MATERIALS WITH IMPROVED HEAT-PHYSICAL PROPERTIES FOR BALLONETS OF HYBRID AIRSHIP

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Abstract

This article discusses the possibility of returning to the use of hybrid airships. Using the advantages provided over traditional airships, the development of hybrid aircraft allows expanding their capabilities. By combining the benefits of aircraft, helicopters, airships. It is proposed to use modern energy-saving thermal insulation materials capable of withstanding significant temperatures such as aerogel. To confirm the effectiveness of the use of these materials, the guidelines consider the basis for the use of materials in the creation of hybrid airships.

Keywords: hybrid airship, airship, keywords, aerogel, keywords, thermal insulation material, aircraft.

INTRODUCTION

The high fuel costs of maintaining fixed-wing and rotary-wing aircraft make designers develop high-efficiency vehicles [1],[2],[3]. Airships widely used in the last century had the lowest fuel consumption for moving goods from point a to point b. When aircraft still had very low range, balloons could lift tens of tons and travel long distances. The main problem with the use of these aircraft was the direct proportionality between the payload and the volume, which reached significant values [4]. There was also a danger of operation associated with the use of combustible gas. This paper substantiates the theoretical use of modern airgel and increase the operating temperature of the gas to reduce the size.

EXPOSITION

Hybrid airships are lighter-than-air aircraft, the use of light gas and hot air is the main difference from the traditional airships. The combination of these two ways allows making the most of the advantages of each of the ways of ensuring the buoyancy of the vessel in the air [4]. The presence of a thermal balloon simplifies the control of the device in the vertical direction; also the balloon allows to reduce also loss of easy gas (in particular, for example, He).

For example, the Lokomoskainer thermoplane uses four types of lift for its flight: aerostatic forces, helium, and hot air, aerodynamic forces: aerostatic forces, helium, and hot air, aerodynamic forces, owing to the flow of the wing, and forces created by impellers equipped with electric motors Fig. 1,[5], [7].

Fig. 1. *Hybrid thermoplane Lokomoskainer*

In addition, to determine the lift that creates the working volume of the aircraft, you can define the formula (1)

$$F_A = g \cdot (\rho - \rho_{lift}) \cdot V \qquad (1)$$

where g – coefficient of free fall, ρ, ρ_{lift} – the density of the environment, and the density of the work gas, V – shell volume. That is, from this formula it is obvious that in order to obtain the maximum lifting force, it is necessary to reduce the density of the working gas, which in turn approaches zero. This creates a limiting maximum value of lift when the density of the working gas is equal to zero.

There are two ways to reduce the density. The first way is to use gases lighter than air such as hydrogen, helium. The second way is to use heated air. The use of gas is limited by its significant cost, which makes it inappropriate to use an airship.

The second method is more attractive because the heated air reduces the gas permeability requirements for the casing and reduces the operating cost. It is also worth noting that a change in altitude, the temperature difference between the thermoplane and the environment increases, and creates an additional lifting force. The ambient temperature is determined by the formula(2).

$$t = t_c + k \cdot h, \tag{2}$$

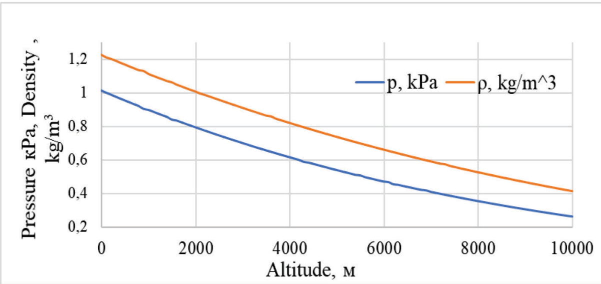

***Fig. 2.** Change in air pressure and density from altitude*

Consequently [6], that f_{lift} the lift force of the gas is decided by the given equation, and acquires the maximum value at $\rho_{lift} \to 0$:

$$f_{lift} = g \cdot (\rho - \rho_{lift}), \tag{3}$$

To create a lifting force and overcome the resistance forces arising from the flow around the hull and other aerodynamic surfaces, necessary to determine the effort F_{AD} from the generalized equation:

$$F_{AD} = C_R \cdot \frac{\rho \cdot U^2}{2} \cdot S, \tag{4}$$

where U – body velocity in the air flow, m/s, C_R – dimensionless coefficient of total aerodynamic force, there C_R can be decomposed in the direction:

$$\overrightarrow{C_R} = \overrightarrow{C_{lift}} + \overrightarrow{C_{drag}} \tag{5}$$

where C_{lift} – dimensionless coefficient of lifting force, C_{drag} – dimensionless coefficient of body resistance. These values are determined experimentally, as they depend on many parameters of the aircraft.

Lifting force F_D which is formed due to the rotation of the impeller screw is defined as follows:

$$F_D = C_p \cdot \frac{\rho \cdot U^2}{2} \cdot S, \tag{5}$$

where C_p - dimensionless coefficient of total thrust of the screw.

Since the shell with rarefied and heated air has a lower density than ambient air, there is an aerostatic lifting force of Archimedes, which is determined by equation (2.5) and has the form.

$$F_A = g(h) \cdot \left(\rho_{atm}(h) - \rho_{gas}(h)\right) \cdot V \\ = g(h) \cdot f(h) \cdot V, H \tag{6}$$

where $g(h)$ – coefficient of free fall, $\rho_{atm}(h)$ – atmospheric density, $\rho_{gas}(h)$ - the density of the heated working fluid, V – working volume, $f(h)$ – specific lift force of gas. The coefficient of free fall can be determined for a certain point of the earth as follows.

$$g = 9.780318 \cdot (1 + 5.302 \cdot 10^{-3} \cdot \sin\varphi - \\ -6 \cdot 10^{-3} \cdot \sin^2 2 \cdot \varphi) - \\ -3.086 \cdot 10^{-6} \cdot h, \tag{7}$$

where φ – latitude, h - altitude.

The gas density is determined from the Mendeleev-Clapeyron equation.

$$\rho_g = \frac{Mr_{gas} \cdot p_{gas}}{R \cdot T_{gas}}, \frac{kg}{m^3} \tag{8}$$

where Mr_{gas} – molar mass of the gas mixture. For the atmosphere, the molar mass is $Mr_{atm} = 28.96\ g/mol$, for gas, the molar mass is determined by the formula (7.2.4) and table 7.2 , , T_{gas} – gas temperature in Kelvin, $R = 8{,}31447\ Dg/mol \cdot K$- universal gas constant, p_{atm} – atmospheric pressure, Pa.

In order to determine the specific lift force of the heated gas mixture, it is necessary to express the difference between the density of the environment and the density of the heated working mixture:

$$f = \rho_{atm} - \rho_{gas}, \frac{kg}{m^3} \tag{9}$$

Assuming that the pressure drop between the gas mixture Δp and the temperature of the gas mixture to the environment is Δt the lifting force of the gas mixture in a given volume will be determined by:

$$f = \left(\rho_{atm} - \frac{(p_{atm} + \Delta p) \cdot Mr_{gas}}{(T + \Delta t) \cdot R}\right), H \tag{10}$$

The obtained formula makes it possible to determine the theoretical value of the specific lift force of the airship without taking into account the processes occurring in the middle of the shell. Such processes include convection, external thermal radiation, heat loss through holes and leaks in the thermal ballonets. Therefore, the specific lift will be determined from the following formula:

$$f = \rho_{atm}(h) - \frac{p_{atm}(h) + \Delta p}{\big(T(h) + \Delta t(h)\big) \cdot R} \cdot \cdot (Mr_{gas}), \frac{kg}{m^3} \tag{11}$$

where $\rho_{atm}(h)$, $T(h)$, $\Delta t(h)$ – parameters that are a function of height.

Molar mass of the gas mixture - air is defined as the sum of the atomic masses of the elements of the gas mixture to their percentage component 23 % O_2, 76% N_2, 1% Ar.

$$Mr_{gas} = \frac{Mr(O_2) \cdot 23 + Mr(N_2) \cdot 76 + Mr(Ar) \cdot 1}{100}, kg/mol$$

Under normal conditions, the gas temperature in the thermal ballon is on average 340…350 K. However, the use of modern ultra-light insulation materials can increase the temperature of the ballonet to more 600 K. the main problem remains the mechanical strength of the shell of the ballonet with a heat-insulating layer..

The following requirements were set for thermal ballet materials: minimum weight, high strength, high resistance to ultraviolet and ozone, resistance to the atmosphere, low gas permeability, flexibility and ductility at a wide temperature range, long service life.

It is proposed to use the outer bearing shell from the materials of table 1., and thermal insulation from materials such as pyrogel and airgel [8],[9].

Pyrogel 6650 is a heat-insulating material, which is a flexible fabric designed for high temperatures (up to 650 C). The pyrogel is made on the basis of quartz airgel with microfiber reinforcement. This material is easy to process and mount. The disadvantage of this material is the hygroscopicity. Therefore, it requires the use of materials for coating with protective films and separating it from the working gases. Airgel is a more effective thermal insulation material, but its cost is significantly higher.

Temperature-mechanical characteristics [10],[11], namely thermal conductivity, and mechanical characteristics were determined for this material. A modified pipe method was used to determine the heat transfer coefficient.

To determine the characteristics of the bond strength of the materials of Table 1 and Table 2.

The joints were made with Epoflex KM glue with the application of gluing points in a certain order and at a controlled distance.

Table 1 *- Protective film of polyvinyl fluoride*

Material	Tedlar®, PVF	Tedlar®, PFA	Skived TFE
Thickness, mm	0.025-0.05	0.025-0.05	0.0125-6
Density, $\frac{kg}{m^3}$	1370	220	2130
Jung's module E, MP_a	2068	480	
Tension MP_a	55.1	250	27.58
Temperature, °C	-72… +107	0… +205	-195… +260
Heat capacity, $\frac{J}{kg \cdot K}$	1760	1172	
Thermal conductivity, $\frac{W}{m \cdot K}$	0.13	0.195	

Table 2 -*Results of research samples*

	Airgel	Airgel	Pyrogel 6650
Material			
λ, $W/m \cdot K$	0.0191	0.0208	0.0163
σ_0, *МПа*	0.22	0.16	0.21

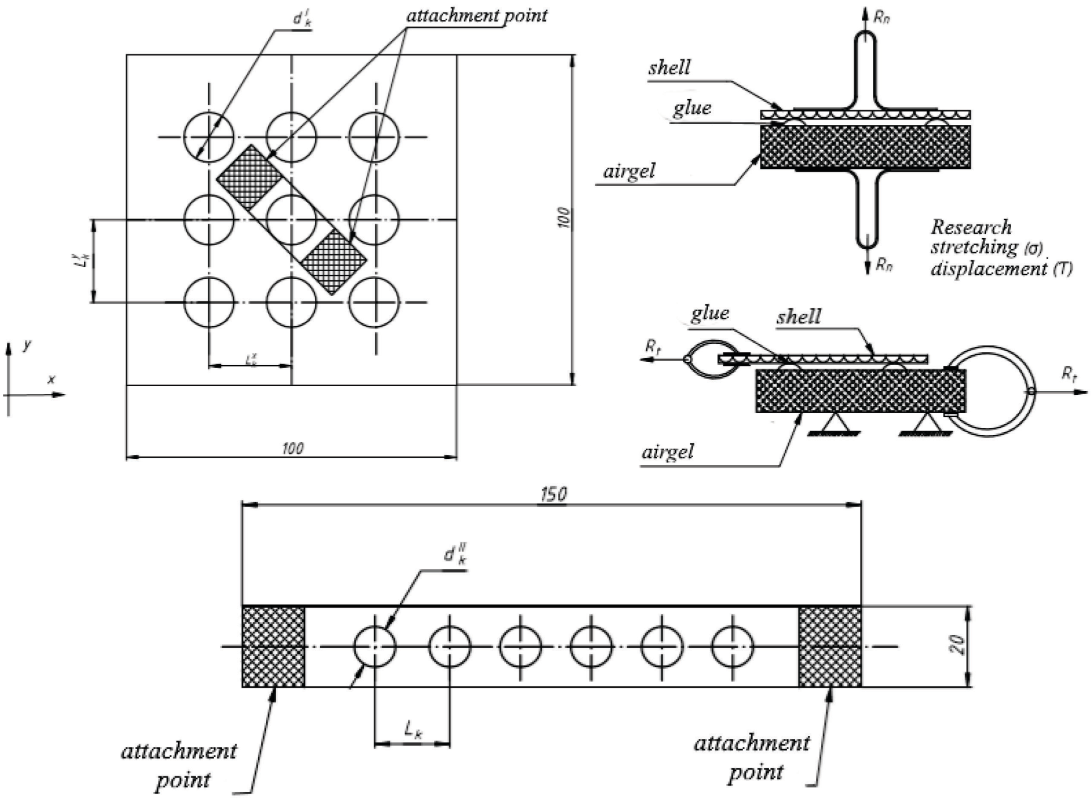

Fig. 3 - *Scheme of application of adhesive points and special clamps for mechanical tests: a) normal separation; b) shift; c) fixing in the vise*

The size of the test samples for normal separation was 100 mm x 100 mm, for the shear test using airgel fabric with a size of 150 mm. x 20 mm.

The glue is applied to individual points in diameter d_k t_x, t_y or with a linear step t_k.

Mechanical tests are performed by static loading of the working bodies of the breaking machine with force R_t, R_n, which allow you to determine the critical values [σ], [τ] at the time of loss of contact between the layers.

We will consider that the determining factors influencing durability of connection, are diameter of drops of glue d_k, also step t_x, t_y to determine [σ], also d_k, t_k to determine [τ].

It is assumed that the strength of the joint is not affected by the thickness of the layers of pyro- and airgel, but these figures depend on the brand of adhesive used and the insulating material used. The order of the experiment

1) Prepare test samples, for each material, size 100x100 mm;

2) Apply glue points with a special needle;

3) Make combinations of sandwich elements without damaging the layer of heat-protective material;

4) After the glue dries (at least 24 hours), the samples are weighed. Weighing accuracy 0.001 mg.

5) Mechanical tests are performed in accordance with the experimental plan;

6) Statistical processing of results is performed.

The data of loading schemes are executed with points of glue with a diameter d_k, with a step t_k to determine the critical voltage $[\sigma]$, $[\tau]$ at the time of loss of contact between the layers.

Variable factors were: the diameter of the drops d_k, step t_k, Table.3.

After the rupture study, a series of results were obtained by changing the input parameters, d_k, t_{kx}, t_{ky} and the limiting force R_n. was obtained. The results of the analysis allowed to obtain a regression equation

$$R = 12.7625 - 3.6833 \cdot d_k - \\ -0.109444 \cdot t_{kx} - 0.213899 \cdot t_{ky} + \\ +0.0377778 \cdot d_k, t_{kx} + 0.108889 \cdot \\ \cdot d_k, t_{ky} - 0.003333 \cdot t_{ky}, t_{kx} \quad (12)$$

Analysis of the obtained equation proves that the maximum strength can be achieved by reducing the diameter of the drops of glue and reducing the step between the drops, based on design considerations.

Table 3 *- Matrix of factors*

№	Factor	The limits of change	
1	The diameter of the glue point, d_k mm.	1	2.5
2	Step point along the axis *Ox*, t_{kx} mm.	5	20
3	Step point along the axis *Oy*, t_{ky} mm.	5	20
$[\sigma] = \frac{4 \cdot R_n}{\sum_{i=1}^{n} \pi \cdot d_k^2}$ – *rupture voltage*, МПа $R_n = f(d_k, t_{kx}, t_{ky})$ – *efforts acting on contact*, Н			

CONCLUSION

It is established that there is a dependence of the strength of airgel attachment to the bearing shell of the thermoplane on the size of the adhesive point and the step of their application. It is shown that increasing the diameter of the adhesive contact surface causes a decrease in strength, which can be explained by the effect of dissolving the loose material under the action of adhesive solvents; instead, a more compact adhesive plate allows you to form a deep adhesive rod, without a significant change in the properties of the heat-insulating material (add strength indicators). The difference in properties along the x and y axes can be explained by the fact that the material is made with the formation in the latter of a small anisotropy of properties, which is more pronounced on thin materials and less on materials of considerable thickness.

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