EXPERIMENTAL INVESTIGATIONS OF THE AERODYNAMIC STABILIZATION METHODS OF THE LAUNCH VEHICLE PAYLOAD FAIRING HALF

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This paper considers the aerodynamic characteristics of the model of detachable payload fairing half having passive stabilization devices which are conical bodies with flexible or rigid connections. In order to determine the trim angles of attack we carried out experiments in a subsonic wind tunnel. We also conducted mathematical modelling of airflow around the model and calculated the values of the lift-to-drag ratio for the obtained trimmed angles of attack. We compared the characteristics of the considered stabilization devices.

Key words: aerodynamic characteristics, launch vehicle, payload fairing half, airflow modelling, passive stabilization, ANSYS CFX.

Introduction

One of the reasons for the fall location scatter of the detachable parts of the launch vehicles such as payload fairing halves is non-zero lift-to-drag ratio at trim angle of attack. This happens because the fairing half's shape is a thin curved surface with relatively low mass [1-3] and has no means of stabilization. Because of this the dedicated fall area is very large and requires costly servicing [4]. The task of finding means of reducing fall area of the launch vehicle payload fairing halves is very important [5,6] but to date it has not been researched thoroughly enough.

Various parachute systems can be used for minimizing the payload fairing half fall area:

1) an aerospace parachute system ensuring controlled entry in the dense atmosphere layers, reduction of hypersonic speed and heat loading [7];

2) a parachute system consisting of a drogue parachute and a parafoil for mid-air recovery of the payload fairing halves [8];

3) a parachute system consisting of a drogue parachute and a main parachute for in-water recovery of the payload fairing halves [8].

Passive means of stabilization can be used aside from parachute systems. These means include opening shields with or without ducts and also opening of various utility holes on the surface of the model [4]. The solution of destroying the fairing halves, for example by burning or fine dispersion in the dense atmosphere layers after separation is also discussed in the scientific community [9].

This work is devoted to analyzing different ways of stabilizing the payload fairing half of a launch vehicle by using various combinations of stabilizing cones. We carried out experiments in the wind tunnel in order to determine the trim angles of attack and conducted simulations in ANSYS CFX (licensing agreement number 339001) [10].

Problem setting. We consider the base model – a launch vehicle payload fairing half at a 1:100 scale (figure. 1).

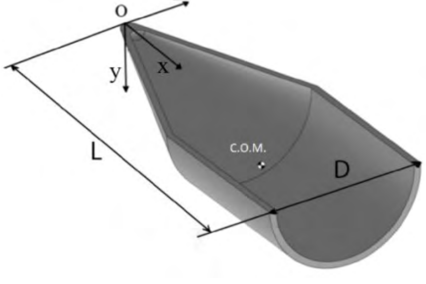
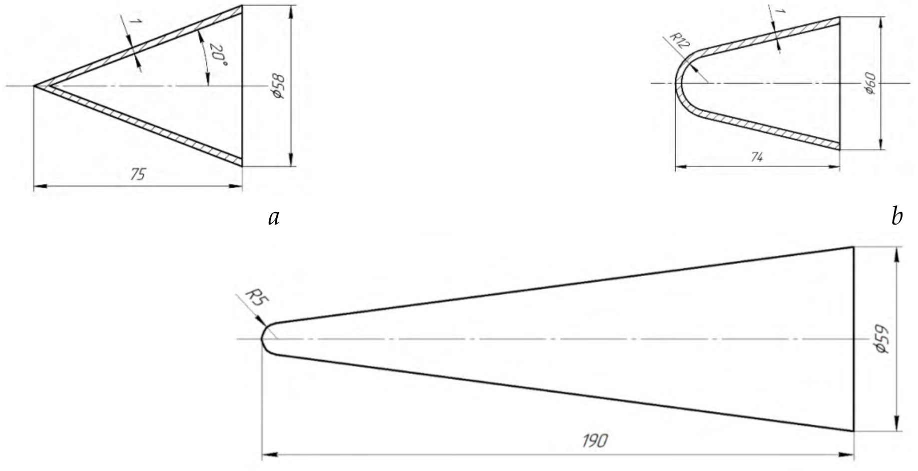


Figure. 1. Base model of the launch vehicle payload fairing half

The aerodynamic characteristics of this model have been researched and presented in [4]. The aerodynamic coefficients were determined in the body-fixed coordinate system OXYZ (figure 1).for calculating aerodynamic characteristics of the base model with various combinations of stabilizing cones. The characteristic length is given by the model length L = 0.1144 m, the characteristic area is given by area of the fairing half projection on the XOZ plane SxOz = 0.000905 m2 for calculating the lift and drag coefficients $\boldsymbol{Cx}$ and $\boldsymbol{Cy}$, the pitching moment coefficient with respect to the center of mass $\boldsymbol{m_{zcom}}$, and the lift-to-drag ratio $\boldsymbol{K} = \frac{\mathbf{Cya}}{\boldsymbol{Cxa}}$.

We consider three models of passive stabilization devices. The models include a solid foam plastic cone (model №3, figure 2 c) and hollow plastic cones: a sharp cone (model №1, figure 2 a) and a blunted one (model №2, figure 2 b). The cones are connected to the base model using rigid or flexible connection.

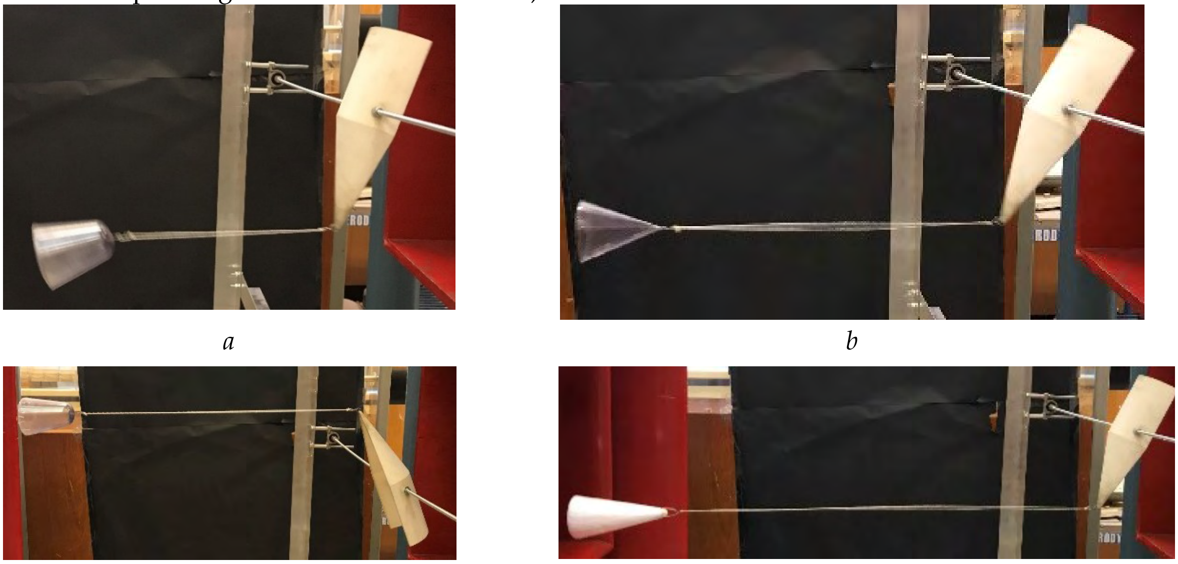


a *b*

c

Figure 2. Models of passive stabilization devices

Determination of trim angles of attack. The considered models of the passive stabilization devices were attached to the payload of the model with a thread. The length of the thread was measured in the base model's characteristic lengths L (figure 3). The results are shown in table 1 ($\Delta\alpha_{trim}=\alpha_i-\alpha_{base}$; $\Delta K=|K_i|-|K_{base}|$, α_i, K_i — trimmed angle of attack and the corresponding lift-to-drag ration of the i-th combination; α_{trim}, K_{trim} — the corresponding values of the base model).



a *b*

c *d*

Figure 3. Models of the passive stabilization devices on threads having length: L (a), 1,5L (b), 2L (c), 3L (d)

Table 1. Change of the trimmed angles of attack and the lift-to-drag ratios of the analyzed models compared to the base model

Thread length	Model	$\Delta\alpha_{trim1}$	ΔK_1	$\Delta\alpha_{trim2}$	ΔK_2
1L	1	11	0.149	-	-
	2	25	0.400	-25	0.046
	3	19	0.247	-57	0.194
1,5L	1	-10	0.173	-19	0.358
	2	19	0.273	-18	0.121
	3	24	0.335	-33	0.126
2L	1	15	0.209	-23	0.314
	2	23	0.343	-22	0.159
	3	16	0.218	-29	0.169
3L	1	8	0.079	-19	0.271
	2	5	0.017	-29	0.125
	3	21	0.289	83	0.235

We also considered the alternative of rigidly attaching two thin-walled cones (figure 2, a) at the head and rear parts of the model. In order to reduce the weight of the structure we made holes in the stabilizing cones with different values of perforation ratio

$$\sigma = \frac{S_{hole}}{S_{cone}} \cdot 100\%, \qquad (1)$$

S_{hole} - the holes total area, S_{cone} - the cone side surface area.

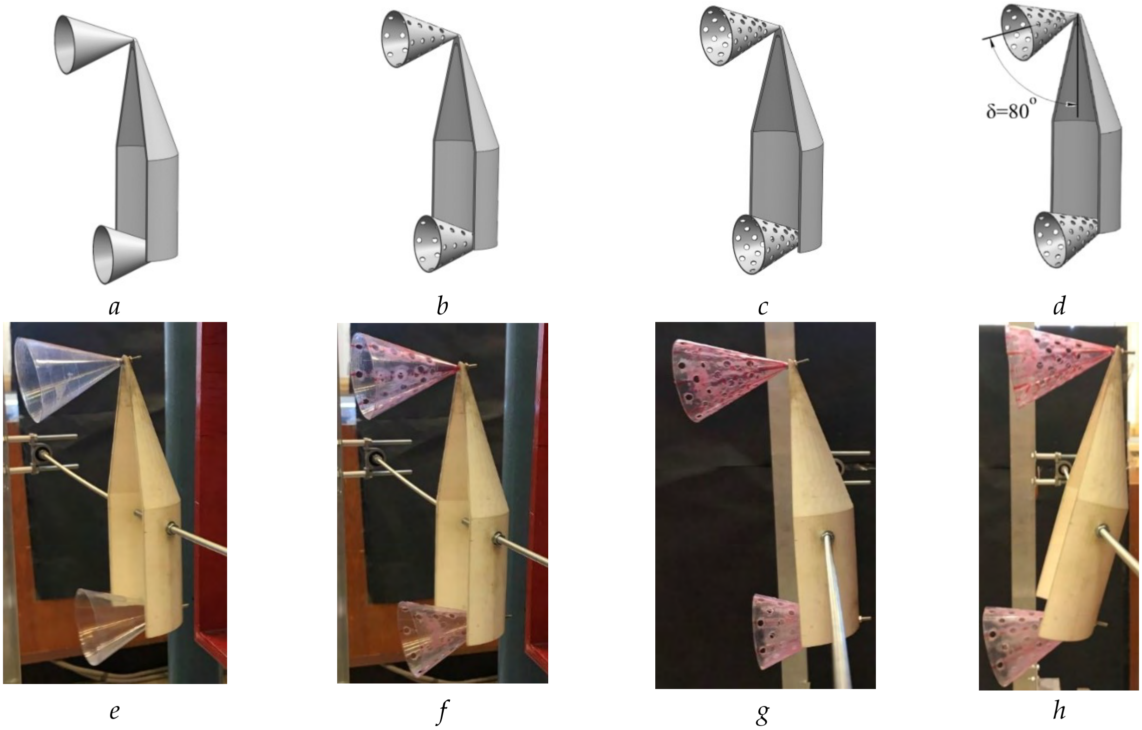


Figure 4. The assemblies of the analyzed models with rigid connection of the cones (a - d – 3D models; e - h – photos of the analyzed model in the wind tunnel; a, e: σ = 0%, b, f: σ = 10.8%, c, g, h, d: σ = 18.8%)

We measured the trim angles of attack of these models in the wind tunnel using the incremental encoder and calculated the lift-to-drag ratios for the obtained angles using ANSYS CFX. The calculations revealed that installing stabilizing cones at the angle of δ = 80o to the half surface yields positive effect for subsonic flow. Because of this, we decided to simulate this configuration for the supersonic airstream speed ($\mathbf{M}_\infty$=2). The calculations also revealed the reduction of the lift-to-drag ratio for the trim angle of attack. The results are presented in table 2.

Table 2. Change of the trim angles of attack and the lift-to-drag ratios of the analyzed models

Assembly №	V, m/s	σ, %	ΔK_1	$\Delta\alpha_{trim1}$
1	20	0	0.109	15
2	20	10.8	0.084	4
3	20	18.8	0.068	6
4	20	18.8	-0.037	-3
4	680.59	18.8	-0.182	-10

Conclusion

The following were identified as a result of the work:

- There are two trim angles of attack if the connection is flexible and one angle trim angle of attack if the connection is rigid.
- In both cases, the rotation of the model in the symmetry plane under external disturbances devices is eliminated unlike when there was no stabilization.
- The lift-to-drag ratio can be reduced down using stabilization with rigid connection only.

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