Estruturas Aeroespaciais I – 10362

2021/2022

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 an ultralight aircraft which has a maximum take-off mass of m = 450 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. The root of the wing is assumed to be built-in at the main spar and the tip is free. One of two different materials can be used in the design of the wingbox, 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.

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 1.5 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 = –0.1 and the design diving speed is V_D = 86 m/s.

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 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) Design the connection between the wing spar and the fuselage considering the loads at the wing 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 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 7 January, 2022. The report must be sent in pdf format to the e-mail address pgamboa@ubi.pt.

4. DATA

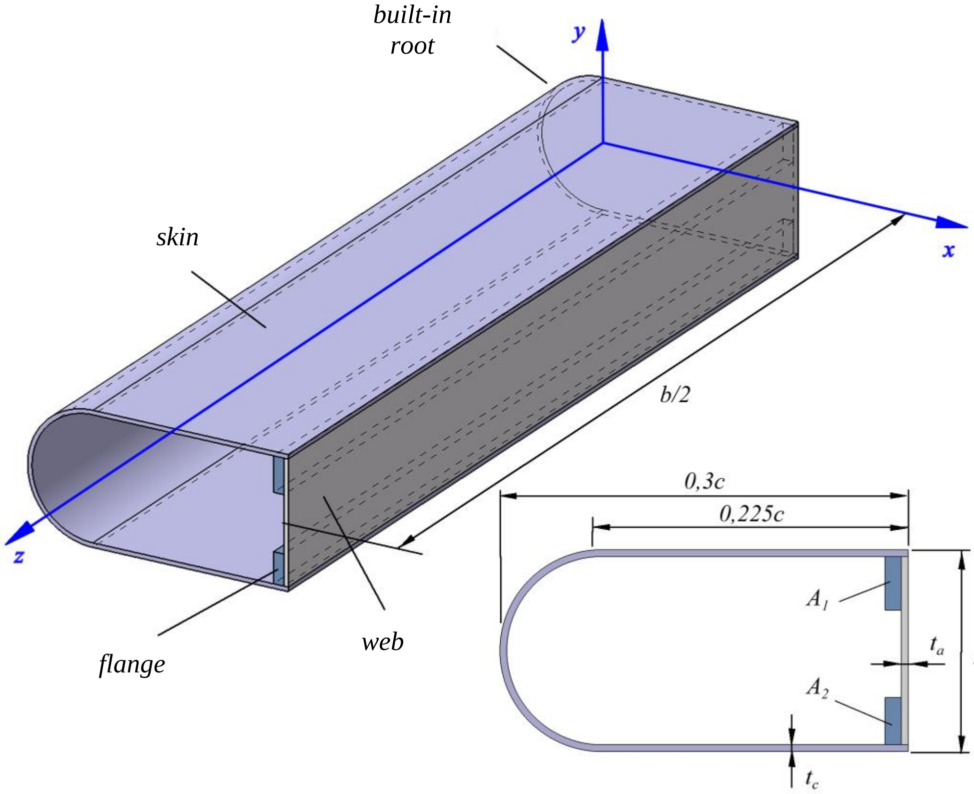

Figure 1 – Wing geometry and parameters.

Table 1 – Material properties

Property	parameter	unit	6061-T6	2024-T3
Density	ρ	kg/m^3	2700	2780
Longitudinal elastic modulus	E	GPa	68,9	73,1
Poisson ratio	ν	-	0,33	0,33
Tensile yeald stress	σ_{yt}	MPa	276	345
Tensile strength	σ_t	MPa	310	483
Compression strength	σ_t	MPa	297	462
Shear strength	τ	MPa	207	283

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)	0.15*c*

Table 4 – Teams.

Team	Student 1	Student 2	Student 3
1	Matilde Figueiredo - 43330	Egor Ukolov - 43882	
2	João Barateiro - 43726	João Charuto - 44204	Nuno Souza - 44515
3	Diego Côrte-Real - 43300	Tomás Figueiredo - 43825	Dany Cardoso - 44605
4	Erika Marques - 43418	Rafael Fernandes - 43421	Francisco Costa - 43465
5	Maria Leonor Patricio -43615	Manuel Azevedo - 44357	Liane Moura - 44473
6	António Pelouro - 45397	Marta Dias - 47088	
7	Vasco Gabriel - 45392	Miguel Sousa - 45402	
8	Rodrigo Silva - 43590	Catarina Oliveira - 43988	Ema Marques - 44070
9	Inês de Medeiros - 44598	Miguel Marques - 44671	
10	Colinet Contreiras - 38883	Edson Varela - 42247	
11	Manuel Matos - 43654	Leonardo Ferreira - 43744	Rafael Rodrigues - 44152
12	Simão Pereira - 43604	Salvador Fernandes - 43748	Diogo Lopes - 44463
13	André Viana - 38593	Diogo Silva - 44099	Hugo Gonçalves - 44198
14	Tiago Nave - 43809	Petro Petrovych - 44040	
15	Francisco Ramos - 43356	António Vilaça - 43693	Rafael Simões - 44069
16	Francisca Serras - 43386	Joana Limpo - 44021	Daniel Pinto - 44963
17	Pedro Cardoso - 43474	Simão Ribeiro - 43823	João Campos - 43854
18	Rimaldini Tavares - 44505	Gilson Lopes - 44636	Jefferson Cardoso - 44655
19	António Duarte - 41977	Bruno Eusébio - 44315	Gonçalo Almeida - 44317
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