FUNCTIONAL CAPABILITIES OF NEW GENERATION TRANSPORT AIRSHIPS GAS-AIR SYSTEM

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Abstract

Functional capabilities of a new type gas-air system (GAS) of transport airships are analyzed. Technical analysis and classification of aerostatic vehicles by type of their GAS are carried out. Structural decisions of rigid airships' GAS are offered; GAS main elements are described. Possibilities of phlegmatized hydrogen using as carrier gas and fuel are considered. The air – heat anti – icing system of airship body, providing year – round outdoor parking in all climate zones of the world, is developed. The system computational simulation under various environmental conditions is carried out; heating power, which is necessary for the effective work of big volume airship anti – icing system, is calculated. Research of increased pressure using possibility in the air ballast system is done.

Keywords. Aerostatics; rigid airship; gas – air system; anti-icing system; ballast system; computational simulation.

INTRODUCTION

In the last years many scientists of different countries make the same conclusion that use of airships can make a revolution in the technology of transportation. New generation's transport airships in comparison with heavier than air vehicles will have small material capacity, very high weight return and fuel efficiency, transport operations low cost. They will have higher safety and environmental friendliness level. One of the most important airships advantage in comparison with other vehicles type is no restrictions on the movement routes. They can vertical take-off and landing, fly on big distances, transport oversized and super heavy cargo «from door to door», demanding for it minimum expenses on infrastructure [1].

On stream airship looks like «living organism», in which there are difficult physical processes, controlling by GAS. GAS is the main airship system, providing not only creation of aerostatic lift force of aircraft but also functioning of many of its subsystems. From efficiency and reliable operation of such subsystems depend in many aspects flight-technical characteristics and aircraft safety in general. That's why developers of new generation airships must to pay special attention to GAS on design stage.

2. THE GAS - AIR SYSTEM FUNCTIONAL CAPABILITIES

The GAS of new generations' airships must have many-sided functional capabilities. Their general list is represented on figure 1 [2].

The GAS main tasks can be divided into traditional and innovative. To the innovative we have to add first of all the air – heat anti-icing system of rigid airship body and also phlegmatized hydrogen using as carrier gas and partially as a fuel. Airship body anti-icing system development will provide aerostatic vehicles year – round maintenance without hangar.

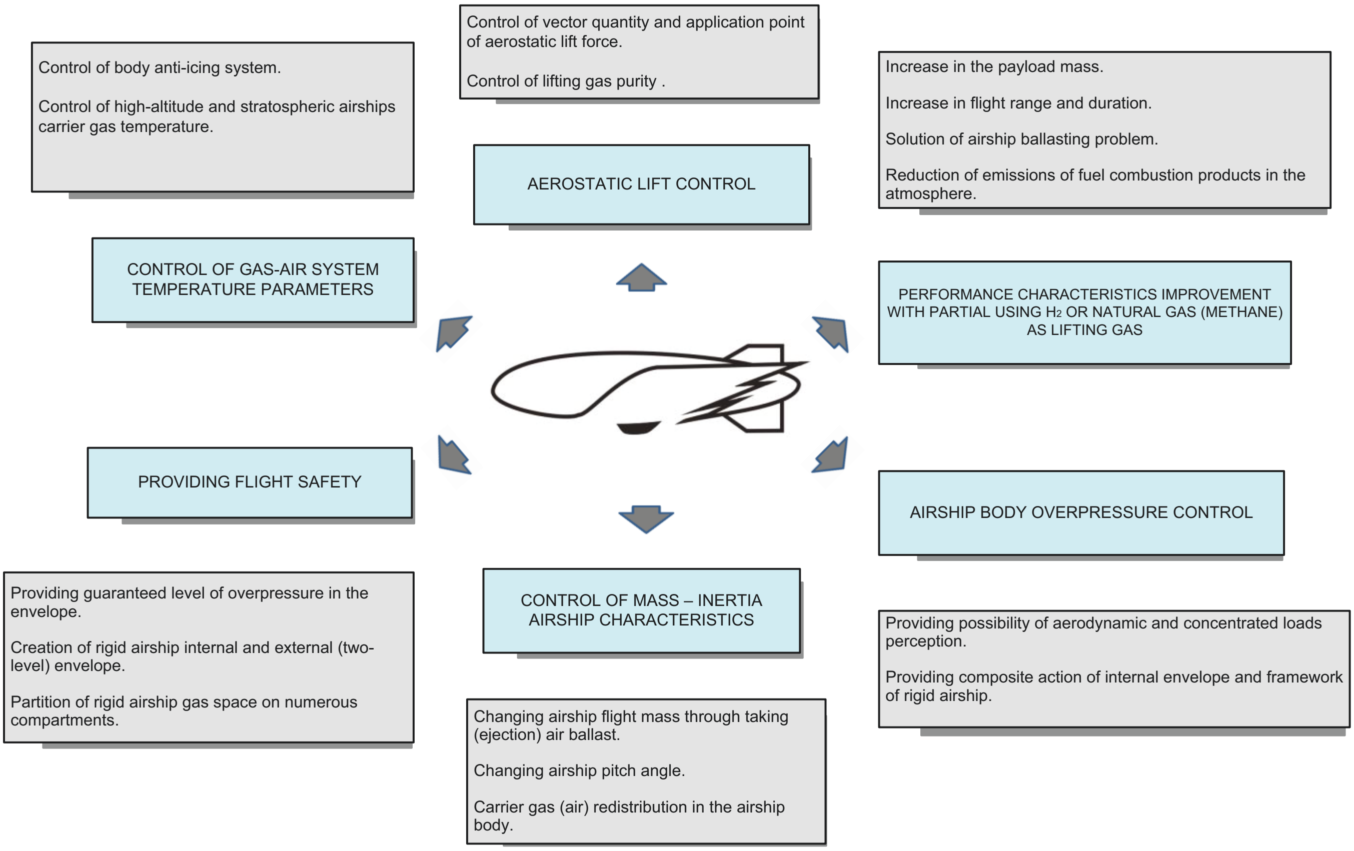


Figure 1. The airships gas – air system functional capabilities

The phlegmatized hydrogen using will help:

- increase aerostatic lift and airship commercial cargo;
- use fluid hydrogen as fuel for power plant and thus to pass partially or completely to absolutely environmentally friendly fuel;
- considerably reduce transport airship ballasting problems and completely delete such problems for stratospheric aerostatic platforms, functioning due to application of explosion engines as a basic propulsion system and working on hydrocarbon fuel.

3. CLASSIFICATION OF LIGHTER THAN AIR VEHICLES BY THEIR GAS-AIR SYSTEM TYPE

Analysis of existing or applied earlier types of GAS of lighter than air (LTA) vehicles was carried out. It allowed classify LTA vehicles GAS on different identification items:

1. Open and closed systems [3]. GAS open system have LTA vehicles, which GAS directly interacts with the atmosphere (hot air balloons, Zeppelin type airships), and closed system – LTA vehicles, having overpressure inside airship body (rigid, non-rigid, semi-rigid, etc.);
2. Systems with ballonets and without ballonets. As systems without ballonets we can consider hot air balloons, Zeppelin type airships, rigid airships, MAAT cruisers and feeders [9];
3. By the type of lifting gas: helium, phlegmatized hydrogen and warm air.

Different GAS type of LTA vehicles due to offered and described above classifications are schematically represented on figure 2. As H_1, H_2 and H_3 three different ascent flights of LTA vehicles are considered and H_3 – maximum flight height. The space, occupied by lifting gas, is marked with the gray color in all cases, except a case of hot air balloons, for which lifting force provide warm air. With white color the air space is marked.

The GAS type choice depends on aircraft type, its constructive and functional opportunities.

4. RIGID AIRSHIP GAS – AIR SYSTEM MAIN ELEMENTS

The new generation transport rigid airships GAS must have at least two fundamental differences from similar Zeppelin type system:

1) support overpressure in LTA body, that is to be the closed type system;
2) provide warming up, sufficient for ice and frost fusion, which can be located in a large number on the aircraft at the bad weather during parking, in the top part of external envelope.

Rigid airships of the first generation were designed in such way that they had open type GAS. Such approach excluded installation of high productivity air valves and significantly reduced load on cloth skin of airship body. But supercharge lack in the aircraft body resulted in need of generation of flat doubling panels with biaxial tension. It significantly increased assembly works labor input, increased a little airship body front resistance, but worsened an airship esthetics.

During the first generation transport airships development the anti-icing system question wasn't opened in general. For the first time serious scientific and practical researches on snow and ice removal from the LTA vehicles surface were carried out in the second half of the last century on the patrol airship ZPG-2W and TCOM company fastened aerostats [1]. Many mechanical and physical and chemical ways were approved in this period, for example:

- pressure pulsation in the envelope;
- low frequency stick shaker;
- polymeric and polyurethane covering;
- high-speed fan;
- scraper;
- electric heater;
- ethylene glycol and water warmed-up mix.

All these ways, except for the last, were ineffective. The warmed-up liquid using for snow and ice removal from airship body, having big height and huge washed surface, is very difficult and labour – consuming action, demanding special equipment existence. At the same time, it's known that in aviation thermal anti-icing systems are widely applied. They are divided into two groups: electro thermal and air-heat.

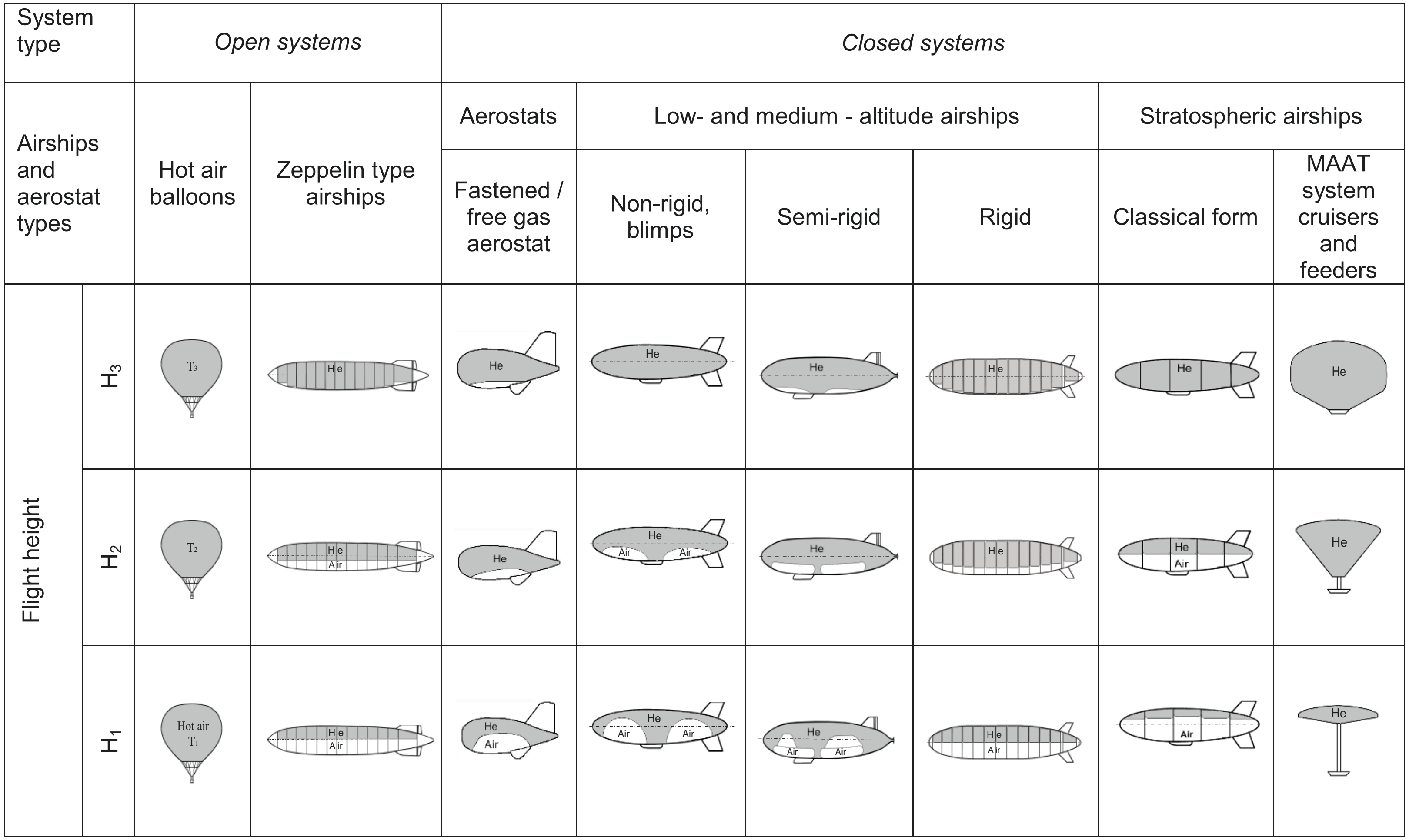


Figure 2. The aerostatic vehicles classification by their gas-air system type

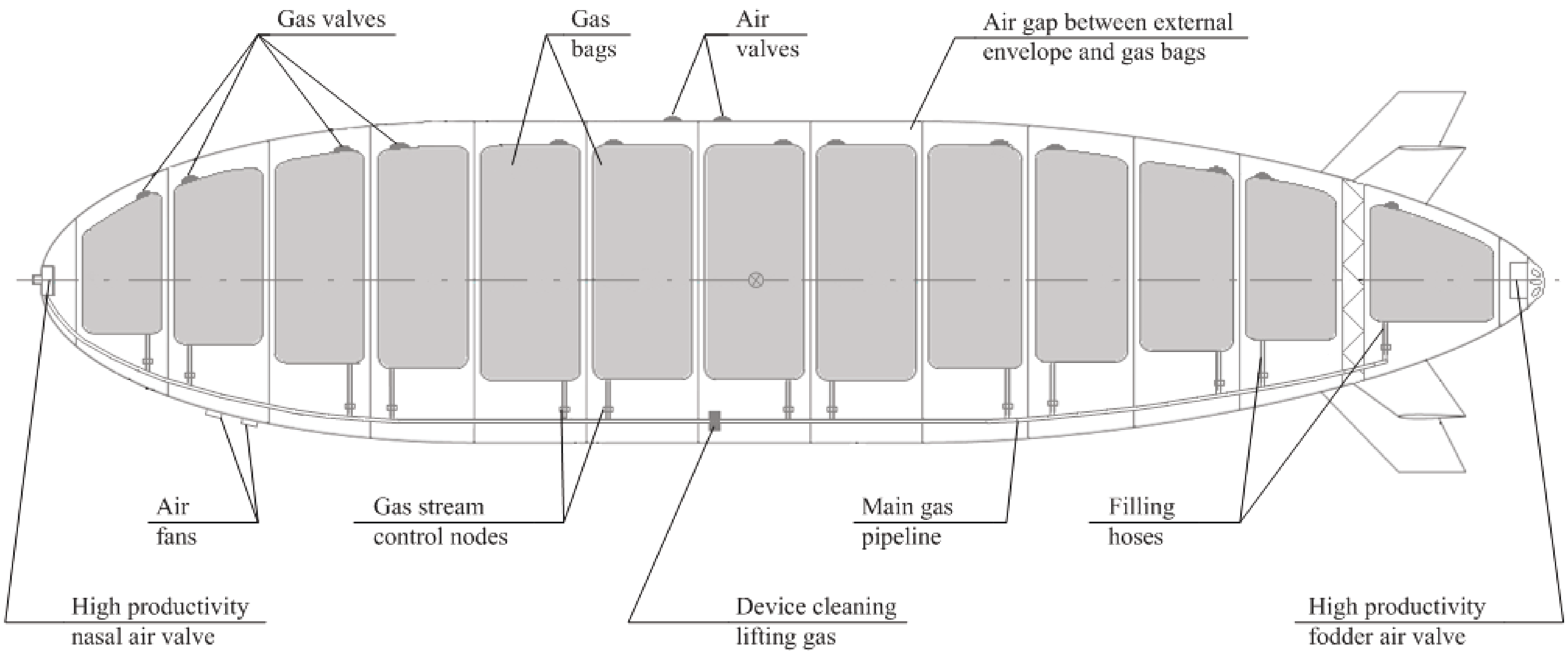


Figure 3.The rigid airship GAS schematic illustration

In relation to airships electro thermal systems can be used for protection from icing of engines, propellers, gas and air valves, gondola's glazing and probably empennage. The air-heat system, due to its simplicity and universality, can protect airship body from icing in the best way.

One of the possible variants of schematic design of modern rigid airship GAS (except for a case of body heat protection) is represented on figure 3. The schematic illustration of air-heat airship body protection will be described in the next section.

The main GAS elements are:
- gas bags;
- main pipeline;
- gas stream control nodes;
- gas and air valves;
- input and outflow air valves of the high productivity;
- air fans;
- device cleaning lifting gas.

The main pipeline is intended for gas bags filling with lifting gas, and also for lifting gas redistribution between gas sections.

The gas stream control nodes, depending on operating modes of spill valve (open / close) and fan thrust reverser (direct or opposite motion), form lifting gas movement in gas section or in the opposite direction. Also with mass flowmeter they keep its quantitative account.

The gas valves purpose – is prevention of gas bags destruction from excessive supercharge. They can be also used for letting out carrier gas in the atmosphere at gas bags dismantle.

The top air valves have three functions:
1) allow to ventilate air space in the airship body;
2) allow to let out lifting gas from gas bags in the case of emergency;
3) they are safety for the case of the outflow fodder air valve of high productivity failure.

High productivity nasal and fodder air valve provide aircraft ascent (descent) with the speed not less 15 m/s. Thus case filling body by the air at airship descent is carried out through nasal valve due to running air stream energy.

Air fans are intended for air blow to the airship body during its parking on the mooring mast. The air fans work allows to support supercharge in the aircraft body, sufficient for giving of an aerodynamic form to it. It can occur despite of variable intensity of sunlight and air temperature differences.

The desirable element of modern GAS is a device, located on a board LTA, cleaning carrier gas from impurity polluting it. Such device may have small productivity and weight under condition that it will work almost constantly, including flight time.

5. THE AIRSHIP BODY AIR – HEAT ANTI - ICING SYSTEM

The schematic illustration of one of the most preferable variants of rigid airship body air – heat anti-icing system is presented on figure 4.

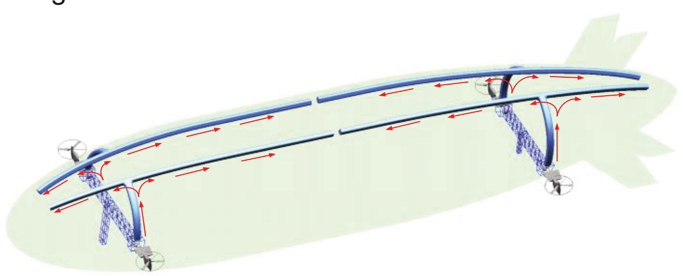
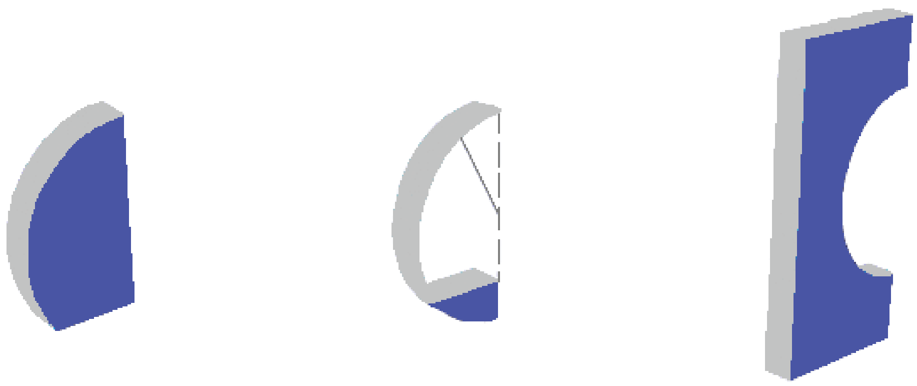


Figure 4. The schematic illustration of rigid airship body air – heat anti-icing system

It's included 4 heat exchangers and collectors system, on which the warm air goes to the air gap between top part of external envelope and gas bags. Heat exchangers consist of water cooling radiators of diesel engines and electric heaters, working from strong generators of mid-flight power plant.

The mid-flight power plant engines and heat exchangers generators get into the work only in the case of intensive snowfall or icing during outdoor airship parking. The anti-icing system design model geometry is represented on figure 5.

The computational simulation of heat exchange in the airship body and related with it area was carried out for airship with volume 26 thous. m^3 and 13 gas bags. The gap size between external covering and gas bags was 0, 2 m. The anti-icing system required heat power was calculated for different snowfall intensity at the air temperature variation from 0 to -10 ºC and wind speed from 0 to 30 m/s. Thus the temperature of airship body external wall was taken as more or equal 2 ºC.



a) b) c)

Figure 5. The anti-icing system design model (in an isometry):
a – gas bag; b – air gap between external envelope and gas bag; c – external area

Non-stationary calculation of the three-dimensional turbulent stream with using of computational fluid dynamic method (CFD) was carried out with FlowVision 2.5 software.

In the table there are required power calculated values for the effective work of air - heat anti-icing system of above mentioned volume transport airship. Total mechanical power of fourth engines, providing maximum cruiser speed 140 km/h for such volume airship, is approximately 1500 kW. It's easy to see that this power is enough for effectivework of anti-icing system at all wind modes at air temperature is more than – 5 ºC and ensuring airship body external wall (covering) temperature on the level of 2 ºC.

The heat using of water cooling system of internal combustion engines will allow improve essential calculated parameters of anti-icing system.

All above mentioned statements can be use for all transport airships of any volume, because required power of mid-flight power plant and required heat powerof anti-icing systemare in the same dependence from changing of airship linear size, namely in the square.

Table

Necessary heating power for anti-icing system effective work, kW (airship volume – 26 thous. m³, length – 104 m)

	Required heat power for snow melting - 120 kW						
1	Heat power at a set temperature of an external wall 2 ºC						
		Wind speed, m/s					
	Air temperature, ºC	0	10	15	20	25	30
	-10	539	1140	1530	1895	2242	2576
	-5	324	715	943	1156	1358	1553
	0	159	290	355	416	474	529
2	Heat power at a set temperature of an external wall 5 ºC						
		Wind speed, m/s					
	Air temperature, ºC	0	10	15	20	25	30
	-10	684	1395	1883	2339	2773	3189
	-5	449	970	1295	1600	1889	2166
	0	251	545	708	860	1004	1 143

6. THE GAS-AIR SYSTEM PLACE IN AIRSHIP BALLASTING

In relation to aeronautic equipment the ballast – is load for regulation of aerostatic vehicles lifting ability.

There are three ballast types:
- liquid;
- solid;
- fluid.

The air is used as fluid ballast. The air ballast is used surely at all airships type because during aircraft descent (ascent) the carrier gas volume decreases (increases). Therefore, the air volume and mass, which is located in ballonets of the non-rigid or semi-rigid airship or in the air space between external envelope and gas bags of rigid airship, have to change. In this cases, and also during changing the environment temperature and pressure, air input to airship (and output from it) is the ballast, changing airship flight mass and supporting required supercharge in the aircraft body [1]. Thus, the air ballast is airship weight and supercharge regulator in its body.

It's known some of the modern transport rigid airships projects – DRAGON'S DREAM – ML866 of Aeros (USA) company [4,5], ATLANT-30, ATLANT-100 of RosAeroSystems company (Russia) [6], where the compressed to several atmospheres air (in a combination to the compressed carrier gas) is considered as main and only one ballast. Such idea is very tempting, because its realization would allow solving all transport airships ballasting problems, including actions of taking from aircraft the payload on not prepared places. But, unfortunately, modern materials science conditions not allow materializing this idea without huge increase of the ballast system mass. Let's illustrate it with calculations.

Let's consider the non-rigid airship envelope of classical shape. It's an axisymmetric rotation body with wall thickness h, formed by two curvature radiuses: ρ_m – meridian and ρ_t – main, perpendicular to meridian arch. If to create the supercharge p in the envelope, then in it will be meridian (σ_m) and district (σ_t) tensions. The pressure, curvature radiuses and tensions are connected among themselves Laplace's equation [7]

$$\sigma_m / \rho_m + \sigma_t / \rho_t = p / h.$$

In the envelope front profile (cylindrical part) there are following tensions

$$\sigma_m = pR / 2h, \ \sigma_t = pR / h,$$

i.e. district tension is twice more than meridian.

For perception operating on the envelope resisting moments during the flight in the envelope supercharge p is created. It's known after first generation airships and modern airships exploitation that this pressure doesn't exceed 100 mm of a water column that is no more than 1% from atmospheric pressure. Increase in pressure in the envelope on 0, 01 from atmospheric has no practically impact on airship bearing properties (lift, air ballast weight), but involves need of aeronautic materials using with high mechanical properties and specific weight. Depending on cruiser flight speed, volume and aircraft body length and also strength fabric properties relative envelope weight ($\dot{m}_{env} = m_{env} / m_{takeoff}$) is from 10 till 25% [1]. If we want to use air as a main ballast in transport airship, then we have to make supercharge level in the envelope and ballonets to 0, 25 – 0, 4 atmospheres, that will cause the increase envelope weight in tens time. This is nonsense!

Such conclusion can be rechecked on the next example. Let's consider widespread steel gas balloon with volume of 40 liters, having weight 65 kg and calculated on pressure in 150 atmospheres, as ballast containers. The small geometrical sizes of container shouldn't confuse us, because due to Laplace's equation pressure, district (main) radius and thickness envelope are connected among themselves such way that from their variation ballast container weight, falling on 1 m^3 of pumped air, remains to a constant.

In the 40 liter balloon under pressure of 150 atmospheres it's possible to download 6 m^3 of air with weight 7, 35 kg. Thus on 1 kg of ballast will be 8, 8 kg of ballast system construction. It's possible significantly reduce ballast container weight if to make them not from steel, but from composite material on the basis of high-strength (6, 0 – 7, 0 hPa) aramide or coal fibers [8]. But in this case ballast system weight will exceed air ballast weight many times, too. I.e. some tons of ballast system weight are required on each ton of transported cargo. Instead of transporting cargo, airship will be mainly occupied with ballast system transportation.

7. CONCLUSIONS

1. GAS is the main airship system, providing not only aerostatic lift creation but also functioning of its many subsystems; their efficiency and reliable work in many aspects define performance characteristics and safety of the airship as a whole.
2. In aerostatic vehicles different types of GAS are used: open and closed systems; systems with ballonets and without them; GAS with using helium, phlegmatized hydrogen or warm air as lifting gas. The GAS type choice depends on aircraft type, its constructive and functional opportunities.
3. It's necessary to use closed GAS with small supercharge inside the body of the new generation transport rigid airships, unlike Zeppelin type airships. The use of overpressure will allow simplify and reduce considerably the price of vehicle general assembly processes, improve its aerodynamics and an esthetics.
4. Transport airships have big volumes; that's why their GAS must have high productivity. For it the nasal and fodder air valve of high productivity are

expedient to be used in the vehicle air system. Thus case filling by air at the airship descent should be made due to energy of a running air stream.

5. Transport airships must be all-weather, including their outdoor parking. That's why they must have air-heat anti-icing system of airship body. The numerical modeling of heat exchangein the airship body and related with it area was carried out for airship (volume 26 thous. m^3,13 gas bags) with using CFD of FlowVision 2.5 software. It showed that mid-flight power plant is enough for airship body anti-icing system effective work at the outdoor parking.

6. The phlegmatized hydrogen is a perspective carrier gas-air system gas of the new generation airships, which can be used also as an ecologically clean fuel. The fluid hydrogen using as fuel will allow solve partially or completely ballasting problem of air vehicles at long flights or on long distances flights.

7. The use of compressed to several atmospheres air in airship GAS as the main and the only one ballast is impossible at the modern level of materials science, because it leads to huge increase in ballast system mass.

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