DO NEW GENERATION AIRSHIPS CHANGE A PARADIGM IN TRANSPORT LOGISTICS?

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Abstract

Modern vehicles flight principles are considered. It's noted that aerostatic principle, which is based on using of Archimedean lift force is the most energetically economic. It's proved that for airships to float on air is energetically more economic than for sea vessels to float on water. Regularities of mass efficiency from linear sizes for lighter and heavier than air vehicles are described. This regularities show that unlike plans and helicopters, airships can be constructed with high weight return of practically any load capacity.

New methods of airships operations are offered:

- new methods of airships mooring, providing reduction of land team number to 1-2 persons and landing on small size platform, including high-rise buildings roofs in the center of the city;
- air – heat method of anti-icing system of airship body, providing year – round outdoor parking of lighter than air vehicles in any world climate zone

The structural-parametrical analysis of airships with different types of constructions and power plant in the high range of dimensions is carried out. On the basis of the analysis the conclusion is made: classical shape rigid transport airships of new generation with loading capacity of 20 – 200 tons will have small material capacity, very high weight return and fuel efficiency, transport operations low cost in comparison with heavier than air vehicles. Today mankind can build such vehicles. But in the short term we need to design airships with length up to 500 meters and loading capacity up to 1500 tons. Such air "super lorry" will be capable to carry out transport operations approximately in 10 times more economic, than planes, and in 3-4 times more economic, than motor transport. On them it will be possible to transport practically any loads on long distances with big profitability.

Vertical take-off and landing, big distances of flights without landing, environmental compatibility, perspective transport airships profitability in combination with usual safety and no restrictions on the movement routes open for airships big perspectives in the future logistics.

INTRODUCTION

The law, on which aerostatic principle of flight is based, was discovered by Archimedes in the III century B.C. However, despite its seeming simplicity, it took more than 1500 years for mankind to offer on the basis of this law a way for bodies to fly in the air and more than 500 years to put this idea in practice. The first steps in the history of air ocean conquest were made as late as in the XVIII century, when people began to open Nature's laws actively and widely use them in everyday life. Air vehicles progress is presented on figure 1.

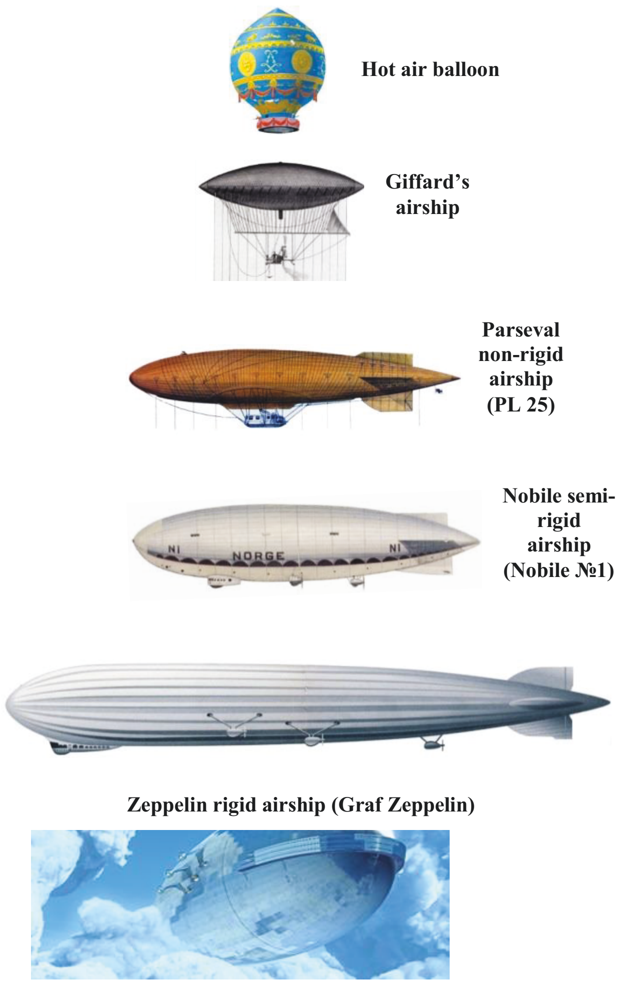


Figure 1. Air vehicles progress

Unfortunately today airships are not so popular and well-known to people as planes, helicopters or rockets. Their maximum heyday corresponds to the period, when lighter than air aircrafts was practically the only possible means of flight. The so-called «golden age» of airships building is the first third of the last century. In those days, airships reached a length of up to 250 meters and could carry up to 100 tons of payload, actively worked regular passenger aeronautic lines, including intercontinental. From Europe to North and South America you could fly only on airship, but already in those times on good level of comfort: in 1-2 bed cabins, walking on spacious decks, having dinner in the restaurant with live music. Daring technical decisions were realized on aircraft carrier – airships «Akron» and «Micon». Inside each of them (in hangar) settled down on 5 planes-fighters, which had the opportunity take-off from airship and landing on it when returning after performance of a fighting task.

Conventionally, all airships - from the beginning of their development until almost the end of the 20th century - should be referred to the airships of the 1st generation. From the standpoint of modern science and technology development their constructive-technological and operational characteristics are outdated. When developing a new generation airships is necessary to "adopt" such modern technical solutions that would fully reveal the enormous potential of aerostatic machines.

It's necessary to convince the public and, above all, politicians and technicians that initially airships failed because they were born before their time. The small required thrust led to the temptation of very fast building of giant airliners. However, in the first third of the last century, mankind has not yet accumulated enough experience in the design and operation of aircrafts. The creation of reliable super oversized and ultra-lightly loaded designs is a challenge even at the present level of science and technology development.

It's necessary to convince customers and investors that it's possible to create heavy lift airships with very high load ratio at relatively low labor intensity and the unit cost of production design. In turn, high efficiency design for weight payload in combination with low-cost indicators of airships, low specific power and fuel consumption will help achieve significantly lower unit (per ton × km) operating in comparison with heavier than air aircrafts.

Airships «Achilles' heel » is their flight (take-off, landing, hanging over a point) and ground operations (mooring, parking). Unfortunately, ground operation of the first generation airships was solved very poorly. During airship mooring to the mooring mast numerous landing team was required. Today it's necessary to develop fundamentally new methods of flight and ground operations of airships. Mooring should be carried out by means of 1-2 persons. It's necessary to provide opportunity of airship parking on the ground preferably in stationary (not feathered) state. Multipurpose, passenger and touristic airships must have opportunity of landing on small sizes platforms, including on the hotel roof in the center of the city, on special platforms of summer and winter (ski) resorts. Transport airships must deliver heavy and large payload «from door to door». Also it's necessary to provide opportunity of all-year outdoor parking in the open air in any world climate zone, for that they must have anti-icing systems.

2. AIRCRAFTS FLIGHT PRINCIPLES CLASSIFICATION

In modern technology 4 principles of aircraft's flight are used (fig. 2):

- aerostatic;
- aerodynamic;
- rocket-dynamic;
- ballistic.

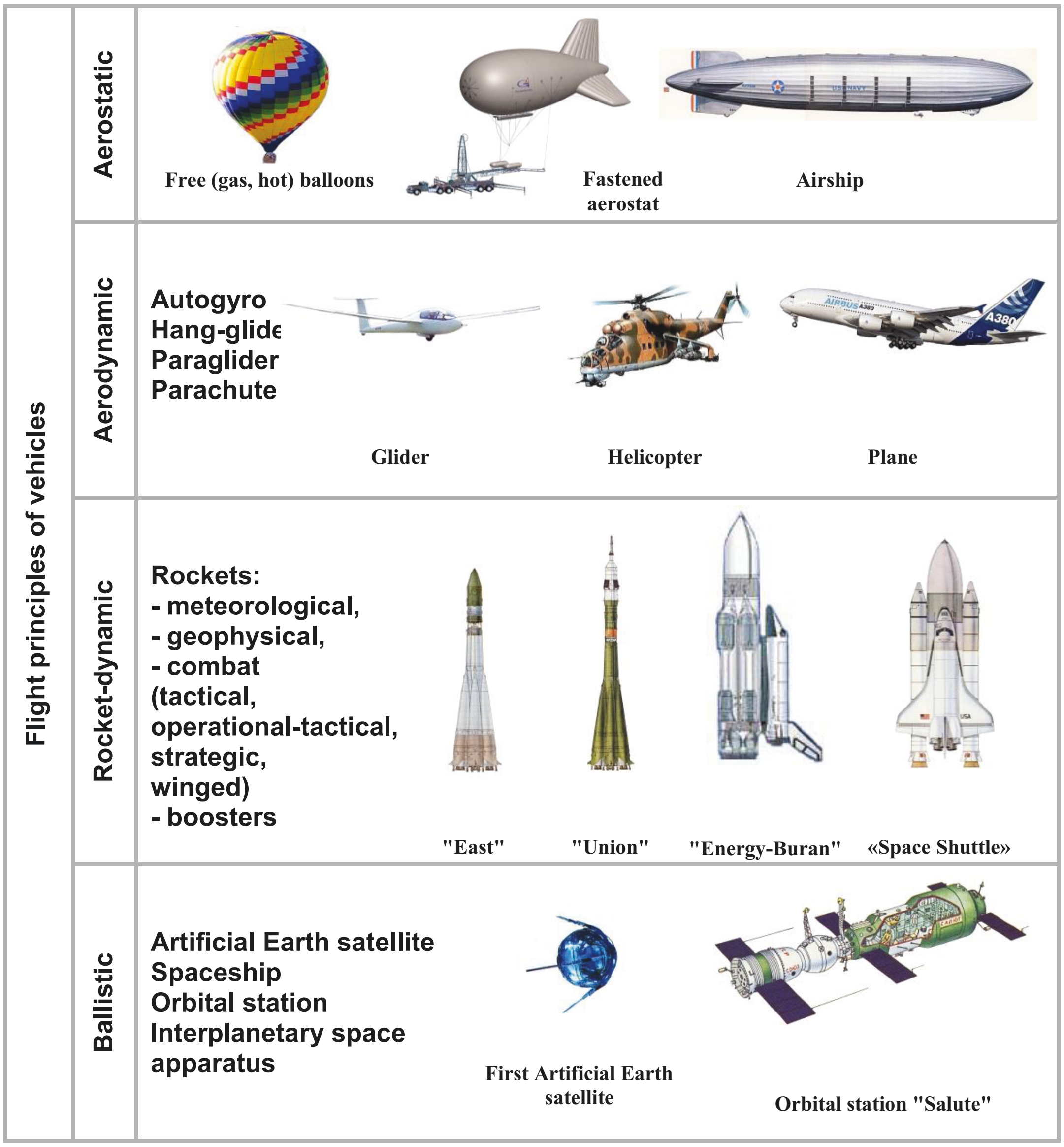


Figure 2. Aircrafts flight principles classification

Airships flights are mainly based on aerostatic way of lift force creation and partly – on aerodynamic. For the creation of aerostatic (Archimedean) lift force the energy is not needed, that let us to consider airships as the most energetically economic air vehicles.

In the work [1] on easy algebraic dependencies it's proved that for airships to float on air is energetically more economic than for sea vessels to float on water. At the same time it's well known that today sea transport is exactly the most popular in the world as a result of its high economic efficiency. This efficiency first of all is related with minimal energetic expenses per 1 ton on km of transported payload.

3. STRUCTURAL-PARAMETRIC ANALYSIS OF NEW GENERATION TRANSPORT AIRSHIPS

Made by the author structural – parametrical analysis of classical shape airships with different types of construction (non-rigid, semi-rigid, rigid) and power plant (diesel, reciprocating engine, axial-flow turbine engine) in the high range of dimensions (from 1 thous. till 5 million m^3) showed [2], that new generation rigid transport airships of big payload in comparison with aircrafts heavier than air will have small material capacity, very high weight return and fuel efficiency, transport operations low cost.

3.1. Airship geometric shape choice

One of the most principal questions in developing of new generation aerostatic vehicles is choice of well-streamlined airship shape. From the shape choice essentially depends drag, thrust, thrust-weight ratio, weight return, fuel efficiency and, finally, economic efficiency of transport aerostatic vehicle.

First researches on parameters assessment of various airships shapes refer to the beginning of XX century, i.e. to those period, when began to build and work the first aerodynamic laboratories. When selecting models for wind-tunnel test experimenters were previously studied the outlines of marine fish (mackerel, salmon, sword fish), dolphin, shark and whale (fig. 3), having rather high speed of movement [1]. It was found that the main parameter influencing the resistance of well-streamlined shape is its profile in meridian plane. As a result of numerous experimental studies as a basis was adopted «cigar» shape: with meridional contours, close to two conjugate semi-ellipse (with mid-section approximately 40-45% L) and circular cross section. This well-streamlined shape is considered classical.

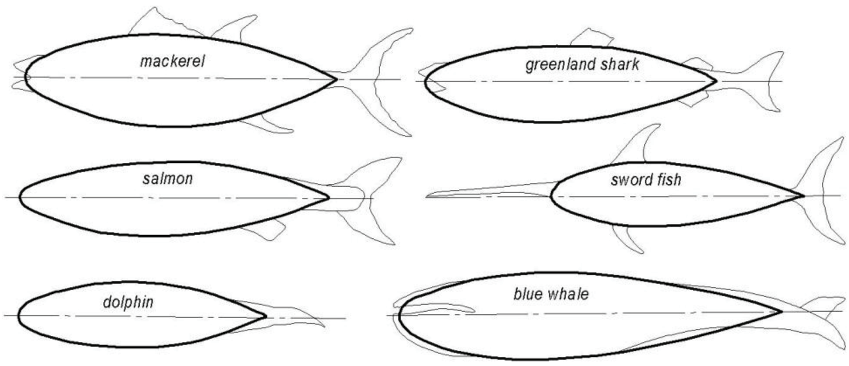
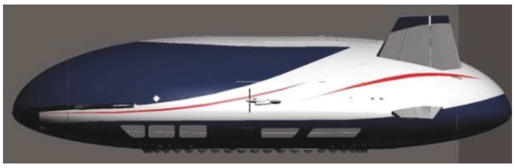


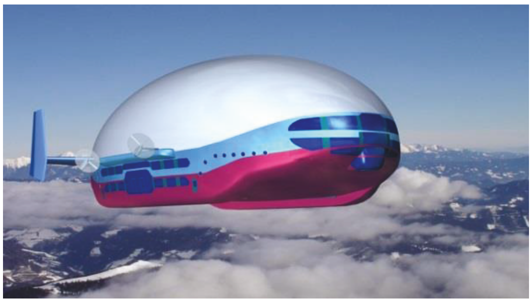
Figure 3. Profiles of "high-speed" fishes

Practically all previously constructed airships and most of modern airships projects have classic shape. However exceptions are known: disk, oblate spheroid, three-axial ellipsoid, sphere, etc. In USA, Russia and China hybrid vehicles with aerodynamically good load-carrying body developed or are in the design stage (fig. 4) [3-6]. Is it correct to change classical shape for airships?

Small size prototype R-791
(Lockheed Martin, TCOM, США)



Aeros ML-866 (Worldwide Aeros Corporation, USA)



Atlant-30 (RosAeroSystems, Russia)

Patrol airship LEMV
(NorthropGrumman, USA)

Figure 4. Projects of hybrid air vehicles with all-body and rotary carrier-pulling screws

In different periods of time many tests of aerostatic vehicles models of different configurations in wind tunnel were carried out by the author of this article in Moscow Aviation Institute (MAI) [1, 7]. Generalized analysis of this results and wind-tunnel tests of airships in Central Aerohydrodynamic Institute (TsAGI) [8] is presented in tables1-3 and on figures 5-7.

Experiments results showed (table 1), that lighter than air aircrafts having disk and three-axial ellipsoid shape don't have good functional qualities. In particular, the resistance of such shape isolated body in 1.7-3.5 times higher than the resistance of elongate rotation bodies. In this case, the volume coefficient of aerodynamic pitching moment m_{za}^{α} for disk and three-axial ellipsoid in 1,5 – 2,5 times higher, and arm for parry of pitching moment by empennage approximately in 1,5 times less than oblate spheroid has. This requires the formulation of such body empennage in 2 - 3 times larger in area, but leads to an additional increase of the resistance and the capacity of the empty airship weight.

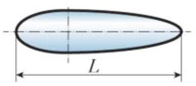
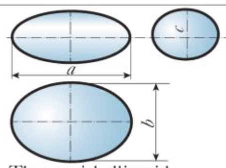
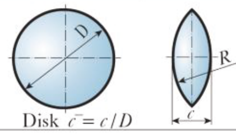
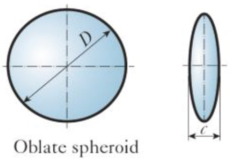
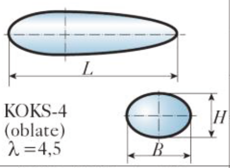
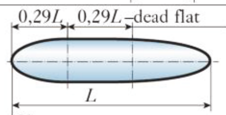
Let's now analyze the aerodynamic characteristics of empennage airships body, differing from each other degrees of elliptic cross-sections, and therefore bearing properties. In the work [8] a series of four models studied, every of this models had length *L* =1, 2 m. For a basis of a selected series was taken a model of rotation body of series «Koks № 4» with extension *L* / *D* = 4, 5, where *D* – the maximum diameter of body (fig. 5). Three other models had the body with elliptical cross-sections, which was equal to the area of the corresponding section of the rotation body. The ratio of the ellipse axes in the cross sections of these models (*B* / *H*) was respectively 1, 5; 2, 0; 2, 28 (fig. 6). The volume of each model is *U* = 0, 0424 m^3. Position of volume center from the model edge is x_0 **=** 0, 45, *L* = 0, 54 m.

On model with body in the form of rotation body five variants of tail empennage studied (fig. 5).

Results of the aerodynamic characteristics study of isolated bodies (table 2) indicate a significant effect of the degree of the cross sections ellipticity on its body bearing properties: c_y^{α} increase from 0,22 (*B/H=1,0)* to 0,44 (*B/H=1,5)*, 0,72 (*B/H=2,0)* and 0,96 (*B/H=2,28)*, i.e in 2-4 times. Herewith models lateral resistance (c_z^{β}) decreases only in 1, 5 times. An increase in the load-bearing properties of the body accompanied by a significant increase of drag force and pitching moment (in 1,5-2,0 times – at zero angle of attack and in 2,0-2,5 times for angles of attack 5-10°).

Table 1

Aerodynamic characteristics of body models of different shapes airships

№ п/п	Air vehicle model shape	Geometrical sizes, m	Volume, m³	c^{α}_{ya}	m^{α}_{za}	c_{xa0}	Note
1		$\lambda = 3{,}0$, $L = 0{,}90$	0,0402	0,22	1,11	0,0255	MAI
		$\lambda = 4{,}0$, $L = 1{,}007$	0,0317	0,21	1,37	0,0231	MAI
2		$\lambda = 6{,}0$, $L = 2{,}15$	0,1428	0,27	1,21	0,0220	TsAGI
3		$\lambda = 4{,}5$, $L = 1{,}78$		0,25	1,23	0,0206	
4	KOKS-4	$\lambda = 3{,}0$, $L = 1{,}36$		0,24	1,16	0,0235	
5	Parseval	$\lambda = 3{,}21$, $L = 1{,}35$	0,1248	0,3	1,11	0,0251	TsAGI
6	 Three-axial ellipsoid	$a{:}b{:}c$ = =3,33:2:1; 0,76 х 0,46 х 0,233 м	0,0429	1,09	0,75	0,0411	MAI
7		$\bar{c} = 0{,}29$, $D = 0{,}698$	0,0451	1,6	2,81	0,0350	TsAGI
8	Disk $\bar{c} = c/D$	$\bar{c} = 0{,}40$, $D = 0{,}635$	0,0416	0,79	2,14	0,0444	MAI
9		$\bar{c} = 0{,}341$, $D = 0{,}677$	0,055	1,67	2,18	0,0692	MAI
10	Oblate spheroid	$\bar{c} = 0{,}403$, $D = 0{,}642$	0,055	0,74	1,92	0,0829	
11		$L = 1{,}2$, $B/H = 1$	0,0424	0,22	0,95	0,028	TsAGI
12		$B/H = 1{,}5$		0,44	1,4		
13	KOKS-4 (oblate)	$B/H = 2{,}0$		0,72	1,94		
14	$\lambda = 4{,}5$	$B/H = 2{,}28$		0,96	2,06		
15	 «Sigar»	$\lambda = 5{,}0$, $L = 1{,}1$	0,0308	0,22	1,25	0,025	MAI

* MAI – Moscow Aviation Institute (National Research University), Russia
** TsAGI – Central Aerohydrodynamic Institute, Russia

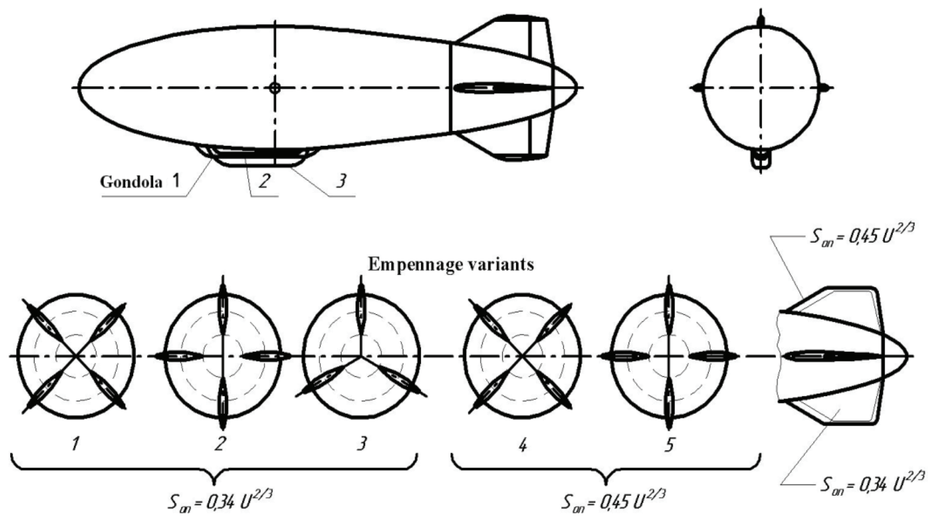


Figure 5. Airship model of «Koks №4»

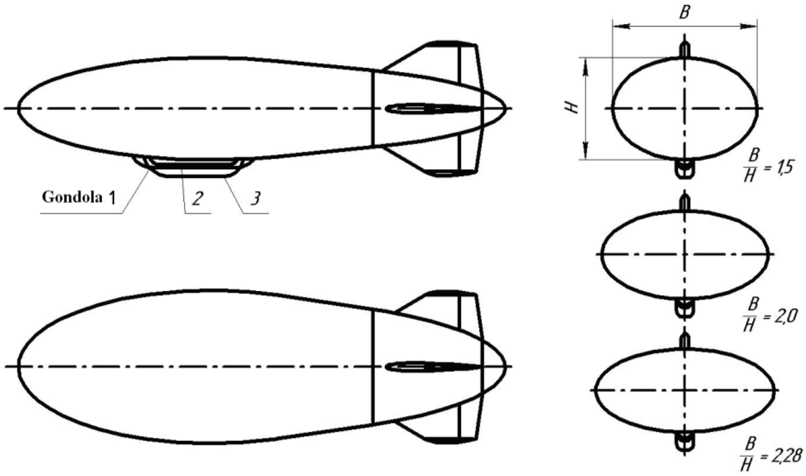


Figure 6. Airships models with elliptical body

From Table 2 it's easy to see that the installation of empennage on the rotation body gives the same effect as an increase in bearing properties of the model, and imparting body that ellipticity. Bearing properties of empennage models (for empennage variants 1-3) increase more than in 3 times (c_y^α increased from 0, 22 to 0, 70 - 0, 74). At the same time it's very important that coefficient of aerodynamic pitching moment significantly reduced.

Table 2

Influence of body cross sections ellipticity and empennage on its lift characteristics

B/H	Empennage variant	m_z^α	c_y^α	Increase from body $\Delta c_{y\,body}^\alpha$	Increase from empennage $\Delta c_{y\,emp}^\alpha$
1	-	0,95	0,22	-	-
	1	0,65	0,73	-	0,51
	2	0,76	0,70	-	0,48
	3	0,55	0,74	-	0,52
	4	0,43	0,95	-	0,73
	5	0,63	0,91	-	0,69
1,5	-	1,4	0,44	0,22	-
	2	1,12	1,05	0,22	0,61
2,0	-	1,94	0,72	0,5	-
	2	1,66	1,12	0,5	0,42
2,28	-	2,06	0,96	0,74	-
	2	1,80	1,30	0,74	0,56

Certainly empennage setting on body with elliptical cross-section gives additional increase for c_y^α (approximately by 0, 5). But similar or even much larger increase by c_y^α for classical shape airship modelcan be obtained by setting the wings on the body, which have in many times greater aerodynamic efficiency than airship lifting body.

Tests of classical shape airship model with a cylindrical insert (fig. 7, table 3) also showed that setting of 4 pylons of basic propulsion system with a total area of less than 10% of the empennage area (0,028$U^{2/3}$) will significantly ($\Delta c_{ya\,pil}^\alpha$= 0,216) increase bearing properties of blowing-off model.

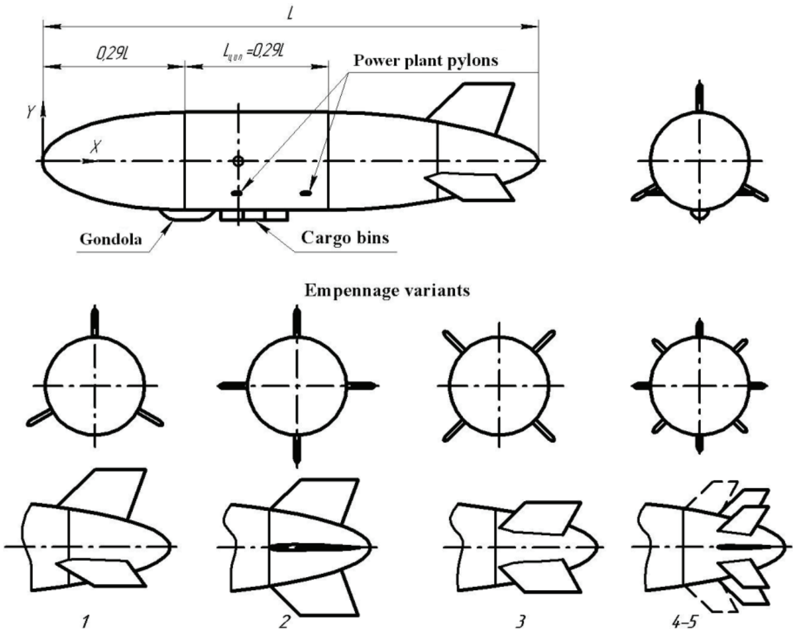


Figure 7. Empennage variants of classical shape airship blowing-off model

Table 3

Layout influence of airship model on its lift characteristics

Variant of model layout	c^{α}_{ya}	$\Delta c^{\alpha}_{ya\ pyl}$	$\Delta c^{\alpha}_{ya\ emp}$	$\Delta c^{\alpha}_{ya\ \Sigma}$
Isolated body	0.221	0.000	0.000	0.000
Body, pylons, gondola	0.437	0.216	0.000	0.216
Body, pylons, gondola, 3 planned empennage	0.937	0.216	0.500	0.716
Body, pylons, gondola, 8 planned empennage (front position)	0.990	0.216	0.552	0.768
Body, pylons, gondola, 8 planned empennage (back position)	0.792	0.216	0.355	0.571
Body, pylons, gondola, 4 planned empennage, scheme "+"	0.722	0.216	0.285	0.501
Body, pylons, gondola, 4 planned empennage, scheme "x"	0.846	0.216	0.409	0.625

Increasing the bearing properties of the airships classical shape will take place due to allowances of cruise speed. Having in 1,5-2,5 times less drag compared to aerostatic aircraft with the support body, such aircraft (with equal power of control system) will have at least 15% ($\sqrt[3]{1,5}$) higher cruise speed. Increased by 15% flight speed will allow in 1.31 times to increase airship aerodynamic lift and in 15% - transport productivity and economic efficiency of the airship.

Summarizing all-above mentioned, we can say: many wind-tunnel tests of airships models of various configurations have shown that visual appeal and futuristic of aerostatic aircrafts in the shape of disk, oblate spheroid, three-axial ellipsoid, an elongated body with an elliptical cross-sections are not supported by good functional properties. The analysis of the aerodynamic characteristics of airships models strongly supports the priority of the classical form.

3.2. Energy and fuel efficiency of perspective transport airships

Economically feasible range of cruise speeds: 120-170 km/h (liners speed cruise can be increased up to 180-200 km / h). Thrust-weight ratio – in the range from 1 to 5% (planes – 25-35%, helicopters – more than 100%).

Fuel efficiency – fuel consumption per unit of transport work (on 1 ton·km) – is one of the most important comprehensive evaluation criteria of transport aircrafts. Fuel efficiency level depends primarily on the specific fuel consumption of engines, weight and aerodynamic perfection of aircraft, its carrying capacity and cruise speed.

Despite the fact that airships, in comparison with helicopters, and especially planes, have low speed, they not only did not lose, but also greatly benefit from these vehicles in fuel efficiency rate (q_t). This is primarily due to the very low power per aerostatic aircraft and, in part, high-impact weight to payload. Airships fuel efficiency depends on a number of design parameters: system control type, propulsion characteristics, weight and aerodynamic perfection of aircraft, etc. But the main factors, significantly effect on the rate q_t, - flight speed and especially airship volume (many times), that well correlated with dependence thrust-weight ratio from volume.

Conventionally, there are three types of transport airships volumes (take-off weight), which are characterized by significantly different levels of fuel efficiency. The first type – airships of small and medium volume (to 20-30 thous. m^3), which have rate of fuel efficiency is much better, than helicopters, and comparable to rate q_t for planes. The second type (from 20-30 to 200-300 thous. m^3) – airships, having specific fuel consumption per ton-kilometer in 2-5 times less in comparison with transport planes and in 10-15 times and more – in comparison with helicopters. And finally, the third type (from 200-300 thous. m^3 to several million m^3) – airships with extra high load capacity. Their specific fuel consumption is only 10-40 g/ton·km. It significantly less similar averaged rate for road transport and only a little more in comparison with the most efficient modes of transport - rail and sea.

These arguments clearly indicate the feasibility of transport airships development of high and extra high load capacity.

3.3. Mass efficiency of transport airships of high and extra high load capacity

Complex indicators of transport efficiency, giving an indication of airship technical perfection, are weighted returns indicators: full load ratio (m_{fl} / m_{toff}), load ratio on the commercial load (m_{com} / m_{toff}) and load ratio of an unladen airship on the commercial load (m_{com} / m_{emp}). The last indicator is the most important. According to this criterion estimate how many units of the payload mass is capable of carrying the unit of mass construction. For the most planes and helicopters this rate is not more than 0, 5. For certain types of aircrafts (B-747, C-5A, Mi-26) it's 0, 65 – 0, 72. And as an outstanding achievement should be considered the design load ratio on payload of An-124 («Ruslan») plane, it's equal to 0, 86. Analysis of mass perfection results of new generation rigid airships shows, that 1 kg of lighter than air aircraft design is capable of carrying up to 2 - 2,5 kg of commercial load, i.e. in 3-6 times more, than modern aircrafts heavier than air (table 4). By the way, first generation rigid airships had weight impact on payload and weight impact of airship design on commercial load is comparable to the same indicators of modern planes and helicopters.

It should be noted that the airships with a high load ratio can be constructed of almost any capacity. While plans and helicopters have severe restrictions, because the relationship between the weight and the lifting force of the aircraft when changing their linear dimensions are subject to the following laws: «cube-square» - for heavier than air aircrafts and «cube-cube» (adjusted for control system) – for lighter than air aircrafts. Therefore, when we found in one of the works of the great Russian scientist K.E. Tsiolkovsky [9] outlines of the airship project with diameter of about 300 and a length of 2000 meters, intended for the 8000 passengers' transportation, we can't say that it's impossible. At least because it is not contrary to the laws of physics and mechanics.

Table 4

Weight return of planes, helicopters and rigid airships

Aircraft type	m_{toff}, tons	m_{emp}, tons	m_{fl}, tons	m_{com}, tons	$\frac{m_{fl}}{m_{toff}}$	$\frac{m_{com}}{m_{toff}}$	$\frac{m_{com}}{m_{emp}}$	Flight range, km
Planes								
An-124	405	175	230	150	0,568	0,37	0,86	4500
Il-76	157	98	59	40	0,375	0,25	0,41	5000
Il-96-300	216	117	99	40	0,458	0,19	0,34	7000
B-747	322	157	165	113,4	0,512	0,35	0,72	3200
C-5A	323	144,5	178,5	99,8	0,553	0,31	0,69	5600
A-380	560	276,8	283,2	90,8	0,506	0,16	0,33	16000
Helicopters								
Mi-26	56	28,2	27,8	18,38	0,496	0,33	0,65	200 – 700km
Mi-8	12,0	7,2	4,8	4,0	0,40	0,33	0,56	
S-65	15,2	9,5	5,7	4,5	0,375	0,29	0,47	
V-114	14,97	8,11	6,86	5,2	0,458	0,35	0,64	
First generation airships								
LZ-59 (LZ104)	74,0	26,6	47,4	31	0,64	0,42	1,17	calcula-ted on 5000 km
LZ-126	75,6	39	36,6	22	0,464	0,29	0,56	
LZ-127	118	62,1	55,9	33	0,474	0,28	0,53	
LZ-129	207,8	118,8	89	60	0,428	0,29	0,51	
ZRS-5	182,8	109,9	72,87	48	0,40	0,26	0,44	
R-100	150	105,7	44,3	29	0,295	0,19	0,27	
R-101	161	119,7	41,3	28	0,257	0,17	0,23	
New generation airships								
					0,60-0,74	0,50-0,67	1,7-2,5	5000

3.4. Transport operations economic efficiency

The giant airships with length of about 1000 m and lifting capacity of 10 thous. tons could have the economy, comparable with the most cost-effective today water transport. If this dimension of airships and will be implemented, it is likely, in the long run. Today humanity can build airships with lifting capacity of 20-200 tons. To design airships with length up to 500 meters and a capacity of up to 1500 tons (this are 70-80 containers of 20 tons or a train of 25 wagons of 60 tons) could begin in five years or ten. Such air “super lorry” will be capable to carry out transport operations approximately in 10 times more economic, than planes, and in 3-4 times more economic, than motor transport. On them it will be possible to transport practically any loads on long distances with big profitability.

4. AIRSHIPS ENVIRONMENTAL COMPATIBILITY AND SAFETY. NO RESTRICTIONS ON THE MOVEMENT ROUTES

One of the most important advantages of airships in comparison with other vehicles is that they have no restriction 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.

Airships also have high

environmental friendliness level. They are characterized by:

- low emission of the hydrocarbon fuel combustion into the atmosphere;
- low noise level;
- completely insignificant level of anthropogenic impact of the necessary infrastructure on the surrounding nature.

It should also be noted the possibility of widespread using of absolutely clean energy sources such as hydrogen and solar energy for power plant of the future airships, because:

a) airships characterized by a combination of low required power availability with the presence of a large washed surface, on considerable part of which can be placed solar panels;

b) airships have sufficient volume to contain not only liquid but also hydrogen gas, which is extremely important.

Another important advantage of airships, at least in comparison with planes and helicopters, is comfort. Flight on the passenger, and especially high-bay cruise airship, equipped with cabins, promenade decks, solariums, cinemas, which is practically not subject to "buffeting" and takes place at low altitude, in non-aggressive environment (air pressure and temperature– near-earth) – is not only the flight, it's exciting journey.

The main airship advantage is that they can "float on air". Thus airships have a positive metacentric height, which ensures the static stability at low speeds and in the hover mode, and their aerostatic lift force is not dependent on the speed of flight, and thus of the propulsion system. These two factors determine the main contribution to what should be called natural airships safety. Even the failure of all engines and flight control systems are not disastrous for the airship!

5. NEED OF NEW METHODS DEVELOPMENT OF AIRSHIPS GROUND OPERATION

5.1.New methods of airships mooring to the mooring mast

The need for a large ground crew during airships take-off and landing accompanied this type of aircraft, ranging from the earliest days of their operation. In the case of start-up of large number of rigid airships special team reached 100-500 people. The reason for such a large ground crew is a combination of a large inertial mass of the aircraft and its huge surface area. This makes it difficult to maneuver the airship in near-earth space and on the ground when it is exposed to lateral wind gusts. In this case, the wind loads on the aircraft body will increase manifold.

The fact that the airship, perfectly controlled in flight, is unacceptably low handling on the ground during the mooring. And this is detrimental to the development of aeronautical engineering. And if using power plants with variable thrust vectoring just managed to solve the problem of vertical handling, the modern methods of controlling the airship in the horizontal plane is currently only partially designed and being tested. The search for new technical solutions is going on. They can't be simple and straightforward. Problem cannot be solved directly, as due to energy constraints is impossible to provide required aircraft lateral movement (opposition to wind): when moving sideways airship resistance increase in 25-40 times. To airship unaided resist lateral wind of 15-17 m/s is required thrust-weight ratio in 6-10 more than required thrust-weight ratio for cruising with speed of 110-125 km/h (30-35 m/s). It's clear that follow the path of a major increase capacity of power plants is not economically feasible. It makes more sense to improve the mechanisms, both ground and the aircraft that have a minimum number of the ground crew members would guarantee airships mooring to mooring mast or other anchoring devices.

Analysis of papers on the mechanized mooring airships, demonstrates that in this area there have been positive developments. A number of mechanized masts are developed. They are combined with the action of the main propulsion with variable vector or thrust reverser and allow the operation of the airship mooring using of a small ground crew. Zeppelin's company (Germany) fully mechanized mooring of airship NT-07 [10]. Moreover, is provided mooring towards the nose of the airship body, and towards the landing gear. Ground crew reduced to 3 people, allowing up to 30% reduction in operating costs. DERA's company

(England) built a mobile hydro-mast that has side bars and high-speed winch. Thanks to them, it can safely carry out the clutch with the airship, move with the aircraft on the airfield, to keep the airship at a wind speed of 40 m / s.

Aeronautical enterprise «Aerostatica» (Russia) lays in the design of their airships and associated ground equipment such technical decisions, which would allow carry out airship mooring to high (low) mooring mast and anchor device with using only of 1-2 persons.

In order to ensure autonomous relocation of the aircraft, including long-distance with water obstacles, mooring masts should be designed so that they can be transported on the airship. To do this, they should be made foldable, quickly assembled and have a light weight.

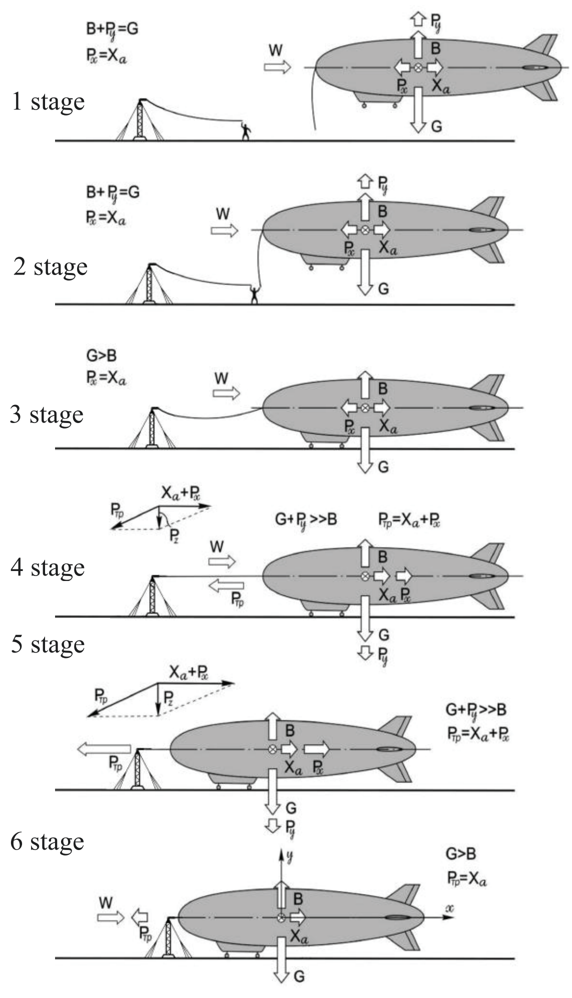


Figure 8. The operations sequence of mechanized mooring to high (low) mooring mast

High mooring mast is used for hold the nasal part of airship and parking it in the ground at a wind speed up to 40 m/s (in the feathered position) and also routine maintenance at a wind speed of 15-17 m / s (in static position). In the case of abnormal weather forecasting (tsunami, tornado etc.), when speed can be 50-60 m/s and more, airship must leave dangerous zone.

Low mooring mast can be made in two variants: mobile and stationary. Mobile mooring mast set on automobile or tractor and is applied for:

- airship output (input) from hangar and move it to the airfield;
- airship maintenance on ground at a wind speed of 12-15 m / s.

The operations sequence of mechanized mooring to high (low) mooring mast and acting on airship and mooring cable forces are presented on figure 8.

Such mooring method means existence on the airship (besides mooring mast) additional winch with special connecting lock on the end of the cable.

Anchoring the airship via winch with follow-up airship feathering relative to the anchor - fundamentally new and promising mooring method. It allows mobile loading and unloading of passengers and cargo from the small size platforms, including roofs of high buildings in the center of the city. Realization of such idea is not easy technical decision. Only carrying out of extensive researches and calculations, including wind-tunnel test of airship model with the screen effect and bench tests (fig. 9) have identified several new technical decisions.

Figure 9. Stand for testing of new technical variants on the airships ground operation

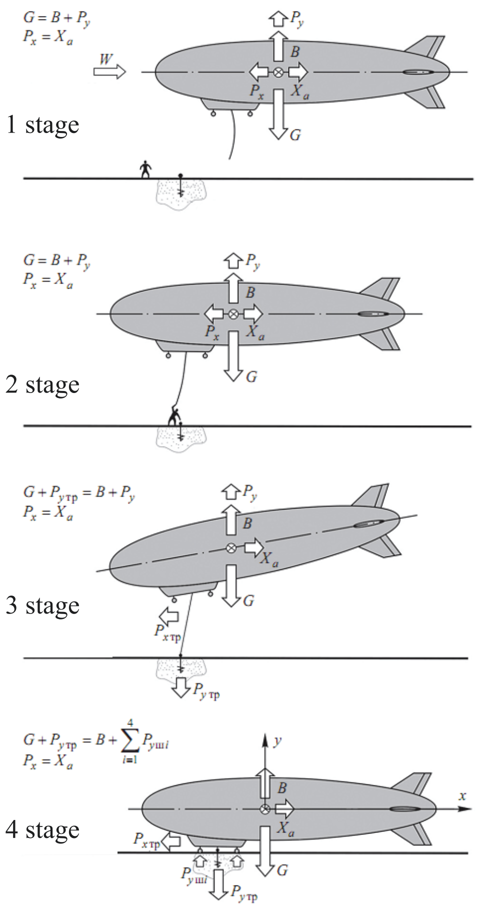


Figure 10. The operations sequence of mechanized airship mooring to anchor device

Their combination provided the desired result.

Design obligatory elements of airship, capable to be moored to anchor, are:
- auxiliary system control, providing along with mid-flight system control, airship exact hanging «under point»;
- 3-4 self-orientating landing gear;
- winch under nacelle.

The stages of airship mooring to anchor device are shown on figure 10.

5.2. Airship body protection from icing and snow

Today in relation to airships anti-icing systems of air propellers, nacelle's glazing, gas and air valves, and main pilot-static tube are developed and successfully function. Primary they are electro thermal anti-icing systems. Airships bodies (envelopes) have big surface and can be destroyed from intensive snowfall (more than 20 kg/m^2 in 10 hours) during airship parking on the ground under the open sky. That's why it's necessary to develop for them anti-icing system. Such tries were made in the past. Different mechanical and physical – chemical ways of snow and ice removal from airships and fastened aerostats were approved: 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 [1]. As practice showed all these ways were labour – consuming and ineffective. At the same time it's known that in aviation in most cases thermal anti-icing systems are used. Air – heat anti-icing systems of constant action – are the most popular and simple systems.

Ice and snow melting over a large area, especially in severe icing conditions and very heavy snowfall requires higher energy costs.

But as the calculation of three-dimensional non-stationary air heat flow in the rigid airship body (with using of FlowVision 2.5 software) shown thermal energy is carried away by the wind flow will be several times more. In order to minimize these losses, warm air from the heat exchanger must be delivered on a special sleeve in the area of snow accumulation. One of the possible variants of the schematic illustration of rigid airship body air-heat anti-icing system is presented on figure 11. Realization of such system provides obligatory existence of air gap between external envelope and gas bags.

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.Airship body external wall temperature was ≥ 2 ºC. As calculations showed, mid-flight power plant, intended for performance of cruiser flight, is enough for intensive work of anti-icing system during its parking under the open sky. However such airborne system will have considerable weight and difficult transmission. It's better to use special ground thermal installation, temporarily docked to the airship.

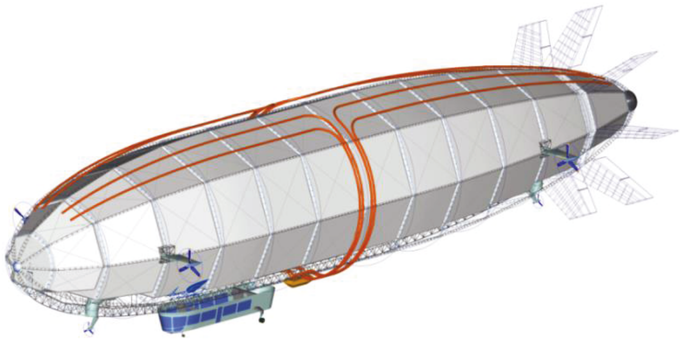


Figure 11. Variant of the schematic illustration of rigid airship body anti-icing system

6. CONCLUSION

Vertical take-off and landing, big distances of flights without landing, environmental compatibility, perspective transport airships profitability in combination with usual safety and no restrictions on the movement routes (for other transport vehicles its airfields, roads, railways, rivers, seas and oceans) open for airships big perspectives in the future logistics. There are many reasons to believe that in the 21 century can be revival of aeronautic vehicles as one of the transport type of the future. After all there was an aeronautics mass sport in 200 years after brother's Montgolfier invention. Soon we will see mass airships return to the sky.

ACKNOWLEDGEMENTS

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REFERENCES

1. Kirilin A.N. Airships. – Moscow: Publishing house MAI-PRINT, 2013. – 416 p.: illustrated, ISBN 978-5-7035-2314-8.
2. Kirilin A.N. Analysis of technical and economical criteria of advanced transport airships. Proceedings of the 4th International Airship Conference, 17 p., 2002, ISBN 0-9528578-3-9.
3. Talesnikov M. The latest development of Hybrid Airship Technology. Proceedings of the 9th International Airship Conference, Ashford, 2012, ISBN 0-9528578-8-x.
4. Paul A. Adams. Aeroscraft – An Industry Game Changer? AIRSHIP, The Journal of the Airship Association, №178, December 2012. – P. 20 – 25, ISBN 1353-1891.
5. LEMV first flight. Airship, Journal of the Airship association, September 2012, pp.5-6, ISBN 1353-1891.
6. Tompson K. The heavenly ship of dream. – The popular mechanics, 2014 May, № 5 (139).
7. Kirilin A.N., Egorov A.B. Aerodynamic characteristics of different shape airships models – Thematic collection of scientific works of MAI, 1992. - P. 48-53.
8. Zasolov R.A. Aerodynamic characteristics of airships models. – M. : Proceedings of TsAGI, volume 2268, 1985. – 22 p.
9. Tsiolkovsky K.E. Collected works. – M. : Publishing house AN USSR, 1959. – T.3. 316 p.
10. Zeppelin NT Description and Landing Techniques. – Airship № 108, June 1995. – P. 11-20.