UNIVERSIDADE BEIRA INTERIOR

DEPARTAMENTO DE CIÊNCIAS AEROESPACIAIS

Estruturas Aeroespaciais I – 10362

2022/2023

# 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 an ultralight aircraft which has a maximum take-off mass of $m$ = 472.5 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 two different materials can be used in the design of the tail boom, the aluminium alloys 6061-T6 or 2024-T3, both being isotropic materials with properties given in Table 1. The available thicknesses are given in Table 2.

Two distinct load case 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 $y_V$ = 0.75 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 $n_g$ = 3.5. The combined mass of the horizontal and vertical tails is $m_T$ = 10 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 $C_M$ = –0.1 and the design diving speed is $V_D$ = 80 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-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 not the skin; and you can 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) Design a possible connection between the tail boom and the mid fuselage considering the loads at the tail boom root.
e) Analise and comment the results.
f) 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 final hand-in date of the report is 6 January, 2023. The report must be sent in pdf format to the e-mail address pgamboa@ubi.pt.**

## **4.** DATA

Table 1 – Material properties.

| Property | parameter | unit | 6061-T6 | 2024-T3 |
|---|---|---|---|---|
| Density | $\rho$ | kg/m$^3$ | 2700 | 2780 |
| Longitudinal elastic modulus | $E$ | GPa | 68.9 | 73.1 |
| Poisson ratio | $\nu$ | - | 0.33 | 0.33 |
| Tensile yeald stress | $\sigma_{yt}$ | MPa | 276 | 345 |
| Tensile strength | $\sigma_t$ | MPa | 310 | 483 |
| Compression strength | $\sigma_t$ | MPa | 297 | 462 |
| Shear strength | $\tau$ | MPa | 207 | 283 |

Table 2 – Available aluminium alloy sheet 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) | 0.7×(1-0.5*z*/*L*) | 0.9×(1-0.6*z*/*L*) | 4-0.02×(*i*-1) |

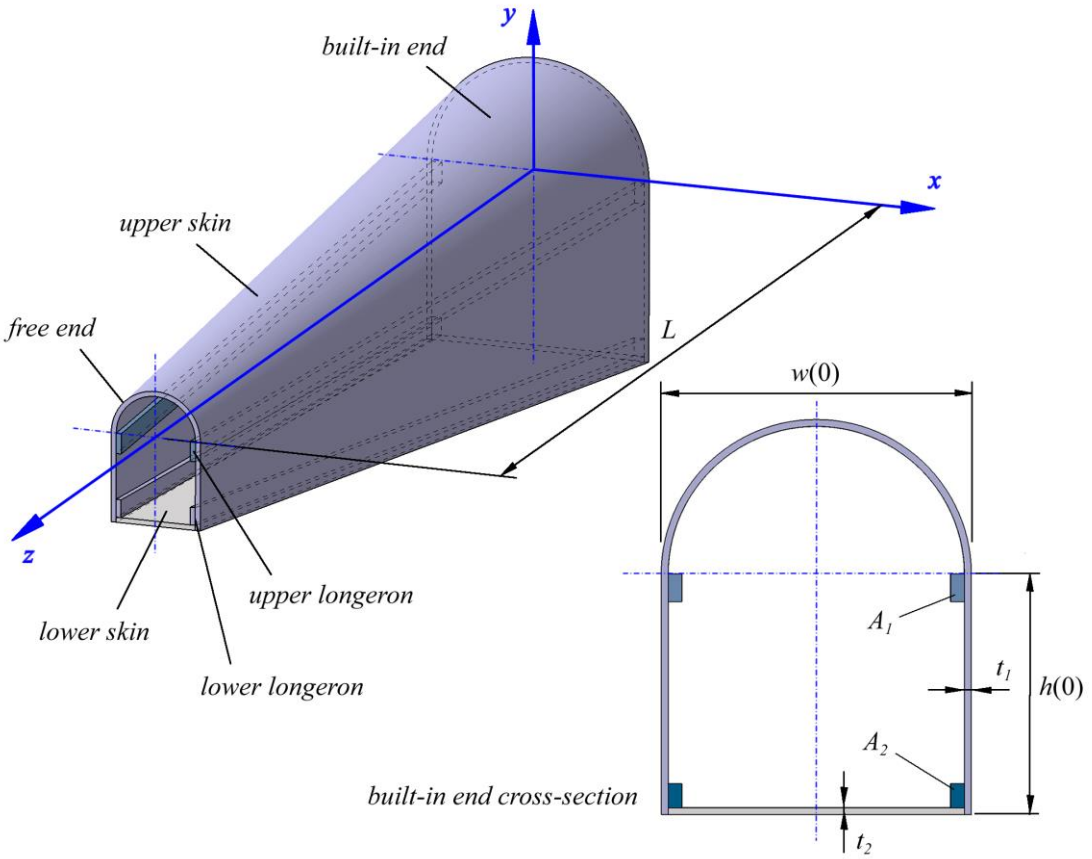


Figure 1 – Fuselage tail boom geometry and parameters.

Table 4 – Teams.

| Team | Student 1 | Student 2 | Student 3 |
|---|---|---|---|
| 1 | Rodrigo Bombas - 45824 | Diogo Lemos - 46010 | Diogo Cadete - 46775 |
| 2 | Duarte Pereira - 47603 | Vasco Ribeiro - 47609 | Leonardo Santos - 47610 |
| 3 | Mariana Pereira - 45619 | Beatriz Gonçalves - 45839 | Diogo Ferreira - 47507 |
| 4 | David Cleto - 45556 | Miguel Bulha - 46019 | Simão Marques - 46190 |
| 5 | Tomás Santos Romão - | Francisco Pinho Costa - | Diogo Miranda Esteves - |
| 6 | Colinet Contreiras - 38883 | Jacibela Cardoso - 47090 | Ludnésia da Mata - 47093 |
| 7 | António Pimenta - 42135 | António Pelouro - 45397 | Marta Dias - 47088 |
| 8 | Fábio Teixeira - 45724 | Rodrigo Oliveira - 45752 | Erik do Rosário - 46712 |
| 9 | Admir Marques - 43871 | Dany Cardoso - 44605 | Gilson Lopes - 44636 |
| 10 | Filipe Vicente - 45546 | Rui Rita - 45774 | Rafael Santos - 46181 |
| 11 | Francisco Vale - 45684 | Diana Pereira - 45821 | Ana Margarida Silva - 46784 |
| 12 | Rúben Pavia - 45557 | Daniel Martins - 45637 | João Ferreira - 45765 |
| 13 | David Jorge - 45632 | João Coelho - 45807 | Alexandre Oliveira - 46457 |
| 14 | André Oliveira - 45697 | Pedro Olim - 46024 | Pedro Gaspar - 46677 |
| 15 | André Almeida - 32776 | Nuno Ferreira - 42471 | Filip Podwyszynski - 51138 |
| 16 | João Rosa - 45676 | Luís Pestana - 45828 | |
| 17 | Gonçalo Tinoco- 45654 | Matilde Silva- 45826 | Nuno Fernandes- 45849 |
| 18 | Bernardo Barbosa - 45588 | Nuno Quitério - 45834 | Tomás Anjo - 46085 |
| 19 | Filipe Soares - 45608 | Eduardo Silva - 45618 | Guilherme Resende - 45845 |
| 20 | | | |
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