UNIVERSIDADE BEIRA INTERIOR

DEPARTAMENTO DE CIÊNCIAS AEROESPACIAIS

MECÂNICA ESTRUTURAL – 10391/10411

2020/2021

Mini-Project 2

1. OBJECTIVES

The main objectives of this project are:

- To learn how to implement a computer code to solve a structural problem, using the finite element method (FEM).
- To develop a one-dimensional (1D) finite element (FE) which couples two beam elements one torsion element to create a single linear element with 10 degrees-of-freedom (DOF).
- To use the developed 10-DOF element to create a representation of the wing, fuselage, horizontal tail and vertical tail structures.
- To implement a computer code to perform static analyses of a given aircraft structure with prescribed cross-section geometries, materials, loads and constraints.
- To develop critical thinking when developing mathematical and computational models.
- To develop critical thinking when analysing computer codes' results.

2. PROBLEM

It is necessary to develop a numerical tool which uses beam finite elements and thin-walled cross-section data to analyse the structure of an airplane made of wing, fuselage, horizontal tail and vertical tail. The tool should be able to calculate deflections and cross-section stresses due to static loads.

3. PROJECT REQUIREMENTS

The development of the computer code to calculate the static deflections and stresses and the natural mode shapes of vibration with the corresponding natural frequencies of an airplane structure shall be divided into the following tasks:

1. Review of the previous independent models and code.
2. Development of a flowchart indicating the program structure and the relationship between its various modules.

3. Integration of the various program modules to create the FEM program for the complete airplane structure.
4. Preparation of a final report describing the previous tasks. The report should not have more than around 30 pages. The code should be included in an appendix.

4. CASE STUDY

The case study to be analysed consists of an Air Cargo Challenge 2021 prototype with the characteristics described below.

Layout

The aircraft layout is shown in Figure 1 with the component relevant sections numbered. The origin is placed at the wing´s quarter chord. All lifting surfaces have zero sweep. Tables 1 through to 4 summarize the dimensions.

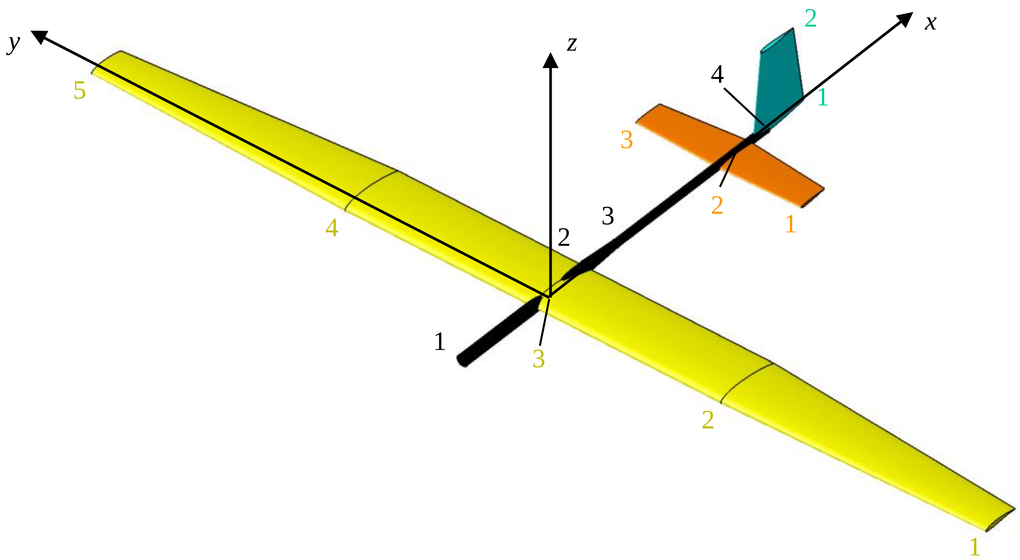

Figure 1: Aircraft layout.

Table 1: Wing dimensions - origin (0,0,0).

Section	*y*, mm	chord, mm	incidence, deg
1	-1190	100	-1
2	-500	180	1
3	0	180	1
4	500	180	1
5	1190	100	-1

Table 2: Horizontal tail dimensions - origin (600,0,0).

Section	*y*, mm	chord, mm	incidence, deg
1	-220	80	-2
2	0	110	-2
3	220	80	-2

Table 3: Vertical tail dimensions - origin (740,0,0).

Section	*z*, mm	chord, mm
1	0	170
2	220	110

Table 4: Fuselage - origin (-280,0,0).

Section	*x*, mm	diameter, mm	thickness, mm
1	-280	30	1
2	135	30	1
3	235	20	1
4	740	20	1

Airfoils

The wing airfoil is the PVG_ACC21_14. The horizontal and vertical tails airfoil is the NACA 0009. Their coordinates are given in separate files.

Mass distribution

All mass components may be assumed to be concentrated at their corresponding coordinate as shown in Table 5. The origin is at the wing´s quarter chord. The masses of the wing, horizontal tail and vertical tail may be uniformly distributed along their respective span.

Table 5: Mass location of main components.

Component	mass, kg	*x*, mm
wing	0.75	24.5
horizontal tail	0.03	571.1
vertical tail	0.03	757.7
fuselage	0.37	58.9
landing gear	0.33	-13.7
motor	0.20	-294.1
systems	0.17	24.4
motor battery	0.27	-120.9
payload	1.80	11.5
total	3.95	3.5

Loads

The aircraft has a mass of 3.95 kg. The aircraft is in a flight condition where the normal load factor is 2 and the wing aerodynamic pitching moment is -2.25 Nm. The wing lift and the horizontal tail lift must be computed so that the aircraft is in a state of longitudinal equilibrium. The drag force on the wing is 1/30 of its lift and the vertical tail lateral load is 1/3 of the horizontal tail lift. All loads on the lifting surfaces may be assumed uniformly distributed along their quarter chord lines.

Structure

For the sake of validation of the developed tool, a single isotropic material may be used for all with the properties shown in Table 6. The main section dimensions are summarized in Table 7.

Table 6: Material properties.

Property	unit	2024-T3
Density	kg/m^3	2780
Elastic modulus	GPa	73.1
Poisson ratio	-	0.33
Tensile yield stress	MPa	345
Tensile strength	MPa	483
Compressive strength	MPa	462
Shear strength	MPa	283

Table 7: Structure dimensions.

Part	thickness, mm	position	area, mm^2
Wing spar	-	0.25c	-
Wing spar web	0.5	-	-
Wing spar flange		-	24
Wing skin	0.25	-	-
Horizontal tail spar	-	0.5c	-
Horizontal tail web	0.25	-	-
Horizontal tail flange		-	5
Horizontal tail skin	0.15	-	-
Vertical tail spar	-	0.5c	-
Vertical tail web	0.25	-	-
Vertical tail flange		-	5
Vertical tail skin	0.15	-	-
Fuselage	1	-	-

5. TASK RESPONSIBLITY

This is a group project where each student should develop his/her task so that it is integrated seamlessly in the final program.