UNIVERSIDADE
BEIRA INTERIOR

DEPARTAMENTO DE CIÊNCIAS AEROESPACIAIS

MECÂNICA ESTRUTURAL – 10391/10411

2023/2024

Mini-Project

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 two-dimensional (2D) shell finite element (FE) suitable to be used on thin-walled structures subjected to transverse arbitrarily distributed loads and having the required number of degrees-of-freedom (DOF).
- To use the developed FE to create a representation of a 3D surface of revolution.
- To develop a computer code to perform static, modal, and dynamic analyses of a axi-symmetric thin-walled structure with given shape, materials, loads and constraints.
- To perform the static, modal, and dynamic analyses of a rocket engine under a time dependent internal pressure profile.
- 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 shell elements to analyse the structure of a rocket engine. The tool should be able to calculate deflections, strains, and stresses due to static and dynamic loads and mode shapes with corresponding frequencies. The general the axi-symmetric shell under a distributed load is illustrated in Figure 1.

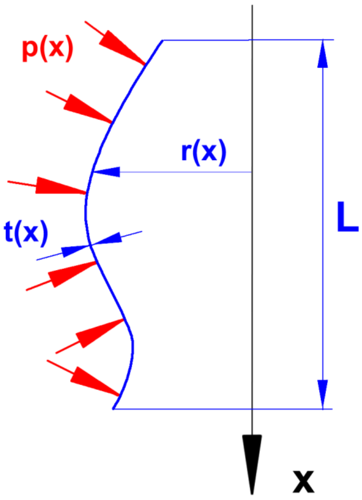

Figure 1: Axi-symmetric shell under distributed load.

3. PROJECT REQUIREMENTS

Part I

The development of the computer code to calculate the static and dynamic deflections, strains, and stresses and the natural mode shapes of vibration with the corresponding natural frequencies of a rocket engine structure shall be divided into the following tasks:

1. Investigation of the typical structure of a FEM program.
2. Development of a flowchart indicating the problem structure and the relationship between its various modules.
3. Investigation of the existing shell finite elements and selection of the most appropriate for the current problem.
4. Development of the mathematical models for the rocket engine structure:
    a. Two-dimensional n-DOF linear shell finite element model for static analysis.
    b. Two-dimensional n-DOF linear shell finite element model for modal analysis.
    c. Two-dimensional n-DOF linear shell finite element model for dynamic analysis.
    d. Rotated shell model (consider the use of axi-symmetric elements).
    e. Loads and boundary conditions.
    f. Geometry and structural properties.
    g. Meshing.
    h. System of equations and problem solving.
    i. Data post-processing and visualization.
5. Development of the algorithms for the mathematical models previously developed.
6. Implementation in a suitable programming language (Fortran, Python, etc.), validation, and testing of the code modules of the previously developed algorithms.
7. Preparation of an individual report describing the previous tasks. The report should not have more than 15 pages. The codes should be included in an appendix.

Part II

A case study should be used to validate the code (see Section 4). The development of the computer code to calculate the static and dynamic deflections, strains, and stresses and the natural mode shapes of vibration with the corresponding natural frequencies of a rocket engine structure shall be divided into the following tasks:

8. Review of the previous independent models and code.
9. Development of a flowchart indicating the program structure and the relationship between its various modules.
10. Integration of the various program modules to create the FEM program for the complete airplane structure.
11. Develop the case study and compare with commercially available software solutions.
12. Preparation of a single final report describing the previous tasks. The report should not have more than around 60 pages. The code should be included in an appendix.

4. CASE STUDY

The case study to be analysed consists of a rocket engine to be used in the Fenix rocket with the characteristics described below.

Geometry

The rocket engine geometry is shown in Figure 2. This is an axi-symmetric thin-walled structure.

Figure 2: Rocket engine geometry.

Mass distribution

The density of the material used in the shell is uniform. The density value is shown in Table 1.

Loads

The load applied to the structure consists of a time dependent axi-symmetric pressure distribution. This pressure distribution is then a function of position and time, which can be defined as an analytic function or as a set of profiles discretised in space and time.

Structure

For the sake of validation of the developed tool, a single isotropic material may be used for the complete structure with the properties shown in Table 1. The main dimensions are given in Figure 2.

Table 1: 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

5. TASK RESPONSIBLITY

This is a group project where each student should select a different task to contribute to the final program. Each student should develop his/her task so that it is integrated seamlessly in the final program. The task distribution is summarized in Table 2.

Table 2: Tasks and students' names.

Taks	Name
1	all
2	all
3	all
4,5,6: a,d - static	
4,5,6; b,d - modal	
4,5,6: c,d - dynamic	
4,5,6: e – load conditions	
4,5,6: f,g – properties, mesh	
4h,5h,6h - solution	
4i,5i,6i - output	
7	all
8	all
9	all
10	all
11	all
12	all