

# Methodology for improving the mechanical and operational properties of aircraft structural elements during its maintenance using gas pulse treatment

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**Abstract.** A methodology has been developed to ensure airworthiness by improving the reliability of structural elements of aviation and airfield equipment, which differs from the currently available ones by using new effective non-deformational technologies based on pulsating subsonic gas flows during all types of maintenance and repair. New technologies have been developed to improve the mechanical and operational properties of aircraft structural elements, applicable in the production of aviation equipment, in the process of its maintenance and repair, characterized by the ability to increase them in a complex, without deterioration of any parameters. The nature of the impact of unsteady subsonic gas flows on the structure and properties of aircraft structural elements made of metal and polymer materials, the stress states of products, and the corresponding physical model has been created. It is proposed to implement measures for the use of new non-deformational technologies for restoring operational properties, as well as improving the reliability and extending the life cycle of elements, parts and assemblies of aircraft, airfield equipment by transport companies that exceed the currently used efficiency, efficiency and environmental friendliness, making appropriate changes to the maintenance and repair regulations. The direction of improving the methodology for forecasting the technical condition of aircraft structural elements is indicated, which differs from the existing ones by taking into account data on the density of crystal structure defects in surface layers. Keywords: Civil aviation, repair, gas pulse processing.

## 1 Introduction

The processing methods used in the process of maintenance and repair of structural elements of aviation and airfield equipment were developed, which allowed to obtain the following technical results [1-5]:

- to reduce the leash during the heat treatment of products made of two-phase titanium alloys, as well as to increase hardness and wear resistance in comparison with the standard hardening heat treatment of similar alloys;

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- increase the elastic properties of steel twisted springs;
- to increase the durability of a standard heat-strengthened metal-cutting tool made of high-speed steel by 2-2.5 times;
- to increase the reliability of metal products obtained by cold plastic deformation by increasing their plasticity and viscosity without reducing strength and hardness, as well as to reduce the duration of processing by pulsating air flow;
- to increase the values of the dynamic and bending strength of non-metallic composite materials with a binder based on thermosetting resins;

Technologies and methods of non-deformational processing of structural elements of aircraft and airfield equipment using pulsating subsonic air flows have been created, which allow increasing their structural strength and operational life, a methodology for their application in the process of maintenance and repair has been developed;

- a model has been developed, the use of which ensures the achievement of the required mechanical and operational properties with a minimum processing time;
- the dangerous duration of the operational impact of non-stationary air flows on the elements of aircraft vehicles has been established, depending on the flow rates and their amplitude-frequency characteristics, a methodology for identifying and eliminating the consequences of this impact has been developed;
- improving the safety of air transportation by taking into account the influence of non-stationary air flows and other external influences on the reliability and durability of transport equipment.

The amplitudes of vibrations of particles of a body interacting with a non-stationary air flow are determined.

The method of determining the optimal duration of processing aircraft parts by pulsating gas flow (gas pulse processing) is given.

The theoretical foundations of the effect of pulsating gas flows on the strength properties of materials and products are presented, the results of studying and modeling the effect of the placement of a product being processed by a pulsating gas flow (gas pulse processing) on the amplitude-frequency characteristics of the gas flow, determining the amplitude of vibrations of particles of a body interacting with a pulsating gas flow.

The role of the sound pressure value in the achieved technical result was evaluated.

## **2 Experimental data and theoretical provisions**

Experimental studies (table.1) showed, using the example of aluminum alloy AMg3, that a blower (axial fan) can be used as a generator of pulsations of air flow parameters used for blowing products, both as a whole and local areas, in which air movement is carried out by a propeller-type paddle wheel mounted on the shaft of an electric motor rotating the wheel. An electric motor with a paddle wheel is placed in a cylindrical cup.

The air from the environment, captured by the paddle wheel, moves to the bottom of the glass and flows out of it through holes (windows) in the form of elementary flows, the parameters of which periodically change with a frequency equal to the engine shaft rotation frequency, since the blades periodically overlap the windows, changing the area of the output sections of the windows from minimum to maximum and, accordingly, by changing the air flow rate from the maximum to the minimum value (the air flow is constant).

The advantages of such a pulsation generator are low noise (no more than 40 dB compared to 90-140 dB in the case of gas jet generators) and mobility due to compactness and low weight. With the help of such a generator, it is possible to process, in particular, the areas of cracks in the structural elements of aircraft vehicles, in order to prevent their further spread. Such processing can be carried out promptly, without dismantling and decommissioning the vehicle.

**Table 1.** Results of discrete gas pulse processing of samples made of aluminum alloy AMr3 using a low-noise generator.

Duration of processing	0 min	5+5 min	10 min
Bending strength, MPa	368	390	390

The effect of unsteady air flows on the elastic properties of spring elements of aviation and airfield equipment has been studied.

The effect of processing by non-stationary air flows on tools made of steels and hard alloys used in the manufacture and repair of aircraft parts has been studied.

The influence of unsteady air flows on endurance, crack resistance (fracture toughness and long-term strength of elements of aviation and airfield equipment is investigated.

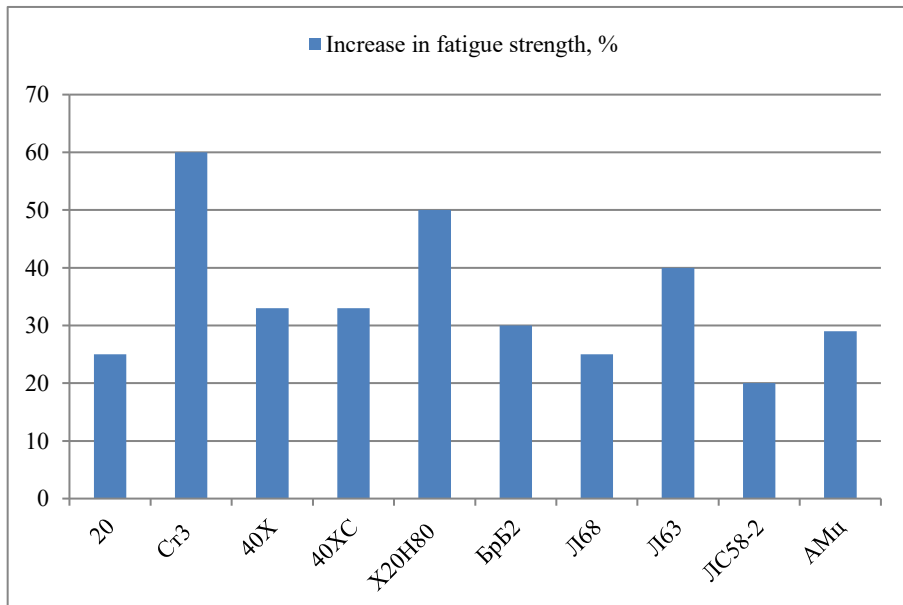
The increase in corrosion resistance is associated with the relaxation of tensile residual stresses on the surface of products as a result of blowing with a pulsating gas stream, as well as the distribution of defects in the crystal structure favorable for corrosion resistance.

So, in particular, the mass loss of an AMr-type aluminum alloy was more than 40 and 18% for untreated and processed samples, respectively.

The developed method provides a volumetric character of increasing corrosion resistance, which is currently achieved either by additional alloying or by changing the electrode potential using an external DC source. Moreover, the comparative corrosion resistance increases with an increase in the duration of stay in an aggressive environment.

In the course of the conducted research, a significant positive effect of processing by non-stationary air flows on the durability of tools made of steels, including high-speed ones, used in the manufacture and repair of aircraft parts, providing an increase in productivity, was revealed.

As part of the study of the effect of gas pulse treatment on the resistance of metal materials to fatigue failure, experiments were conducted using samples from structural steels and non-ferrous alloys of various grades (see Fig. 1).

**Fig. 1.** Growth of fatigue strength of structural metal materials after gas pulse treatment lasting 15 min.

For samples made of 40XC steel (cold rolled sheet metal), the value of K1C after treatment with a pulsating gas flow is 14.3% higher compared to untreated samples. Tests using samples made of cold rolled AMr2 alloy with a degree of deformation during rolling of 40% showed an increase in the value of K1C after gas pulse treatment by 16.7%.

For samples made of this material, crack resistance tests were carried out at elevated temperatures. The test results showed that the K1 value at a temperature of 300 °C is 40% higher. after gas pulse treatment and at this temperature, the tensile strength without treatment is 150 MPa, and the treated samples are 175 MPa, which is 16.7% more.

A methodology has been developed to improve the efficiency and safety of air transportation by ensuring high reliability values of aircraft structural elements, aircraft engines and airfield equipment by using the latest technologies to increase and restore structural strength and operational properties at the maintenance and repair stage;

the use of methods for controlling changes in the structure of the material of parts, assemblies, and other structural elements by controlling changes in electrical resistance, thermal conductivity, surface hardness, sound velocity and other parameters, increasing the service life of structural elements of aircraft vehicles, equipment and mechanisms, optimizing the timing of inspections and repairs.

The results of numerous experimental studies of the effect of non-stationary air flows on the strength, reliability and durability of structural materials used in the creation of an aircraft have made it possible to supplement the existing methodology for organizing the system of preparation and repair of aviation equipment with a set of new methods and recommendations for the use of non-stationary flows to ensure comprehensive safety during the operation of air transport.

It is necessary to know the natural oscillation frequency of the blowing object so that when choosing fan modes, the frequency is as close as possible to its own and there is resonance, the maximum amplitude of the pulses, and therefore the minimum required processing time.

When starting to blow a specific element of the aircraft structure, it is necessary to know the average speed of the pulsating air flow created by the pulsation generator used during blowing (specialized installation, axial or centrifugal fan). It has been experimentally established that the optimal average speed is about 30 m/s.

Knowing the average value of the pulsating flow velocity  $V$ , according to the above empirical formula:

$$\tau_0 = 0,0005V^2 - 0,2V + 30 \quad (1)$$

it is possible to determine the optimal blowing time  $\tau_0$  for samples from medium-carbon steels, as well as economically alloyed steels of the 40X, 40X type.

Since a specific aircraft structural element may differ from the samples for which the formula was obtained (other shape, dimensions, material, density and other parameters), it is necessary to clarify the duration of treatment with pulsating subsonic airflow using correction coefficients that take into account the difference between the blown structural element and the samples for which the optimal blowing time was obtained.

Then the blowing time:

$$\tau = \tau_0 \cdot \prod_{i=1}^g k_i \quad (2)$$

Where:  $\tau$  is the blowing time of the part;  $\tau_0$  is the optimal blowing time for the sample;  $k_i$  are correction coefficients that take into account the differences between a particular part and the sample.

Having determined the value of the processing time, you should make sure that it is really optimal, that is, process the part and evaluate the result.

The test showed a good match of the calculated optimal duration of blowing with a certain experimental method.

An important factor affecting the duration of blowing is the distance from the frontal surface of the object being processed to the output section of the pulsating flow  $d_0$ , since the average flow velocity decreases rapidly as it moves away from the cut, which leads to an increase in the required processing time. It has been experimentally established that if the blown object is small and the area of its mid-section (the projection of the body on a plane perpendicular to the flow axis) does not exceed 50% of the area of the output section, the optimal distance is zero. Otherwise, it is slightly larger (on the order of  $0.2 d_0$ ), so as not to block the flow, but not more than  $1 d_0$ .

The optimal processing time obtained as a result of calculations practically coincides with the empirical data.

Preventing the formation of cracks by redistributing dislocations and relaxing residual stresses requires improving the methodology for diagnosing aviation equipment in terms of detecting areas with increased dislocation density in the surface layers of structural elements.

The search for areas with an increased concentration of defects in the crystal structure is primarily conducted in places most prone, according to statistical data, to the formation of cracks and other damages, the occurrence of which is preceded by an increase in the density of dislocations.

### 3 Conclusions

The calculations carried out showed a significant economic effect from the use of gas pulse treatment.

Measures have also been developed to improve the methodology for diagnosing aviation equipment, characterized by a more complete account of the influence of environments, including non-stationary air flows on the mechanical and operational properties of the material of aircraft structural elements, due to the intellectualization of the diagnostic process, the use of methods for controlling changes in the structure of the material of parts, assemblies, and other structural elements.

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