THE EFFECTIVENESS OF THE NEW GENERATION AIRSHIP'S TAIL-WING SCHEMES AND ITS EFFECT ON THE AERODYNAMIC CHARACTERISTICS OF THE AIRSHIP

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Abstract

When the airship moves in the air, the tail-wings play a very important role in controlling and maintaining stability. The choice of the tail-wing layout determines the design, manufacture, construction and aerodynamic shape of each type of airship. On the tail-wings extra wings, brake wings are also put to help the flight process of safety. Therefore, the purpose of this paper is to study the effectiveness of the tail-wing layouts. The authors used the numerical method to study the aerodynamic characteristics of airships with different tail-wing layouts. The results obtained show the effectiveness of each type of tail-wing layout in ranges of angle of attack. This result can also be used for the calculation and design of the airship.

Keywords: *Airship; aerodynamic characteristics; tail-wing; numerical method.*

1. Introduction

The tail-wings on the airship greatly affect the aerodynamic characteristics of the whole airship. Study of this effect has previously been available but is limited to cases of small angle of attack ($\alpha \leq 20°$) and with a traditional "+" diagram [1, 2, 3, 4]. In modern airships today, most airships have an elongation of λ = 4-5 to minimize drag and change the tail-wing layout to optimize control and use the effect of the tail-wing on the aerodynamic characteristics of the airships. The purpose of this study is to use ANSYS Fluent to determine the aerodynamic characteristics of a tail-wing airship, then compare with the results obtained by experiments in aerodynamic tube of the Russian Federation National Aerodynamic Institute (SAGI) to verify the accuracy of the method. From there, using this method to calculate the effects of the tail-wing on the aerodynamic characteristics of the airship, to make conclusions about the effects of the tail-wing as well as to study the effects of other components on forces and moment coefficients of airships.

2. Problem

Study the aerodynamic characteristics of the airship using different tail-wing diagrams with varying angle of attack range 0-80°. Calculation of this effect is

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conducted for the airship which tail-wings installed according to the "X" diagram (diagram 1), "+" diagram (diagram 2), and "reverse Y" diagram (diagram 3). The tail-wing is fixed and has a symmetrical profile of the form NACA 0008, shown in Fig. 1:

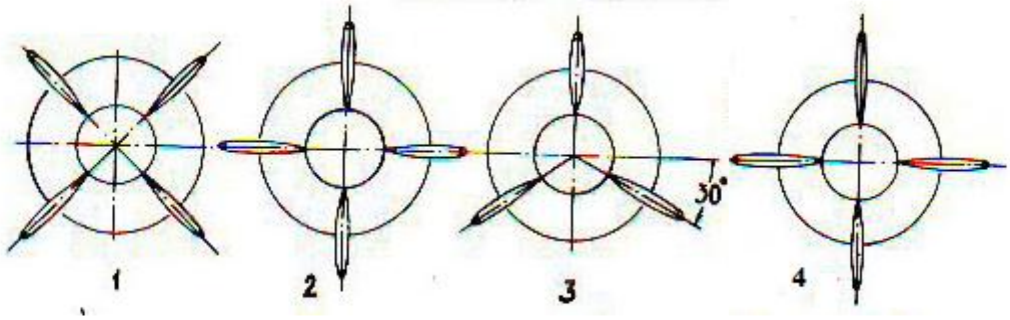


Fig. 1. Diagrams of a tail-wings on an airship.

In addition, we also consider another case as diagram 4: the tail-wing has a "+" diagram, but the area of the tail is larger to consider the effect of the area of the tail on the aerodynamic characteristics of the airship. The equation for the airship body contour at the longitudinal section (in the coordinate system with the origin coinciding with the top of the airship body) has the form [5]:

$$y = 0.972D[(x/L)(1 - x/L)(1.5 - x/L)]^{1/2}$$

where L is the length of the airship body (L = 1 m); D is the dimensions of the cross-section of the airship in the corresponding coordinate axis (with the Ox axis is $2B$, with the axis Oy is $2H$). The body elongation $\lambda = L/D = 4.5$. The airship is treated as an absolute solid and does not take into account the effect of reinforcement bars at the nose.

The problem is solved numerically, using program ANSYS 15 (lisence 00632255). The velocity of the airship V = 50 m/s corresponds to Reynold Re = $4 \cdot 10^6$, the angle of attack changes in the range α = 0...80°, β = 0. The airship moves steadily. The airship has a round cross-section of the body (B/H = 1.0), without engine and compartments. A diagram of the airship is shown in Fig. 2.

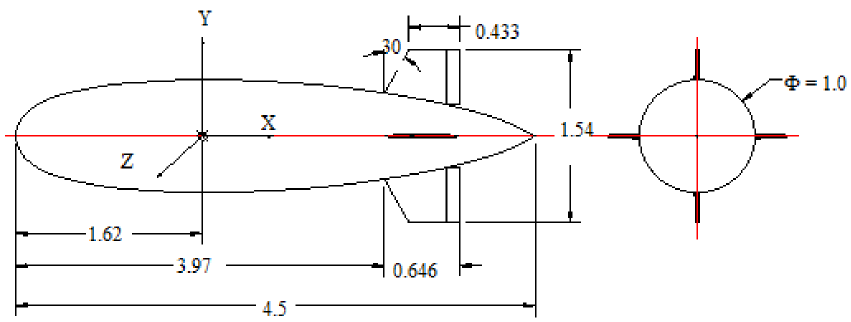


Fig. 2. The airship with a "+" diagram of tail-wings.

The volume of each calculated model is W = 0.0424 m^3, the length of the airship body L = 1.0 m, the position of the center of mass from the nose is $x_0 = 0.45L$ = 0.45 m. The total area of tail-wings in diagrams 1, 2, 3 is equal to $0.34W^{2/3}$. Because in diagrams 1 and 2, the tail has 4 wings, the area of each tail-wing in diagram "inverted Y" (diagram 3) will be 33% of the total area of tail-wings in diagram 1 and 2. The area of the tail-wing in diagram 4 is $0.45W^{2/3}$.

3. The system of aerodynamic equations

To determine the parameters of the air flow, it is necessary to solve the system of equations describing the movement of the air flow around the airship. The equations include: motion equation, continuity equation, equation for scalar quantities, equation of state [6].

After calculating with many different turbulence models and comparing with experimental results in the aerodynamic tube, SAGI has found a suitable model to calculate for this problem is the «k - ε -standard» [7]. For the airship we have the following formulas to calculate the coefficient of aerodynamic forces and moments as follows [8]:

$$\begin{cases} C_x = \dfrac{R_x}{\frac{1}{2}\rho_\infty v_\infty^2 W^{\frac{2}{3}}}, & m_x = \dfrac{M_x}{\frac{1}{2}\rho_\infty v_\infty^2 W} \\ C_y = \dfrac{R_y}{\frac{1}{2}\rho_\infty v_\infty^2 W^{\frac{2}{3}}}, & m_y = \dfrac{M_y}{\frac{1}{2}\rho_\infty v_\infty^2 W} \\ C_z = \dfrac{R_z}{\frac{1}{2}\rho_\infty v_\infty^2 W^{\frac{2}{3}}}, & m_z = \dfrac{M_z}{\frac{1}{2}\rho_\infty v_\infty^2 W} \end{cases}$$

where W is the volume of the airship body, ρ_∞, v_∞ are the density and velocity of the air flow, R_x is the axial force, R_y is the normal force, R_z is the side force, M_x, M_y, M_z are the moment components Ox, Oy, Oz.

4. The airship model and the computational domain

The 3D model of the airship and the computational domain are shown in Fig. 3. Body length of the airship model L = 1.2 m, elongation λ = 4.5. The computational domain is cylindrical with a length of 11L, diameter 6L and subdivided into structured grid cells. The mesh in the area closer to the airship is divided thicker than the outside to ensure accurate calculation of the boundary of the airship.

At a distance of 5L from the tip of the airship sets the boundary condition, and a distance of 5L from the tail sets the output condition.

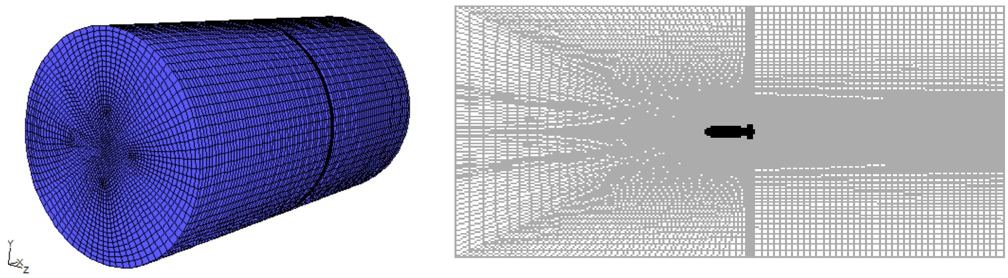


Fig. 3. The computational domain and the mesh in the symmetry plane of the airship body.

5. CFD and experimental data comparison

To check the reliability of the calculations, the authors calculated the aerodynamic characteristics of the airship body with the circular cross-section and compared the results obtained with test data in the tube aerodynamics of the Russian Federal Institute of Aerodynamics (SAGI). From the above graphs we see that the tangled model k - ε - standard is suitable for the calculations in this study. Therefore, all future calculations of this paper use the k - ε - standard model.

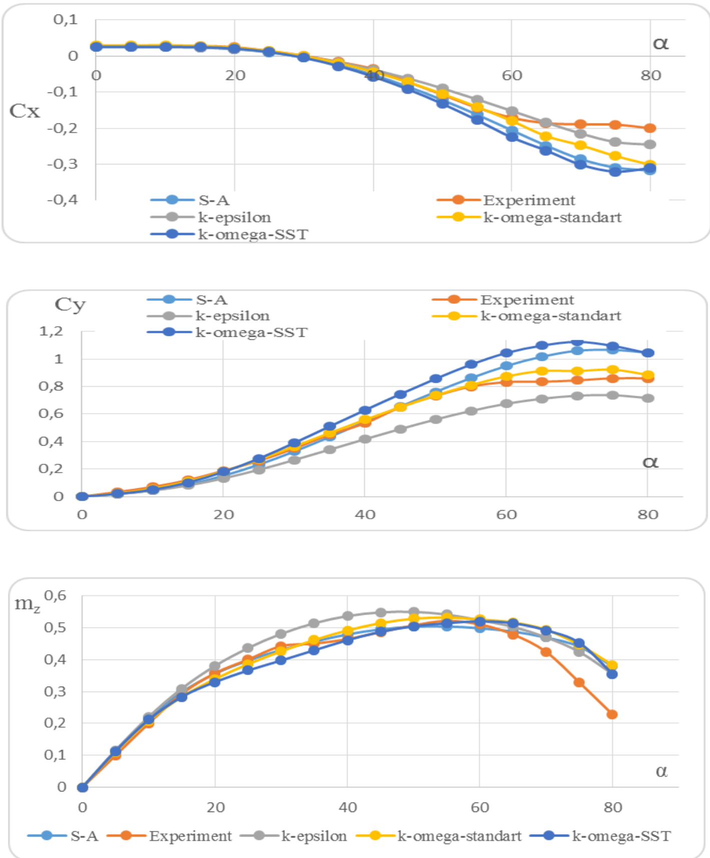
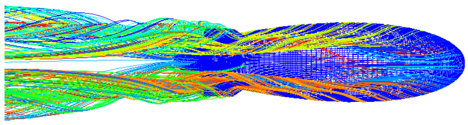
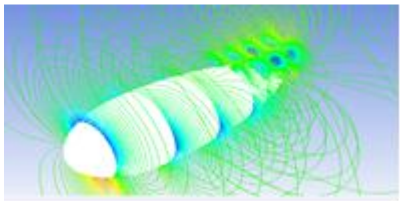


Fig. 4. CFD and experimental data comparison.

6. Results and discussion

Simulation results for all four cases of tail-wing are shown in the following figures:





a) With tail-wings *b) Without tail-wings*

Fig. 5. The streamline for an airship with the tail-wings of "X" diagram and for the tail-wingless airship (angle of attack α = 30º).

We see that at the same angle of attack α = 30º, the tail-wing airship forms a vortex system earlier (closer to the nose of the airship) and the structure of the resulting vortex is also more complicated. This greatly influenced the aerodynamic characteristics of the tail-wing airship compared to the tail-wingless airships. Comparison of the aerodynamic coefficients of the tail-wing and tail-wingless airships:

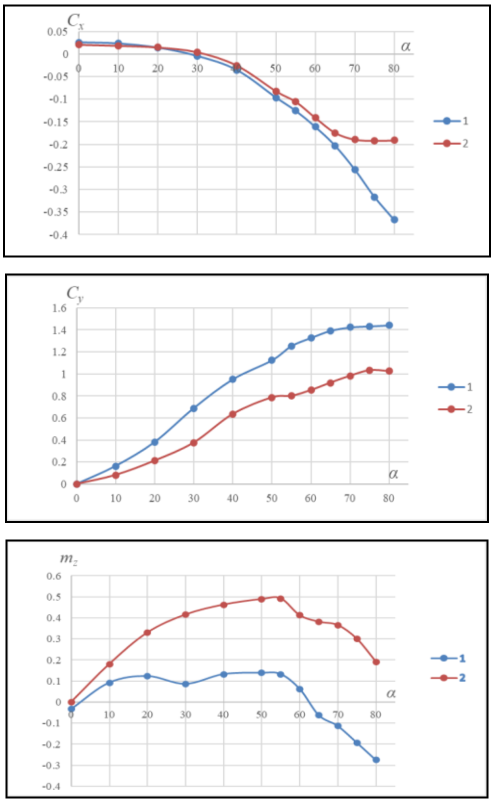


Fig. 6. Comparison of aerodynamic coefficients of the tail-wing airship and the tail-wingless airship (1- tail-wing airship, 2- tail-wingless airship).

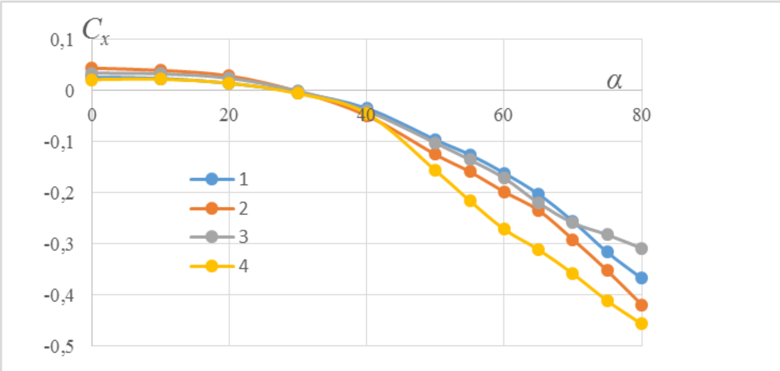


Fig. 7. Coefficients $C_x(\alpha)$ of 4 models of the airship (1 - "X" diagram, 2- "+" diagram, 3 - "reverse Y" diagram, 4 - "+" diagram when increasing the area of the tail-wing).

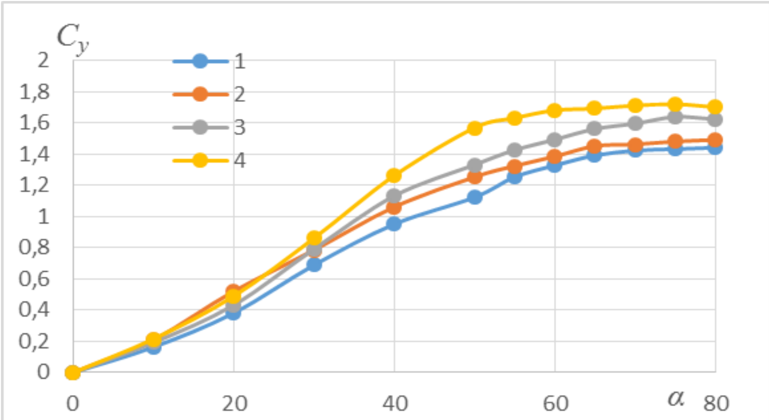


Fig. 8. Coefficients Cy(α) of 4 models of the airship (1 - "X" diagram, 2- "+" diagram, 3 - "reverse Y" diagram, 4 - "+" diagram when increasing the area of the tail-wing).

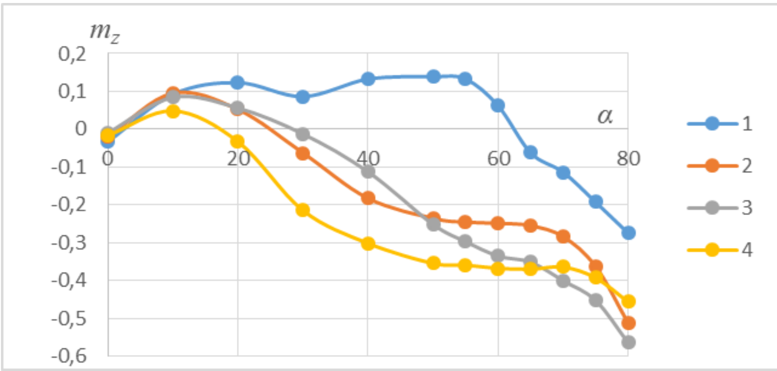


Fig. 9. Coefficients $m_z(\alpha)$ of 4 models of the airship (1 - "X" diagram, 2- "+" diagram, 3 - "reverse Y" diagram, 4 - "+" diagram when increasing the area of the tail-wing).

The results of the study show that when the total area of the tail of the "X" diagram and "+" diagram are the same, the "X" diagram is more effective at the small angle of attack as shown in the following comparison table:

Derivative of the normal force and the pitching moment with respect to angle of attack

Diagram	C_y^α	m_z^α
1	0.761	0.661
2	0.725	0.953
3	0.78	0.583
4	0.912	0.812

When the angle of attack increases, the influence of tail-wing “X” diagram will be reduced due to the appearance of local deviation angles on the control wing of the tail-wing, which reduces the efficiency of the wings "X" compared to the “+” diagram at the medium and large angles of attack (Fig. 9).

7. Conclusion

Attaching the tail-wings to the airship body significantly increase the normal force. When the area of the tail-wings are increased, the normal force increases. Research results show that when the area of tail-wings of the “X” diagram and “+” diagram are the same, the "X" diagram is more effective in the region of small angle of attack. The tail-wings of the "reverse Y" diagram in the small angle of attack is as effective as the "X" diagram. When the angle of attack is increased, its effect decreases significantly compared to the "X" diagram. When attaching the tail-wings, it significantly reduces the value of the moment m_z. At a large angle of attack, the m_z changes the sign and gets the negative value. Then the tail-wings of the "X" diagram are less efficient because the m_z is only negative when the angle of attack is greater than 60^o. For the "reverse Y" diagram and the "+" diagram, the m_z takes negative values when the angle of attack is greater than 25^o.

The airship bodies considered in this study are not static stable ($m_{z\alpha} > 0$) in the small angle of attack. When the area of the tail is increased, derivative of the normal force with respect to angle of attack increases and the derivative of the m_z with respect to angle of attack decreases. Therefore, fitting the tail-wing or increasing the area of the tail-wings will increase the stability of the airship.

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TÍNH HIỆU QUẢ CỦA CÁC SƠ ĐỒ CÁNH ĐUÔI TRÊN KHÍ CẦU THẾ HỆ MỚI VÀ ẢNH HƯỞNG CỦA NÓ LÊN CÁC ĐẶC TRƯNG KHÍ ĐỘNG HỌC CỦA KHÍ CẦU

Tạ Xuân Tùng, Vũ Mạnh Hiếu, Vũ Văn Chiên

Tóm tắt: *Khi khí cầu chuyển động thì cánh đuôi đóng vai trò hết sức quan trọng trong việc điều khiển và giữ ổn định trong suốt quá trình bay. Việc lựa chọn sơ đồ cánh đuôi quyết định tới việc thiết kế, chế tạo, kết cấu và hình dạng khí động học của mỗi loại khí cầu. Trên cánh đuôi còn đặt các cánh phụ, cánh hãm giúp cho quá trình bay của khí cầu được an toàn. Do đó, mục đích của bài báo này là nghiên cứu tính hiệu quả của các sơ đồ cánh đuôi và ảnh hưởng của nó tới các đặc trưng khí động của khí cầu. Nhóm tác giả đã dùng phương pháp số nghiên cứu đặc trưng khí động của khí cầu với các sơ đồ cánh đuôi khác nhau. Kết quả thu được cho biết tính hiệu quả của mỗi loại sơ đồ trong các dải góc tấn khác nhau. Kết quả này cũng có thể sử dụng cho việc tính toán, thiết kế khí cầu.*

Từ khóa: Khí cầu; đặc trưng khí động; cánh đuôi; phương pháp số.

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