3. AATE computer-aided design for the manufacture of PCM aircraft cellular metal panels
The following tools have been developed for AATE computer-aided design using the Siemens NX CAD system: catalogue of basic elements with parametric models and with automated configuration changes; automated formation of the geometry and parameters of the foundation; catalogue of installation and clamping elements with parametric models and with automated configuration change; automated installation of basic, installation, clamping and standard elements by pairing along holes and foundation geometry; catalogue of clamp fixation elements with parametric models and with automated configuration changes; catalogue of transportation units with parametric models and with automated configuration change.

4. Catalogue of basic elements
In order to reduce the time when developing elements for basing the lower skin on the surface of the AATE foundation, an electronic catalogue of basic elements (stops) was developed. This catalogue consists of two types of stops of the lower skin: foundation and pressure stops; and also, from two types of stops of the upper casing: foundation and pressure stops. It is possible to select the stops from the catalog, as well as the ability to automatically generate the configuration of the stops by entering the necessary parameters in the parameter setting window. The types of stops and adjustable parameters are shown in figure 2.
5. Automated formation of geometry and foundation parameters
The tool for automated formation of the foundation geometry allows reducing the time for the development of AATE. With its use, it becomes possible to design the foundation by setting input parameters: lower skin of the product; boundary conditions (distances from the edges of the lower skin to the edges of the panel); foundation thickness.

After setting these parameters, the foundation is built automatically and the user only needs to make its correction, if necessary.

6. Catalogue of installation and clamping elements
To set the cellular core on the lower skin according to technical task and lay on top of it other elements of the product, it is necessary to use the installation elements (stops for cellular core). These stops have a similar configuration for different AATEs and differ only in size, so it was decided to develop a catalogue of these stops.

The catalogue of these elements is designed to reduce the time of designing the AATE, by analogy with the previous one, there is also the opportunity to select elements of the catalogue nomenclature, and it is also possible to automatically generate the configuration by entering the necessary parameters in the parameter setting window. An example of elements and their parameters is presented in figure 3.

7. Automated installation of basic, installation, clamping and standard elements
When designing AATE in a Siemens NX CAD system [7], there is a constant need to use the operations of imposing restrictions and relations between the elements included in this assembly. The main restrictions are imposed using the geometry of the foundation of the tool, namely the mounting holes. This method of pairing elements through mounting holes was taken as the basis for the development of an automated installation of elements.

8. Catalogue of clamps
In most cases, strips for pressing the upper layers of the product to the lower skin and to the cellular core are installed on the same type (standard) hinges. Therefore, it is also the reason for the creation of a catalogue of such clamps.

The catalogue of clamping elements is also made by analogy with the previous catalogues. An example is shown in figure 4.

![Hinges for fixing clamps](image)

**Figure 4.** Hinges for fixing clamps.

9. **The catalogue of transportation nodes**

To move and transport the device and the product laid out on it, transport nodes are installed. Designing such nodes is a rather time-consuming process.

After analyzing the main types of AATE transportation nodes, it was concluded that all the elements of these nodes are typical, on the basis of this a decision was made on the need to develop a catalogue of transportation nodes for AATE.

This catalogue consists of different types and parameters of transportation nodes, the choice of the type of transportation node is carried out either by name or by sketch. After choosing the appropriate type, it is possible to select items from the catalog nomenclature according to the required parameters. There is also the possibility of automated formation of the configuration of the transport nodes by entering the necessary parameters into the parameter setting window.

10. **The use of computer-aided design tools for AATE for the manufacture of PCM aircraft cellular metal panels at each stage of the AATE design methodology**

The AATE design methodology differs from the AATE automated design methodology proposed in this article. At each design stage, tools are used that help automate the AATE design process for creating PCM cellular panels.

The use of computer-aided design tools for AATE at all stages of a computer-aided design technique is shown in figure 5.
Figure 5. AATE design scheme for manufacturing PCM aircraft cellular metal panels using computer-aided design tools.

Practice shows that this automated design methodology for AATE can reduce up to 20-30% of the time (depending on the complexity of the AATE) for AATE development.

11. Conclusion
The developed automated design methodology for AATE was tested on the example of the aircraft building company “Aviastar-SP” JSC. Namely, using this technique, about ten AATE positions were developed for “Aviastar-SP”. Examples of designed AATE positions are shown in figure 6.

Figure 6. AATE electronic models.

Testing confirmed that the automated design methodology for AATE for the manufacture of aircraft cellular metal panels from polymer composite materials using the Siemens NX CAD system allows one of the main tasks of production preparation, namely the reduction of economic costs, as this technique ensures:

- improving the efficiency of the Siemens NX CAD system in the design of AATE [8];
- reduction of time spent on the development and design of AATE.

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