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К ВОПРОСУ О ПРИМЕНЕНИЕ МЕТОДОВ ОБРАТНОГО ПРОЕКТИРОВАНИЯ ТРУБОПРОВОДОВ СИСТЕМЫ КОНДИЦИОНИРОВАНИЯ ВОЗДУХА НА САМОЛЕТЕ

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ON THE ISSUE OF THE APPLICATION OF METHODS OF REVERSE ENGINEERING OF PIPELINES OF THE AIR CONDITIONING SYSTEM TO THE AIRCRAFT

Nowadays, avionics cooling systems in modern aircraft are key to ensuring the smooth operation of avionics. The design of such systems is fraught with many difficulties: from the high density of device placement to the need to take into account external factors affecting thermal loads. Limited space for installation of pipelines and assembly errors during production add additional challenges. This article analyzes the problems of designing and installing blowing systems, as well as discusses how modern CAD technologies can help solve these problems.

The on-board equipment blowing system is designed to cool and maintain optimal temperature conditions for electronic devices that are sensitive to overheating [1]. It plays a key role in ensuring the reliable operation of avionics, preventing failures caused by thermal stress and extending the service life of components.

The complexities of system design [2, 3]:

1. High density of equipment placement:

The avionics compartment often houses a large number of devices in a limited area. This requires careful consideration of the air supply and exhaust routes to ensure uniform cooling of all components.

2. The need for accurate calculations:

The design of the system requires taking into account the thermal loads of the equipment, the aerodynamic characteristics of the air ducts, as well as the influence of external factors such as changes in pressure and temperature at altitude.

3. Integration with other systems:

The air conditioning system must be compatible with the air conditioning and ventilation system of the aircraft, which complicates the design and requires consideration of the interaction of all systems.

Difficulties with the installation of pipelines:

1. Limited space:

There is very little free space inside the avionics compartments and other technical areas, which makes it difficult to place air ducts.

2. Assembly errors:

Deviations in the size or location of equipment that occur during the assembly of an aircraft may make it impossible to install pipelines designed according to an ideal model.

3. Configuration flexibility:

The ducts must bypass other systems and components such as electrical cables, optical fibers, and aircraft structural elements. This requires precise adjustment at the installation stage, which increases the complexity of the work.

It is important to note that in recent years, digital design methods have been actively used in the aircraft industry. Modern technologies, such as CAD systems (for example, Siemens NX), allow you to create electronic models that simplify the design of pipelines. These EM display the configuration of pipes, help optimize their placement in a virtual environment, and allow testing of the system to improve reliability and efficiency.

However, virtual models often do not take into account the errors that arise from time to time during the serial assembly of equipment, which are taken into account when introducing standards of these pipelines into production. At the Kazan Aviation Plant, the pipeline belongs to the standardization if it is installed on three production machines at the same time.

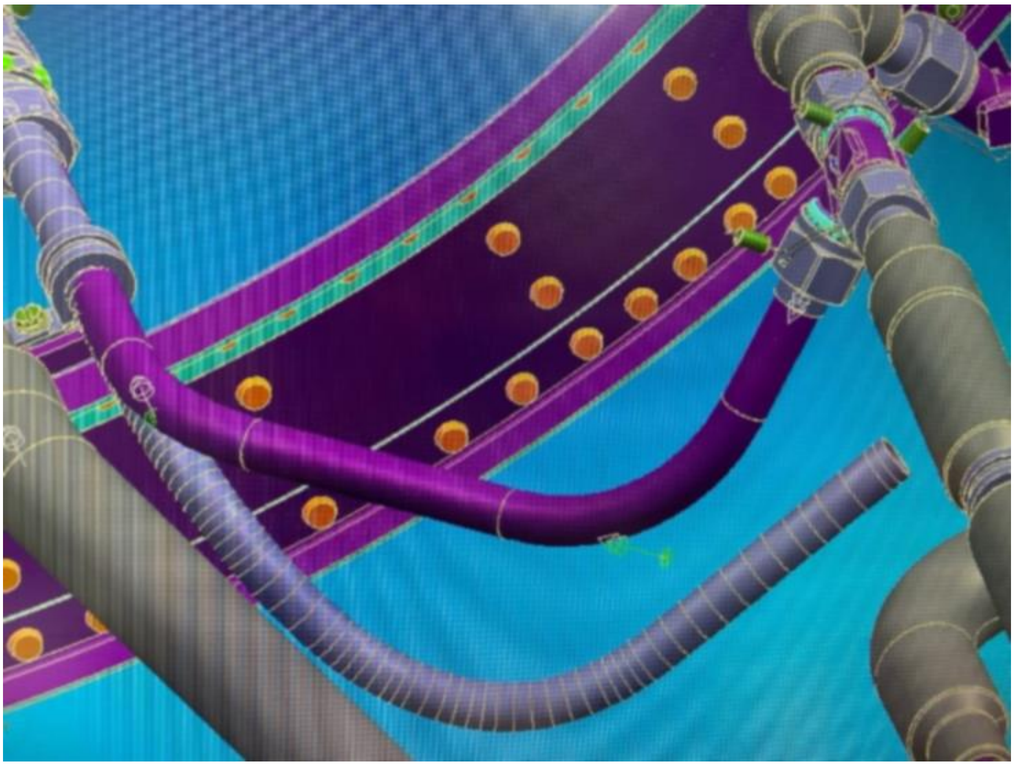

Figure 1 – An electronic model of a part of the aircraft air conditioning system with a superimposed digitized reference (Straight view)

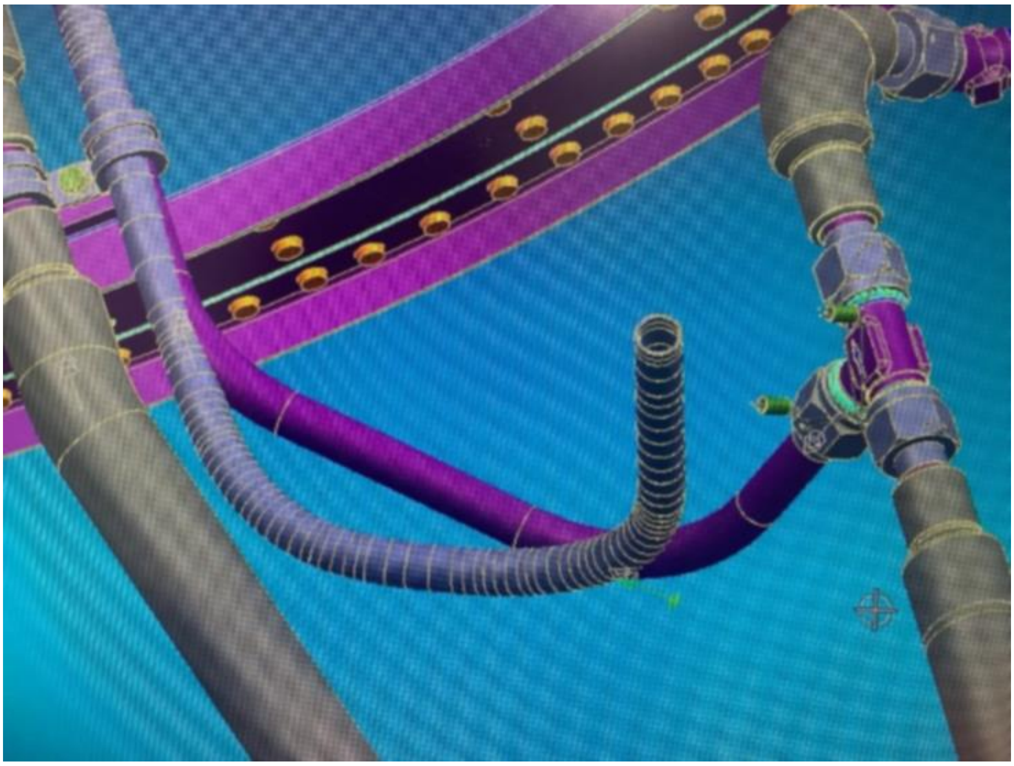

Figure 2 - An electronic model of a part of the aircraft's air conditioning system with a superimposed digitized reference (Side view)

Figures 1 and 2 show the results of comparing the real pipe (standard) installed on the aircraft and its electronic model. As you can see, the pipes do not repeat each other's geometry. During the research, the following reasons for the discrepancy were found and ways to solve the problem were proposed:

1. The pipeline cannot be manufactured on an existing pipe bending machine and therefore requires modification of the electronic model.

The approximation of this pipe will consist only in optimizing the bending angles (Figure 3). Based on the available trajectories, a new centerline is built that meets the requirements for bending on CNC machines, namely, bending radii and minimum lengths of straight sections are set. For example, for a pipe D=6, the recommended bending radius is R=15, R=18, R=24, R=30

2. In reality, the pipeline wraps around the existing elements of the system, which were not taken into account during the design of the electronic environment around the pipe.

The approximation in this case will consist in superimposing the pipe standard and the electronic model, finding the optimal design option and analyzing the possibility of installing the pipe in existing systems without bending in place.

The digitization of existing standards is an important step in the approximation process. It consists in creating an electronic model of standards that reflect the real configuration of the pipe and adaptation to digital production methods.

The most optimal method for obtaining the geometry of the reference pipe in the course of practical experiments turned out to be the scanning method in Aicon

16 (a system designed for non-contact three-dimensional measurement) with obtaining the axis of the pipeline.

The technology of approximation of seamless pipelines:

1. The scan of the reference is loaded into CAD systems.
2. The axial pipeline line is being built.
3. Based on the available trajectories, a new axial line is built that meets the requirements for bending on CNC machines, namely, bending radii and minimum lengths of straight sections are set (Fig. 3).
4. The electronic model of the pipe standard is checked for the possibility of installation.

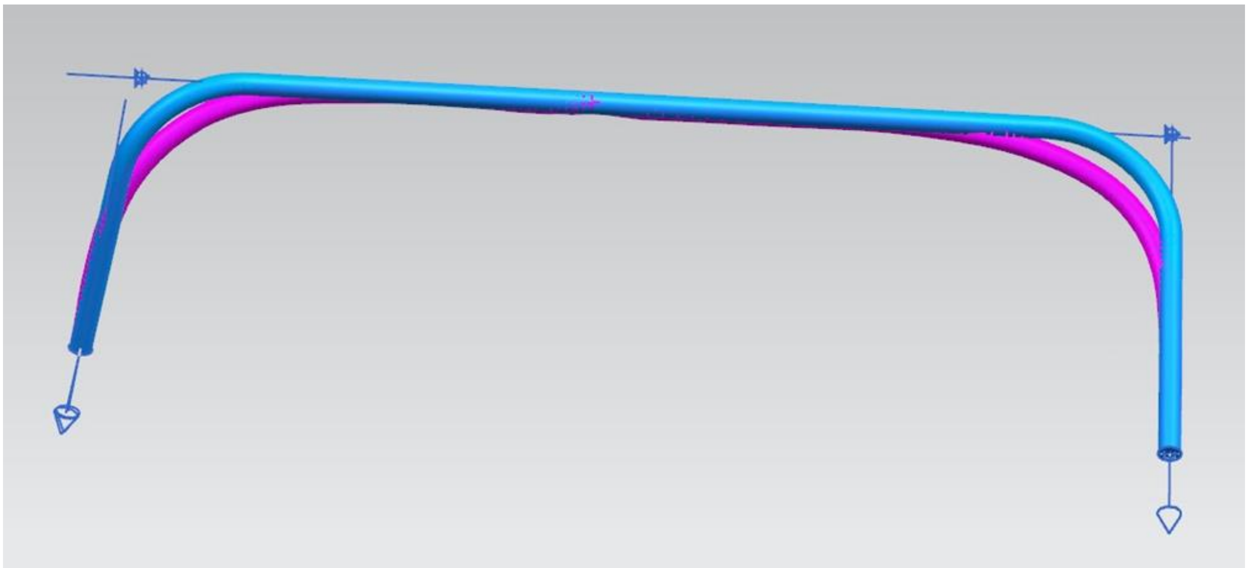

Figure 3 –Optimization of bending angles that meets the requirements for bending on CNC machines.

The result of the approximation is the transfer of pipeline manufacturing according to standards to manufacturing according to electronic models on the Macri Provar 6-90 U-D pipe bending machine by running-in and winding methods.

The use of reverse engineering methods, namely scanning reference databases together with subsequent approximation of existing models in an electronic environment, helps to adapt the project to mass production. This is especially important for air conditioning systems, and in particular for blowing equipment, where pipelines must pass as accurately as possible inside the system.

Application of digital design approximation methods:

1. Speeds up installation, as no on-site bending is required
2. Reduces the likelihood of errors

Thus, the application of an approach based on scanning the existing reference base and approximation using electronic models that were obtained in the process of digital design opens up new horizons for the transfer of production of seamless pipes of the equipment blowing system, as well as other systems with a dense layout. In particular, this will allow the manufacture of pipes on the high-tech Macri

Provar 6-90 U-D pipe bending machine, which is characterized by high productivity and accuracy.

The use of this production method will not only significantly increase the accuracy of pipeline assembly, but also speed up the installation process, which is critically important in the conditions of mass production of aircraft. At the Kazan Aviation Plant, where serial production of aircraft is carried out, such process optimization can lead to a noticeable reduction in the time for manufacturing and installing components, as well as to a decrease in the likelihood of errors during assembly.

In addition, the use of digital technologies and modern design methods makes it possible to manage production resources more efficiently and minimize material costs. This not only improves the quality of the final product, but also improves the overall economic efficiency of production. As a result, the transition to the use of the Macri Provar 6-90 U-D pipe bending machine in combination with digital models and scanning of the reference base will be a significant step forward for the Kazan Aviation Plant in the direction of increasing competitiveness and introducing innovative technologies into production processes.

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