UNIVERSIDADE BEIRA INTERIOR

DEPARTAMENTO DE CIÊNCIAS AEROESPACIAIS

Estruturas Aeroespaciais I – 10362/15089

2024/2025

# Mini Project
## Sizing of a light aircraft tail boom

## 1. OBJECTIVE

To size the structure of a fuselage tail boom subject to strength and stiffness constraints. To write a technical report.

## 2. DESCRIPTION

It is required to size the fuselage tail boom of a light sport aircraft which has a maximum take-off mass of $m = 650$ kg and limit load factors of $n = +4/–2$.

A simplified representation of the tail boom's geometry and the definition of the tail boom parameters are shown in Figure 1. The tail boom has a height $h(z)$, and a width $w(z)$.

The tail boom structure is made of a closed thin-walled single section. The upper tail boom skin has thickness $t_1$ and the lower tail boom skin has thickness $t_2$. The cross-section areas of the upper and lower longerons are $A_1$ and $A_2$, respectively. The root of the tail boom is assumed to be built-in at the mid fuselage (not shown) and the tip is free. One of three different materials can be used in the design of the tail boom, the aluminium alloys 7075-T6, 2024-T3 or 6061-T6, all being isotropic materials with properties given in Table 1. The available material thicknesses are given in Table 2.

Two distinct load cases must be used to size the tail boom: a) A first load case to apply to the tail boom results from flight conditions and includes a vertical force, $S_y$, corresponding to the horizontal tail's balance load and a horizontal force, $S_x = S_y/2$. This load system is applied at the free end of the tail boom at the vertical symmetry axis at a position $y_V = 0.8$ m. b) A second load case results from levelled (3-point) landing conditions and includes a vertical force, $S_y$, resulting from a ground load factor $n_g = 4$. The combined mass of the horizontal and vertical tails is $m_T = 15$ kg.

The maximum lift coefficient of the wing is $C_{Lmax} = 1.66$, the minimum negative lift coefficient is $C_{Lmin} = -C_{Lmax}/2$, the lift coefficient is given by $C_L = 0.011\pi^2 b(\alpha+4)/(b+2c)$, where $\alpha$ is the angle of attack, the pitching moment coefficient of the wing is $C_M = –0.12$ and the design diving speed is $V_D = 135$ m/s.

The centre of gravity of the aircraft is coincident with the aerodynamic centre of the wing, which is located at $z_W = -0.5$ m, and the centre of gravity of the tail is coincident with the aerodynamic centres of the horizontal and vertical tails, which are located at the tip (free end) of the tail boom.

Tasks:

a) Determine the manoeuvre *V-n* diagram using the certification requirements CS-LSA or CS-VLA.
b) Implement a calculation methodology that enables the direct stresses and the shear stresses acting on the skin and longerons of the tail boom root (built-in end) section of Figure 1 to be computed for the load cases provided and for arbitrary values of $t_1$, $t_2$, $A_1$, and $A_2$. In this methodology the longerons can be idealized but the skin cannot; and you may neglect the effects of the tail boom taper.
c) Determine the values of $t_1$, $t_2$, $A_1$ e $A_2$ which minimize the structure mass, considering the applied stresses at the root section, the data of Tables 1, 2, and 3 and guaranteeing that the maximum tip rotation, $\theta_x$, is less than 1º and that the maximum tip twist angle, $\theta_z$, is less than 2º.
d) Analise and comment the results.
e) Write up a technical report.

## **3.** REPORT

Each team of 3 students (each team uses a different value of *i* from Table 3) must present the methodology and the results of its analysis in a technical written report of **no more than 15 pages**. In the report, adequate detail must be provided concerning the solution steps and the final results, explicitly mentioning the values of $t_1$, $t_2$, $A_1$ e $A_2$, the free end rotation, the free end twist, and the stress field over the tail boom built-in end section. A critical analysis of the results with proposals for improving the structural efficiency must be provided.

The report must follow the following structure:

a) Introduction: presentation of the problem, objectives, and geometry. [10 points]
b) Load Calculation: presentation of the mathematical model to calculate the V-n manoeuvre diagram and the trim loads on the tail, description of the selection of critical design loads, description of the implementation of the numerical model, and presentation of the results. [45 points]
c) Structural Analysis: presentation of the mathematical model to calculate stresses and displacements of the structure, description of the implementation of the numerical model, and presentation of the results. [45 points]
d) Structural Optimization: presentation of the mathematical model to minimize the structure's mass while meeting strength and stiffness constraints, description of the implementation of the numerical model, and presentation of the results. [45 points]
e) Analysis and Discussion: evaluation of the results and presentation of concrete corrections/improvements to be applied to the structure. [45 points]
f) Conclusions: considering the objectives, overall assessment of the work and of the obtained results. [10 points]

The final hand-in date of the report is December 20th, 2024. The report must be sent in pdf format to the e-mail address pgamboa@ubi.pt.

# **4.** DATA

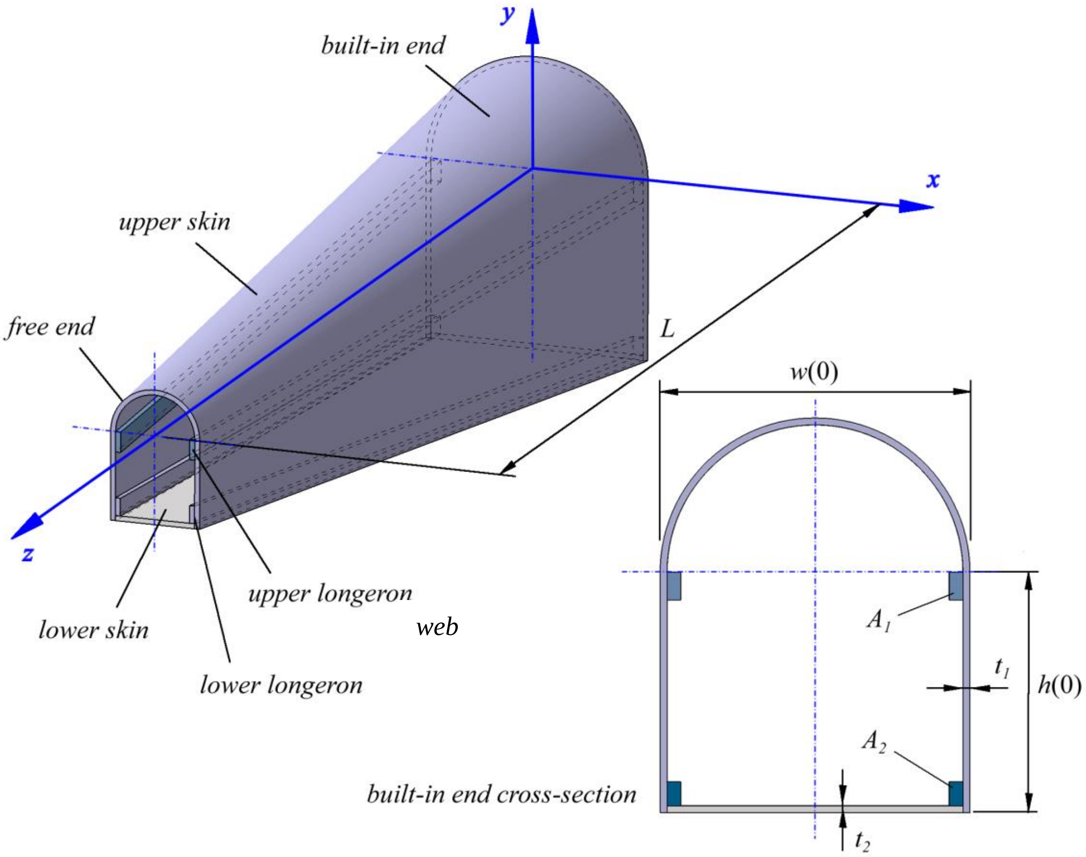


Figure 1 – Fuselage tail boom geometry and parameters.

Table 1 – Material properties

| Property | parameter | unit | 7075-T6 | 2024-T3 | 6061-T6 |
|---|---|---|---|---|---|
| Density | $\rho$ | kg/m$^3$ | 2810 | 2780 | 2700 |
| Longitudinal elastic modulus | $E$ | GPa | 71.7 | 73.1 | 68.9 |
| Poisson ratio | $\nu$ | - | 0,33 | 0,33 | 0,33 |
| Tensile yield stress | $\sigma_{yt}$ | MPa | 469 | 345 | 276 |
| Tensile strength | $\sigma_t$ | MPa | 538 | 483 | 310 |
| Compression strength | $\sigma_t$ | MPa | 514 | 462 | 297 |
| Shear strength | $\tau$ | MPa | 331 | 283 | 207 |

Table 2 – Available thicknesses (in mm).

| |
|---|
| 0.122 ; 0.254 ; 0.417 ; 0.61 ; 0.813 ; 1.02 ; 1.22 ; 1.42 ; 1.63 ; 1.83 ; 2.03 ; 2.34 ; 2.95 ; 4.06 ; 5.38 ; 6.4 ; 8.23 ; 10.16 ; 12.7 |

Table 3 – Wing and fuselage tail boom specifications according to team number.

| Team | span, m | mean chord, m | $h$, m | $w$, m | $L$, m |
|---|---|---|---|---|---|
| $i$ = 1,30 | 11.5-0.1×($i$-1) | 0.75+0.01×($i$-1) | 0.65×(1-0.5$z$/$L$) | 0.85×(1-0.6$z$/$L$) | 4-0.02×($i$-1) |

Table 4 – Teams.

| Team | Student 1 | Student 2 | Student 3 |
|---|---|---|---|
| 1 | Ricardo Fonte - 31505 | David Ponciano - 32959 | Gilberto Correia - 40156 |
| 2 | Bernardo Piteira - 49399 | Carolina Gomes - 49561 | Maria Rebelo - 50345 |
| 3 | David Simões - 49384 | Luís Calmeiro - 49636 | Orlando Fortunato - 49672 |
| 4 | Beatriz Santos - 49536 | Beatriz Massano - 49796 | Joana Quelhas - 50177 |
| 5 | Salvador Vale - 49524 | David Andrade - 49560 | Rafael Ferreira - 49855 |
| 6 | Leonardo Ferreira - 49538 | José Barros - 49616 | Miguel Robalo - 49646 |
| 7 | Vasco Castro - 49551 | Rodrigo Matos - 50053 | João Rodrigues - 50061 |
| 8 | Nuno Riscado - 49681 | João Branco - 49935 | Manuel Baptista - 50666 |
| 9 | Rafael Andrade - 50298 | Rodrigo Condeço - 50498 | Tiago Sequeira - 50873 |
| 10 | Raquel Loureiro - 49406 | Margarida Guerreiro - 49588 | André Teixeira - 49858 |
| 11 | José Costa - 48214 | Gonçalo Coimbra - 49495 | Tomás Saraiva - 50180 |
| 12 | Manuel Pereira -49535 | Jéssica Oliveira- 49721 | Gonçalo Tavares- 53063 |
| 13 | Joana Sousa - 49496 | Alex Burdujan - 49989 | Nicole Silva - 50022 |
| 14 | Patrícia Dores - 49521 | Maria Inês Pina - 49547 | Simão Serra - 49553 |
| 15 | Afonso Salvador - 49818 | André Azevedo - 50930 | Daniel Santo - 50949 |
| 16 | Samuel Macedo - 49552 | José Prata - 49563 | José Bizarro - 49904 |
| 17 | Paulo Rosa - 48150 | João Silva - 48733 | Dmytro Kovalchuk - 50140 |
| 18 | Luís Gonçalves - 49557 | Romeu Daniel - 49895 | Diogo Silva - 50337 |
| 19 | Rui Teixeira - 45442 | Daniela Pereira - 49428 | Cláudio Antunes - 53015 |
| 20 | Gustavo Domingues - 49620 | Rúben Marçal - 50508 | Lucía Carrillo Soriano - 54863 |
| 21 | Pedro Simões - 49781 | Bruno Bernardino - 50257 | Christian Delgado - 48824 |
| 22 | Neusa Panzo - 43082 | Kissange Muthemba - 46713 | Weila Fernandes - 44995 |
| 23 | Admir Marques - 43871 | | |
| 24 | | | |
| 25 | | | |