



Course guide

220351 - 220351 - Advanced Aeroelasticity

Last modified: 02/04/2024

Unit in charge: Terrassa School of Industrial, Aerospace and Audiovisual Engineering
Teaching unit: 220 - ETSEIAT - Terrassa School of Industrial and Aeronautical Engineering.

Degree: MASTER'S DEGREE IN AERONAUTICAL ENGINEERING (Syllabus 2014). (Optional subject).
MASTER'S DEGREE IN SPACE AND AERONAUTICAL ENGINEERING (Syllabus 2016). (Optional subject).

Academic year: 2024 **ECTS Credits:** 5.0 **Languages:** English

LECTURER

Coordinating lecturer: David Roca

Others:

PRIOR SKILLS

It is highly recommended to have acquired knowledge from AEROSPACE STRUCTURES and AERODYNAMICS before this course, or having previously attended the following master's courses:

- ELEMENTS RESISTENTS A L'AERONÀUTICA (220375).
- AERODINÀMICA, MECÀNICA DE VOL I ORBITAL (220301).

Fundamental knowledge from low-speed aerodynamics and structural dynamics is required:

- Thin airfoil theory (Kutta-Joukowski theorem).
- Aerodynamic coefficients and non-dimensional analysis.
- Beams theory (bending and torsion).
- Concept of shear center.
- Lagrange's method to retrieve equations of motion in dynamic systems.
- Structural problems resolutions with matrix methods (concepts of stiffness and mass matrices).

Additionally, basic programming skills are recommended (although not required).

DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES

Specific:

CEEVEHI1. MUEA/MAS: Sufficient applied knowledge of advanced, experimental and computational aerodynamics (specific competency for the specialisation in Aerospace Vehicles).

CEEVEHI2. MUEA/MAS: Sufficient applied knowledge of the aeroelasticity and structural dynamics of aircraft (specific competency for the specialisation in Aerospace Vehicles).

CEEVEHI3. MUEA/MASE: Applied knowledge of composite materials technology and a capacity for designing the basic elements of these materials (specific competency for the specialisation in Aerospace Vehicles).

TEACHING METHODOLOGY

The course is structured in two parts:

a) Theory + practice lessons. During the first half of the course, the students will acquire the fundamental theory with lessons combining presentations of the physical concepts, analysis methods and insightful results by the teacher, with practice problems to be solved by the students, under the teacher's supervision. The objective of such practice lessons is to review the theoretical concepts presented, and for the students to properly understand the underlying theory behind them, as well as their impact in practical contexts. At the end of this part, the students will demonstrate their understanding of the theory along with their problem solving skills through an exam.

b) Project. During the second half of the course, a project will be proposed to the students in which they will have the chance to apply the acquired concepts and skills into a relevant problem. The idea is to introduce the students to new, more sophisticated methodologies that are currently used in practical environments to deal with aeroelastic problems and analysis. To this end, the lecture hours will be devoted to: (1) present the techniques required to solve the problem, (2) provide time for the students to work on the project while solving any questions/doubts that may arise, and (3) open discussions proposed by the teacher or the students about novel aspects in the aeroelasticity field. A project report and oral presentation will be considered to evaluate this part.

While the scope of the course is devised so that most of the work can be done during the lecture hours (including the problems resolution and project related work), some self-study time will be required to gain more in-deep understanding knowledge, which is fundamental in order to acquire the necessary abilities of critical thinking and autonomous problem-solving.

LEARNING OBJECTIVES OF THE SUBJECT

This course serves as an introduction to the field of aeroelasticity, starting from the most basic concepts required from aerodynamics and structural analysis, to end up with a deep understanding of the most relevant phenomena in the context of static and dynamic aeroelasticity. These phenomena will be analysed both from the physical (theoretical) point of view, aiming at acquiring the fundamental base, and from the point of view of implementation (practical), reviewing the numerical techniques used nowadays, and applying them to a proposed problem in the context of a project.

STUDY LOAD

Type	Hours	Percentage
Self study	80,0	64.00
Hours small group	15,0	12.00
Hours large group	30,0	24.00

Total learning time: 125 h

CONTENTS

1. Introduction

Description:

- Course structure.
- The concept of aeroelasticity.
- Basic aerodynamics background.
- Basic structures background.

Full-or-part-time: 11h

Theory classes: 3h

Self study : 8h

2. Static aeroelasticity

Description:

2.1. Airfoil model

- Divergence condition.
- Control reversal condition.

2.2. Wing model

- Lumped panel elements.
- Beam model.

Related activities:

Problem 1. Divergence of an airfoil with a flap.

Problem 2. Control reversal of an airfoil with a leading edge slat.

Problem 3. Divergence and associated modes of a wing.

Full-or-part-time: 25h

Theory classes: 6h

Laboratory classes: 3h

Self study : 16h

3. Dynamic aeroelasticity

Description:

3.1. Airfoil model

- Equations of motion. Lagrange method.
- Flutter.

3.2. Approximate solutions

Related activities:

Problem 4. Airfoil equations of motion.

Problem 5. Flutter analysis with Theodorsen's aerodynamic model of an airfoil.

Full-or-part-time: 25h

Theory classes: 6h

Laboratory classes: 3h

Self study : 16h

4. Project

Description:

The project will involve the implementation of different numerical tools in MATLAB to perform a divergence and flutter analysis of a wing. Lecture time will be devoted to present the required numerical tools and assist the students with their work on the project.

The project can be done individually or in groups of maximum two people. Each group will be required to submit a report to Atenea, presenting and explaining the relevant results along with the MATLAB code implementation, during the final exams period (specific dates will be determined during the course). At the same time, each group will perform an oral presentation in which the teacher can ask each member questions about the results and implementation.

Full-or-part-time: 64h

Theory classes: 15h

Laboratory classes: 9h

Self study : 40h

GRADING SYSTEM

The final course grade will come from the following four evaluation items:

- Exam for the theory + practice part of the course (35% of the final grade). (*)
- Project report. (35% of the final grade).
- Project presentation (20% of the final grade).
- Excellence criteria (10% of the final grade). (**)

(*) Those students with an exam grade < 6.0, are qualified to request a reconduction via an oral exam that will take place at the end of the project presentation. In this case, the final exam grade will be the higher among the two (original exam and oral exam reconduction) but limited to a maximum of 6.0.

(**) Excellence criteria will be established by the teacher based on each student's progress throughout the course (participation during lectures, additional analysis beyond minimum requests, excellent presentation skills, etc.).

Final grade = 0.35 * Final exam + 0.35 * Project report + 0.20 * Project presentation + 0.10 * Excellence criteria

Where:

Final exam grade = MAX (Partial exam grade , MIN (6.0 , Oral exam grade))

The students with a final grade greater of equal to 2.0 but less than 5.0 can request a reevaluation exam (35% of the final grade) during the corresponding period in the next semester. The final grade after the reevaluation will be:

Final grade reevaluation = MIN (5.0 , MAX (Original final grade , 0.35 * Reevaluation exam + 0.35 * Project report + 0.20 * Project presentation + 0.10 * Excellence criteria))

BIBLIOGRAPHY

Basic:

- Hodges, Dewey H.; Pierce, G. Alvin. Introduction to structural dynamics and aeroelasticity [on line]. 2nd ed. Cambridge: Cambridge University Press, 2011 [Consultation: 20/02/2023]. Available on: <https://www-cambridge-org.recursos.biblioteca.upc.edu/core/books/introduction-to-structural-dynamics-and-aeroelasticity/38F8A0FF59844464F5034E8E0EA8BD31>. ISBN 9780521195904.

Complementary:

- Katz, J.; Plotkin, A. Low speed aerodynamics. 2nd ed. Cambridge: Cambridge University Press, 2001. ISBN 0521665523.
- Timoshenko, Stephen. Vibration problems in engineering. 2nd ed. New York: Lulu Com, 2012. ISBN 9781105528422.