Course guide
205015 - 205015 - Turbulence: Phenomenology, Simulation and Aerodynamics

Last modified: 11/04/2025

Unit in charge: Terrassa School of Industrial, Aerospace and Audiovisual Engineering
Teaching unit: 724 - MMT - Department of Heat Engines.

Degree: MASTER'S DEGREE IN AERONAUTICAL ENGINEERING (Syllabus 2014). (Optional subject).
MASTER'S DEGREE IN SPACE AND AERONAUTICAL ENGINEERING (Syllabus 2016). (Optional subject).
MASTER'S DEGREE IN RESEARCH IN MECHANICAL ENGINEERING (Syllabus 2021). (Optional subject).
MASTER'S DEGREE IN MECHANICAL ENGINEERING RESEARCH (Syllabus 2024). (Optional subject).

Academic year: 2025 **ECTS Credits:** 5.0 **Languages:** English

LECTURER

Coordinating lecturer: Trias Miquel, Francesc Xavier
Perez Segarra, Carlos David

Others: Balcázar Arciniega, Néstor Vinicio
Amani, Ahmad

TEACHING METHODOLOGY

The goals of the course are: i) Know and understand the phenomenology of turbulent flows; ii) Understand and correctly interpret statistical tools for turbulent flows; iii) Learn the basics of modelling turbulence; iv) Performing various practical number to better understand the theoretical aspects of the course.
At the end of the course, the student will have basic knowledge of turbulence and its energy spectrum. Furthermore, the statistical treatment of turbulent flows, modelling and resolution of turbulent flows, and their application of basic numerical methods and turbulence to improve energy efficiency by means of efficient aerodynamic designs.
Methodology in large group. The content of the course will follow a model of exhibition class and participation. The material is organised into 5 subject areas or themes. Guided works are proposed to consolidate the explanation in the lecture room.

LEARNING OBJECTIVES OF THE SUBJECT

STUDY LOAD

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

Total learning time: 125 h

CONTENTS

Module 1: Introduction-review of the governing equations: Navier-Stokes and energy conservation. Basic concepts. Theory of boundary layer

Description:
General review of the Navier-Stokes equations. Basic principles, symmetries and invariants. Brief introduction to the theory of the boundary layer.

Related activities:
Know the basic principles of the Navier-Stokes equations and the physical meaning of each of its terms.
Learn the relationship between symmetry operators and invariants.
Know the basic concepts about the theory of the boundary layer needed to perform numerical simulations.

Full-or-part-time: 11h
Theory classes: 3h
Self study : 8h

Module 2: Introduction to turbulence. Energy spectrum. Averaged Navier-Stokes equations. Average flow and Reynolds tensor terms. Statistical treatment: autocorrelations, PDF ...

Description:
From the Navier-Stokes equations the phenomenology of turbulence and its statistical treatment is introduced. Introduction of the concept of energy spectrum from a simple practical exercise.

Related activities:
Review of basic statistical concepts. Introduction of statistical treatment of the Navier-Stokes equations.
Introduction of the concept of energy spectrum and its link with everyday reality.
Introduction to turbulence and its mathematical complexity.

Full-or-part-time: 29h
Theory classes: 6h
Self study : 23h

Module 3: Numerical methods for solving the governing equations. Conservative discretisation. Temporary integration of equations. Solvers.

Description:
Introduction to numerical methods for the resolution of turbulent flows. Analysis of the conservative properties of discrete equations and deduction of which properties must meet the numerical schemes to be consistent.

Related activities:
Be able to represent in an algebraic way a system of discrete equations.
Understand the link between the symmetries of discrete and continuous operators.
Be able to deduce the properties of discrete operators in order to maintain the same invariants continuous.
Implement it in their own code and verify their conservative properties.

Full-or-part-time: 33h
Theory classes: 8h
Laboratory classes: 4h
Self study : 21h

Module 4: Direct turbulence resolution (DNS). Different forms of modelling turbulence: LES and models of regularisation

Description:
Introduction to direct simulation of turbulence. Understand its potential and its limitations. Introduction to modelling techniques of turbulence of Large-Eddy Simulation (LES) types and the models of regularisation of convective heat.

Related activities:
Know what direct simulations of turbulence involve. What is its usefulness and what are its limitations.
Know the basic principles behind the modelling techniques or Large-Eddy Simulation (LES) types of turbulence.
Brief explanation of the models used today.
Know the basic principles behind the turbulence modelling techniques based on regularisation of convective heat.

Full-or-part-time: 24h
Theory classes: 5h
Laboratory classes: 5h
Self study : 14h

Module 5: Application of simulation techniques in the study of flows around obstacles, around a cylinder, around an aerodynamic profile and around a simplified car

Description:
Apply the acquired knowledge to some technological cases.

Related activities:
Know the different technologies used depending on the working temperature range.
Know the different environmental aspects and regulations related to solar thermal installations such as low and high temperature.
Know the different methods and software for calculating solar thermal installations.
Be able to perform the calculation and dimensioning of different types of solar thermal installations such as facilities for sanitary water heating, absorption cooling facilities, thermo-solar plants.

Full-or-part-time: 28h
Theory classes: 8h
Laboratory classes: 6h
Self study : 14h

GRADING SYSTEM

Written test: 35%
Work performed individually and/or in groups: 65%

BIBLIOGRAPHY

Basic:
- Pope, S. B. Turbulent flows. Repr. with corr. Cambridge [etc.]: Cambridge University Press, 2000. ISBN 0521591252.
- Berselli, L.C.; Iliescu, T.; Layton, W.J. Mathematics of large eddy simulation of turbulent flows [on line]. Berlin: Springer, cop. 2006 [Consultation: 03/05/2022]. Available on: https://link-springer-com.recursos.biblioteca.upc.edu/book/10.1007/b137408. ISBN 3540263160.
- Patankar, S.V. Numerical heat transfer and fluid flow [on line]. Washington: New York: Hemisphere; McGraw-Hill, cop. 1980 [Consultation: 16/11/2022]. Available on: https://www-taylorfrancis-com.recursos.biblioteca.upc.edu/books/mono/10.1201/9781482234213/numerical-heat-transfer-fluid-flow-suhas-patankar. ISBN 0891165223.
- Sagaut, P.; Méneveau, C. Large eddy simulation for incompressible flows: an introduction. 3rd ed. Berlin [etc.]: Springer, cop. 2006. ISBN 3540263446.

Complementary:

- Saad, Yousef. Iterative methods for sparse linear systems. 2nd ed. Philadelphia: SIAM, cop. 2003. ISBN 0898715342.
- Foias, Ciprian. Navier-Stokes equations and turbulence. Cambridge: Cambridge University Press, 2001. ISBN 0521360323.
- Frisch, Uriel. Turbulence: the legacy of A.N. Kolmogórov. Cambridge: Cambridge University Press, cop. 1995. ISBN 0521457130.
- Wendt, J.F.; Anderson, J.D. Computational fluid dynamics: an introduction. 3rd ed. Berlin: Springer, 2009. ISBN 9783540850557.