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METHODS FOR MONITORING THE RADIOFREQUENCY OF COMPOSITE MATERIALS USED IN THE AVIATION INDUSTRY

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Annotation: *in the next decades, the use of composite materials in the aviation industry is significantly increasing. Composite materials are materials consisting of a combination of two or more structural elements, with high strength, lightness and aerodynamic properties. They have advantages over traditional metal materials such as light weight, corrosion resistance and good radiofrequency.*

This article analyzes the monitoring of the level of radiofrequency of composite materials and their Metrological supply.

Keywords: *kinetic method, VK-9 ceramic glue, airship, monitoring, composite materials (KM), radiofrequency, electromagnetism, absorption coefficient, nanocompasites.*

Introduction. The radiofrequency of composite materials is an important feature, since the efficiency of antennas and other electronic systems located inside the muzzle of aircraft depends on this indicator. A particularly large role is played by the effect of materials used on electromagnetic signals on the muzzle or other parts of aircraft, where antennas and various radar systems are located.

If the radiofrequency of the material is not high enough, the signal can be swallowed or reflected, which negatively affects the operation of communication systems, navigation and radar equipment. For this reason, composite materials used in aviation techniques must meet the following requirements:

* low electromagnetic absorption and scattering property;
• must have high mechanical strength;
* it is important to be light and aerodynamically comfortable;

Ensuring the Metrological supply of methods for monitoring the quality of radiofrequency of the muzzle part of an airship there are several rules of law, Metrological provision of methods for monitoring the quality of radiofrequency includes a set of measures aimed at ensuring the accuracy, reliability and repeatability of measurement results, as well as compliance with the established requirements of the methods The main aspects of Metrological supply the result of my analyzes shows that we must see below what the level of how correctly the equipment is measured, as well as check the results of the analysis.

Calibration is the process of adjusting measuring instruments to ensure compliance with standards. Regular calibration helps maintain high measurement accuracy [1,2].

Materils and methods: Measurement and evaluation of Radio transparency it uses radar testing techniques to determine the degree of transparency of the material to radio waves of different frequencies. Through this material, it is possible to control the measurement of the conductivity of radio waves.

Defect detection examination systems help to detect internal defects in composite materials, the presence of errors, porosity, delamination or foreign matter, which negatively affects radiosupply.

Performance stability monitoring during the operation of the airship, it is necessary to regularly check the part of the muzzle of the samalyot that the radioshaffof performance remains at the specified level.

Modern control systems are often automated means of data processing therefore combined, which makes it possible to predict possible violations of material properties based not only on diagnostics, but also on trend analysis. Such systems are an important part of the overall program of aircraft maintenance and safety.

The measurement and evaluation of the radiofrequency of the materials of the components of the aircraft made of composite materials is carried out using various methods and instruments that assess how much the material transmits radio waves at certain frequencies. Here are examples of such methods:

Delivery method: this method is the most common method for assessing radiofrequency. Its essence is to measure the intensity of radio waves before and after passing through the material. For this purpose, radio wave generators and receivers are used [3,4,5].

The measurement process consists of:

- radio waves at a certain frequency a certain power is therefore generated;
- these waves are directed to the sample of the composite material;
- records the strength of the wave after passing through the receiving material;
- radiofrequency is defined as the ratio of the transmitted wave force to the initial power;

In the aviation industry, such measurements and errors are carried out in special laboratories, where shielded cameras are therefore equipped to eliminate the external electromagnetic effect.

Reflection backscattering method, this method is used to assess radiosupply and detect defects in the material.

Measurement process:

- radio waves are directed to the surface of the material;
- the amount of energy returned towards the source is measured;
- a high degree of backscattering may indicate the presence of defects that distort radiofrequency;

This method is used to check the quality of the material during the production process, as well as during use to determine the damage that may occur over time.

The microwave measurement method allows you to take a three-dimensional image of the internal structures of the material and assess its radiosupply at different points.

Measurement process:

- microwaves scan the material from different angles;

-the data obtained is processed to create an image of the internal structure;

- evaluation of radiofrequency is carried out for different layers and sections of the material;

- Microwave tomography is used for the detailed analysis of complex composite materials used in the muzzle parts of airships, where it is necessary to evaluate high-precision radiofrequency;

Method of analysis at resonant frequencies:

This method is based on measuring the resonant frequency of the composite material, which depends on the radioshaffof properties.

- the sample is placed in an electromagnetic field of variable frequency;

- the resonance frequency at which maximum energy absorption is observed is measured;

-this data is used to assess the radiosupply of the material;

The main parameters and equations are as below;

Conductivity (T) this parameter is defined as the ratio of the transmitted wave power (PT) to the power (P0) of the incident wave, and is found by the formula below:

$$T = \frac{P_t}{P_0}, \quad (1)$$

Here:

P0-the strength of the electromagnetic wave before passing through the material;

Pt is the wave force after passing through the material.

As the signal weakens as the wave passes through the material, part of the energy is absorbed and part is reflected from the surface. Signal attenuation exponential law can therefore be described:

$$P_t = P_0 e^{-ad}, \quad (2)$$

Here:

a weakening (transparency) coefficient, which depends on the wave frequency of the material and the properties of the material;

d - material thickness.

The attenuation coefficient a can be determined by the complex value of the attenuation indicator $N = \dot{n} - \imath k$, where n is the real part that determines the wave propagation speed and, k, the absorption is therefore the random part to which it depends:

$$\alpha = \frac{2\pi k}{\lambda}, \quad (3)$$

Here: λ - vacuum wavelength.

Permeability through the attenuation coefficient: by substituting the expression Pt into the T permeability equation, we obtain:

$$T = e^{-\alpha d}. \quad (4)$$

Taking the logarithm of both sides of the equation, we can express the weakening coefficient in terms of conductivity:

$$\alpha = -\frac{\ln(T)}{d}. \quad (5)$$

The process of propagation of a wave through a Material is often described in terms of the complex amplitude of the electric field. If one considers a plane wave propagating in a material, one can write the electric field E(z) according to the Z coordinate in the direction of its propagation as: [6,7,8,9]

$$E(z) = E_0 e^{-ikz}. \quad (6)$$

The complex wavenumber is here, $\tilde{k} = \frac{2\pi\tilde{n}}{\lambda_0} = \frac{2\pi}{\lambda}$; λ 0- the wavelength in vacuum is.

Full permeability expression: a more accurate representation of permeability can be obtained by involving reflection at the boundaries of materials:

$$T = \left| \frac{4n_1 n_2}{(n_1 + n_2)^2 e^{-\alpha d} + (n_1 - n_2)^2 e^{\alpha d}} \right|^2, \quad (7)$$

here:

N1 as well as refractive indices of light at N2-boundaries (e.g. when obstructed in air and in composite radiofrequency materials).

Suppose that for a wave with a length of l=0.1 m, it is necessary to determine the radiosupply of a material with a thickness of D=0.01 m, and the measured conductivity is known to be T=0.8.

We calculate the first weakening coefficient and this is found as follows:

$$\alpha = -\frac{\ln(0.8)}{0.01} \approx 22.31 m^{-1}. \quad (8)$$

Based on the weakening coefficient, it is possible to determine losses in a certain thickness of the material and assess its effectiveness as a radioshaffof material.

Determining the disadvantages of an airship in radiofrequency materials used in the muzzle is an important step in ensuring the safe operation of the aircraft's equipment. The disadvantages of the radioshaffof composite materials used for these are holes, delaminations, cracks or foreign inclusions. Because of this, defects can significantly impair the radioshaffof properties of the material, which leads to a decrease in the quality of transmission and reception of radio signals.

The main methods of detecting defects are ultrasonic waves are formed and directed to the material. Waves travel along the material and are reflected from the boundaries of layers or defects. Reflected signals are analyzed to detect the presence of faults and faults.

It is used to analyze complex composite materials, even to detect small defects that can affect radiosupply.

Terahertz waves passing through the material use sensors that are extremely sensitive to changes in the structure, such as holes or delaminations. These waves are in the spectral range between infrared and microwave, allowing them to penetrate multiple dielectric materials [10,11,12]

Analysis. High precision, the surface is therefore the ability to scan without direct contact.

Cracks or foreign inclusions are therefore suitable for detecting internal defects at the surface level and inside the material.

Defects in the material cause signal distortion, which leads to acoustic waves (sound impulses). These pulses are recorded by sensors located on the surface of the material and allow real-time monitoring, detection of active defects.

Before the flight, the condition of the materials on the muzzle of the aircraft is constantly monitored.

Table 1.

The sum of the calculated values of the experimental pressure force (∑SE) and the square deviation of the determination coefficients (R2) in the description of the force growth according to the equations of Formal Kinetics

To bring the material to readiness required temperature ^{0}C	Order of Formal kinetic equations						Critical coefficient of determination
	V=1		V=2		V=3		
	(∑S_E)	(R^2)	(∑S_E)	(R^2)	(∑S_E)	(R^2)	
+50	48 890	0.78	42 896	0.87	41 258	0.79	R2 0.04=(47:339)=0.18
+10	38 780	0.80	41582	0.84	39 247	0.71	R2 0.04=(37:846)=0.04
-25	48 400	0.79	43 201	0.84	44 369	0.84	R2 0.04=(42:229)=0.18
∑ (SE)	136 070		127 679		124 874		

Thus, (Table 1) the following mathematical model can be used to determine the strength of MMKS-type PCMs with different 80kmks and 120kmks content that satisfy this condition, with a high level of filling at hardening temperatures of +50, +10 and minus 25°C:

$$\xi = \xi_\infty \cdot \left(1 - \frac{1}{k_{ef}\xi_\infty(\tau - \tau_a) + 1}\right), \qquad (9)$$

here ξ_∞ - pressure force.

k_{ef} - effective speed constant limit values,

τ -" Induction " period,

τ_a - time to lose fluid.

+50 °C to dry the material and bring it to a solid state:

$$\xi_\infty = 58.6 + \frac{77.3-58.6}{1+3.07\cdot10^8\cdot\exp(-35.8\cdot S_{PB}^{0.14}}, R_f^{\ 2} = 0.39\rangle R^2{}_{0.04}(9;4) = 0.72;$$

$$k_{ef} = 52.00\cdot10^{-5} + \frac{(0.63-52.00)\cdot10^{-5}}{1+4.97\cdot10^9\exp(-10.30\cdot S_{PB}^{0.43}}, R_f^{\ 2} = 0.69\rangle R^2{}_{0.04}(9;4) = 0.72;$$

$$\tau_a = -10.8 + 392.57\cdot S_{PB}^{-1.034} + 1.92\cdot10^{-6}\cdot S_{PB}^{10}, R_f^{\ 2} = 0.69\rangle R^2{}_{0.04}(9;4) = 0.72.$$

Our next temperature +10 ° C to dry our material:

$$\xi_\infty = 64.91 + \frac{0-64.91}{1+108{,}49\cdot\exp(-0.99\cdot S_{PB}^{0.96}}, R_f^{\ 2} = 0.57\rangle R^2{}_{0.04}(6;3) = 0.68;$$

$$k_{ef} = 32.50\cdot10^{-3} + \frac{(0-32.50)\cdot10^{-3}}{1+9.11\cdot10^4\exp(-379\cdot S_{PB}^{1.98}}, R_f^{\ 2} = 0.79\rangle R^2{}_{0.04}(6;3) = 0.68;$$

$$\tau_a = 86.22 + 7.095\cdot10^8\cdot S_{PB}^{-11.26}, R_f^{\ 2} = 0.69\rangle R^2{}_{0.04}(9;4) = 0.72.$$

Our next temperature -25 ° C to dry our material:

$$\xi_\infty = 57.52 + \frac{0-57.52}{1+1350\cdot\exp(-0.195\cdot S_{PB}^{1.94}}, R_f^{\ 2} = 0.38\rangle R^2{}_{0.04}(9;3) = 0.65;$$

$$k_{ef} = 62.13\cdot10^{-5} + \frac{(1.99-62.13)\cdot10^{-5}}{1+2.55\cdot10^7\exp(-0.379\cdot S_{PB}^{2.04}}, R_f^{\ 2} = 0.89\rangle R^2{}_{0.04}(8;4) = 0.68;$$

$$\tau_a = 62.44 + 4.89\cdot10^5\cdot S_{PB}^{-5.34}, R_f^{\ 2} = 0.99\rangle R^2{}_{0.04}(2;10) = 0.45.$$

Electromagnetic induction and pilot flow testing are therefore methods based on changing the electromagnetic field passing through the material. Disadvantages change the area distribution determined by the sensors [13,14].

Cracks are therefore suitable for detecting defects on and near the surface of the material, and are often used to examine mirrors elements in composites.

In aviation, integrated monitoring systems can be used, which combine several methods to ensure comprehensive diagnostics of radioshaffof materials. These, ultrasound diagnostics should be carried out and used with terahertz scanning for a more complete analysis of the structure of the material. During regular maintenance, such systems should automatically analyze the condition of the muzzle parts of the aircraft and identify possible defects before they lead to serious malfunctions.

These methods and technologies make it possible to perform a qualitative and quantitative analysis of the condition of radiofrequency materials, which is very important to ensure the safety and efficiency of aviation systems [15,16]

In conclusion we note that the system for measuring the radiofrequency of a composite material includes several interconnected components: a signal generator, measuring antennas, a test sample, receiving equipment, amplifiers, analog-to-digital switches and a central computer. Each of these elements has its own significance and requires Metrological support to ensure the accuracy and reliability of the measurement results.

Metrological provisioning, which includes calibration, verification and uncertainty assessment, is a key component of the measurement process. This helps to ensure accurate and reproducibility of the measured data, which in turn ensures the reliable operation of the aircraft's equipment.

The development and introduction of effective methods for monitoring and monitoring the radio-safety of composite materials allows aviation enterprises to maintain high standards of flight safety, reduce operational risks and increase the overall reliability of aircraft. Thus, improving the technologies for measuring radiofrequency and ensuring their Metrological accuracy remains important tasks in the field of aviation material science and technology.

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