satellite image transmission methods - from analog transmission in the APT format to the LRPT format, which includes all the attributes of a modern digital data transmission system - efficient compression, error-correction coding/decoding, digital modulation and reception. Using the developed MATLAB-model helps to make more accessible and effective the studying of methods and algorithms for analog and digital transmission and reception of satellite images, without the need in addition to applying equipment for direct reception of signals from satellites.

References:
ABSTRACT. The paper considers one of important areas of engineering, reengineering based on 3D scanning. Schemes of direct and reverse problems have been developed to solve the issue of restoring the analytical standard of the propeller of an ultralight two-seat aircraft. Their analysis is carried out and the implementation of tasks during the control operation in the production of such products is provided.

1. INTRODUCTION.

The term engineering is widely known in the modern world as a set of operations aimed at designing, preproduction, manufacturing and putting into operation. In the modern world, engineering cannot exist without intelligent information systems that perform a special function, the creation and storage of all information of the object under study.

The subject of engineering is not the object itself, but the process of information support for the design of the object, preproduction and direct manufacturing, testing, operation and disposal thereof.

One of the areas of engineering is reengineering or reverse engineering, which is a complex of production systems by minimizing the usage of production resources, reducing the duration of the production cycle, reducing the cost of the production process, improving the quality of products based on radical changes in production processes.

Reengineering of a aircraft object solves the problem of restoring its analytical standard from portrait information for subsequent duplication or refinement in order to its restoration and further improvement [1].

Portrait generation is an important step in reengineering that involves a mathematical 3D model construction of a real, physically existing object, in other words obtaining its portrait in the CAD/CAM system of the enterprise [2].

In this article, the reengineering task is solved through the example of a wooden propeller of an ultralight two-seater aircraft, which represents a multi-layer, glued layer-by-layer, wooden structure (Fig. 1).

Particularly noteworthy is the material for the preparation of the propeller, glued wood (Fig. 1, b), which has a number of properties: lamination, the presence of small internal defects, variability of geometry with humidity changing, and with an increase in the number of individual planks glued together, an increase in the reduced modulus of elasticity and durability.

Hence are the strict requirements for the quality of the multilayer structure of a wooden workpiece for propellers.

To manufacture a single sample and propeller control, the traditional manufacturing method for marking using templates is often used, at which control operations are also performed using templates.

It should be noted that the amount of master tooling produced by the workshop during the preparation for launching a new product is directly dependent on the dimensions and design features of the propeller, which in turn affects the cost, complexity of manufacturing and control of the propeller itself.
Fig. 1. Propeller of an ultralight two-seat aircraft:
a – ultralight two-seat aircraft [3]; b – propeller in section;
c – propeller blade

2. FEATURES OF TRADITIONAL PROPELLER MANUFACTURING TECHNOLOGY.

As a rule, the manufacturing process of a wooden propeller consists of several technological operations:

1. Production according to the drawing of templates – side view, top view, control sections (Fig. 2).
2. Planks manufacturing. Drilling the base hole for the technical axis.
3. Workpiece marking.
5. Marking control sections on the workpiece.
6. Processing the bottom surface of the blade with the control of angles along the control sections.
7. Processing the upper surface of the blade (shaping).
8. Sanding, grinding.
10. Coating and surface cleaning.
11. Adjustment and installation of metal fittings of the leading edge.
12. Surface cleaning and painting.
13. Final equilibration.

The analysis of this incomplete list of operations suggests that the technology for manufacturing a propeller using templates has a number of drawbacks:

- large amount of manual labor;
- high requirements for precision manufacturing of template equipment;
- availability of highly skilled workers of focused specialization;
- availability of a large range of template equipment;
- high cost of propeller manufacturing technology.

As known, the operational efficiency of light and ultralight aircraft is largely determined by mass, strength and geometric characteristics of the propellers used.
As practice has shown, installing a propeller improperly designed or manufactured with significant deviations on a plane can lead to a loss of horizontal thrust or rate of climb of an aircraft up to 50%. Therefore, the manufactured propeller shall meet the specified flight requirements and airworthiness standards of the aircraft [4], and ensuring compliance with the specified requirements of the propeller during its manufacturing with templates may cause certain difficulties, since the screw itself has a complicated geometry and there are cumulative deviations in the manufacturing of templates which are then transferred to the screw. Moreover, introduction of changes to the geometry of propeller leads to necessity of manufacturing new templates, whereas previous templates can be safely disposed of.

Currently, the technology of propeller manufacturing and control using marking and templates has been improved with application of CNC machines and CAD/CAM systems, which has reduced the complexity, increased the accuracy of manufacturing products and tooling, and reduced the cost of manufacturing the propeller. Thereat, the key is the availability of an analytical standard of the part, which allows quick provision of the necessary information for the development of the technological process of its manufacture with the specification of equipment, devices and tools available at the enterprise.
Fig. 2. Main sections of the profiles of the wooden propeller according to the drawing:

- a – control sections of propeller profiles;
- b – propeller control sections templates;
- c – real templates

3. REENGINEERING. DIRECT AND REVERSE PROBLEM OF PROPELLER MANUFACTURING.

However, it raises an acute problem of digitization of aviation products of the former Soviet Union, for which documentation was lost and/or the transfer from template technology to information using CNC machines and CAD/CAM systems is required, which can be implemented by reengineering, the practical implementation whereof begins with the digitization with laser scanners.

As mentioned earlier, the problem considers the propeller made of wood, which limits its operational life and, as a rule, such propellers cannot be repaired after the end of their service life or with the appearance of obvious damage and are simply replaced with a new one. This case considered only a propeller (Fig. 1) with a fulfilled flight life without accompanying documentation thereto; therefore, the reconstruction of the propeller geometry was carried out by the reengineering method using an Artec EVA Lite laser scanner.

Analysis of the obtained portrait of the existing sample indicated the presence of significant deviations of its geometry from the theoretical recommendations of aerodynamics. For instance, the trailing edge of the propeller in the frontal plane had a sinusoidal-like, which can also be the result of not only deterioration, but also the result of errors in the calculation of its characteristics and/or non-compliance with manufacturing technology. In this case, the portrait obtained by scanning cannot serve as a source of information for constructing the analytical standard of the propeller. As consequence, it became necessary to perform design calculations in order to obtain its exact geometry.

There are two ways to create the geometry of the analytical propeller standard, solving the direct or reverse problem (Fig. 3).

The direct problem (Fig. 3, a) is necessary in the early stages of design and development of the propeller and includes the following sequence of operations:

1. Design calculation taking into account the initial data: design point – flight altitude, speed, temperature, engine power, propeller speed, propeller diameter, set of aerodynamic profiles along the radius of the propeller blade and their aerodynamic characteristics; a set of relative profile thicknesses along the radius of the blade, Reynolds number and Mach number.
2. Determination of aerodynamic characteristics of profiles using the XFOIL software package.
3. Calculation and obtaining the geometrical parameters of the propeller.
4. Verification calculation of the results of design calculations.
5. Correction of geometry taking into account verification calculation, if necessary.
6. Data output on the geometry of the propeller blade for construction in the computer-aided design system and the creation of an analytical propeller standard.

![Diagram of propeller manufacturing process](image_url)

**Fig. 3. Direct (a) and reverse (b) problem of propeller manufacturing**

The reverse problem (Fig. 3, b) is the basis of reengineering and consists of the following:
1. Digitization (scanning) of the propeller surface with the creation of a point cloud, i.e. a portrait of the object under study (for example, in the form of «*.stl» format file).
2. Conversion of a point cloud and building a three-dimensional model (for example, in the form of a «.cdw» file), where the coordinates of the profiles, installation angles, chords can be obtained, and the calculated Reynolds numbers and Mach numbers over sections can be determined.
Further, items 3 - 6 are similar to the direct problem.

Analyzing the flowcharts, it can be noted that the direct problem can most often be used in the early stages of product design, whereas the reverse problem can be used to control and develop its manufacturing technology. Therefore, enterprises now combine direct and reverse problems in production based on the coordinate system of machining centers with CNC by equipping them with control tools (Fig. 4). After solving the direct problem of shaping (or its individual operations and transitions), it enables determination of the coordinates of the surface points of the part to build its portrait, which is facilitated by the use of CAD/CAM systems. To perform measurements, the cutting tool is replaced by a measuring one, for which tactile probes or laser are usually used.

The specified movement of the measuring tool along two coordinates of the horizontal plane (for instance, X and Y) referred to the part allows measurement of the distance to its surface. Measurement procedures can be performed without changing the base of the part, which increases their accuracy and reduces the overall complexity of part manufacturing. However, performing this method of the reverse problem solving may raise difficulties associated with the great complexity of constructing portraits of parts and high requirements for the qualification of production personnel when working with various CAD/CAM systems.

Based on the foregoing, it is safe to state that reengineering is used not only to restore the analytical standard of the studied product, but also to control thereof.
4. CONCLUSIONS.

1. 3D scanning reengineering allows to restore the analytical standard of the surface without templates.
2. Reengineering accurately recreates the geometry of the surface under study of the product and, if the surface has damage and other defects, this must be taken into account in design calculations before constructing an analytical standard.
3. 3D scanning digitizes the test surface and creates its prototype, which can be used in control operations of the product manufacturing.
4. It would be advisable to combine the complex of works to solve direct and reverse problems in the manufacturing of aviation products, where the direct task can be solved in the early stages of product design, whereas the reverse problem can be solved during control and refinement of the manufacturing technology thereof.

References: