Mini Project
Sizing of a wingbox

1. OBJECTIVE

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

2. DESCRIPTION

It is required to size the wingbox of a two-seat general aircraft which has a maximum take-off mass of $m = 750$ kg and limit load factors of $n = +4/–2$.

A simplified representation of the wing's geometry and the definition of the wingbox parameters are shown in Figure 1. The wingbox has a constant width $0.3c$, a constant height h, and a span b.

The wingbox structure is made of a closed thin-walled single section. The wingbox skin has thickness t_c and the spar web has thickness t_a. The cross-section areas of the upper and lower spar flanges are A_l and A_2, respectively. These areas are made of L sections of equal sized sides, d_i, and thickness t_i (i=1,2). The root of the wing is assumed to be built-in at the main spar and the tip is free. One of three different materials can be used in the design of the wingbox, 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.

A first load case to apply to the wing includes a uniformly distributed vertical load, w_L, along the span corresponding to the wing lift and a uniformly distributed torsion moment, w_T, along the span. This load system is applied a distance $0.05c$ in front of the wing spar at the horizontal symmetry axis. A second load case has an upward point force acting on the spar at a distance 1.6 m from the wing root. This force represents the ground reaction at the main wheel in a landing condition with a ground load factor $n_g = 3.5$.

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 α is the angle of attack, the pitching moment coefficient of the wing is $C_M = –0.11$ and the design diving speed is $V_D = 125$ m/s.

Tasks:
a) Determine the manoeuvre *V-n* diagram using the certification requirements CS-23.

b) Implement a calculation methodology that enables the direct stresses and the shear stresses acting on the skin and spar of the section of Figure 1 to be computed, for the load cases provided and for arbitrary values of t_c, t_a, A_1, and A_2. In this methodology the spar flanges can be idealized but not the skin.

c) Determine the values of t_c, t_a, 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 deflection is less than $0.1b$ and that the maximum tip twist angle 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 12 pages**. In the report, adequate detail must be provided concerning the solution steps and the final results, explicitly mentioning the values of t_c, t_a, A_1 e A_2, the tip deflection, the tip twist, and the stress field over the wing. 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 <u>12 January, 2023</u>. The report must be sent in pdf format to the e-mail address <u>pgamboa@ubi.pt</u>.
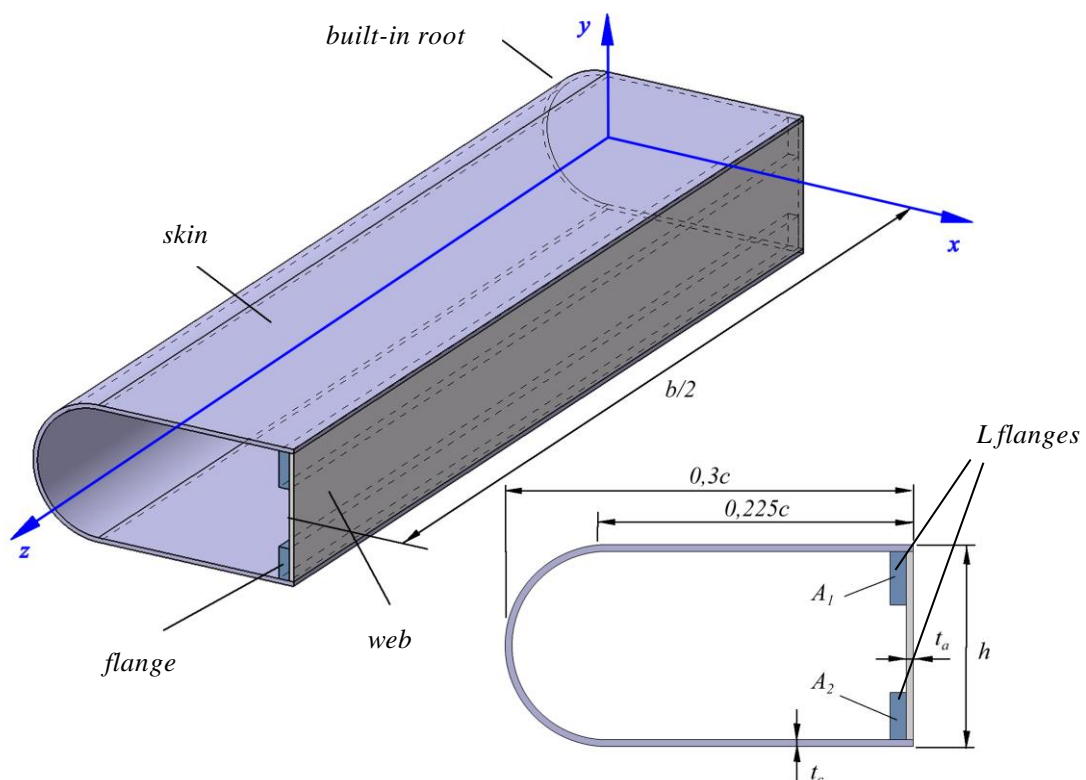

4. DATA

Figure 1 – Wing geometry and parameters.

Table 1 – Material properties

Property	parameter	unit	7075-T6	2024-T3	6061-T6
Density	ρ	kg/m³	2810	2780	2700
Longitudinal elastic modulus	E	GPa	71.7	73.1	68.9
Poisson ratio	ν	-	0,33	0,33	0,33
Tensile yield stress	σ_{yt}	MPa	469	345	276
Tensile strength	σ_t	MPa	538	483	310
Compression strength	σ_t	MPa	514	462	297
Shear strength	τ	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 specifications according to team number.

Team	b, m	c, m	h, m
i = 1,30	11.5-0.01×(i-1)	0.75+0.01×(i-1)	0.15c

Table 4 – Teams.

Team	Student 1	Student 2	Student 3
1	Miguel Ruivo - 48147	André Sousa - 48185	Octávio Lopes - 48508
2	Daniel Câmara - 47795	Fernando Faria - 48082	Raúl Santos - 48558
3	Henrique Vieira - 47797	Gonçalo Dias - 48008	Luís Lopes - 48808
4	Weila Fernandes - 44995	Kissange Muthemba - 46713	Ludnesia da Mata - 47093
5	Diogo Pinho - 47801	Miguel Albino - 47808	Beatriz Gonçalves - 48594
6	Alexandre Teixeira - 47710	Isabel Gomes - 47822	Pedro Moreira - 48317
7	Maria Fernandes - 47978	Bernardo Guerreiro - 48428	Pedro Rafeiro - 48683
8	Pedro Leite - 48141	Mariana Peixoto - 48161	Diogo Garcia - 48587
9	Duarte Pereira - 47603	Leonardo Santos - 47610	José Miguel Costa - 48214
10	Mafalda Assis - 48022	Afonso Gamboa - 48261	Anton Mamus - 48618
11	Guilherme Martins - 48007	Breno Cabral - 48334	Alexandre Pereira - 48502
12	Sebastião Ventura - 47768	Fernando Afonso - 48175	Francisco Albuquerque - 48220
13	Ricardo Fonte - 31505	Neusa Panzo - 43082	Christian Delgado - 48824
14	António Pimenta - 42135	Dany Cardoso - 44605	Gustavo Prado - E11284
15	Lara Sampaio - 47835	Tomás Carneiro - 47964	Guilherme Rebelo - 48107
16	André Tomaz - 48108	Cristina Martins - 48392	Rodrigo Silva - 48599
17	Fábio Teixeira - 45724	Rodrigo Oliveira - 45752	Erik Rosário - 46712
18	Rui Teixeira - 45442	Francisco Ribeiro - 48089	Inês Afonso - 50191
19	Bruno Rocha - 40726	João Rosa - 45676	Gonçalo Moreira - 48327
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