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205015 - Turbulence: Phenomenology, Simulation, Aerodynamics

Coordinating unit: 205 - ESEIAAT - Terrassa School of Industrial, Aerospace and Audiovisual Engineering

Teaching unit: 724 - MMT - Department of Heat Engines

Academic year: 2018

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

ECTS credits: 5 Teaching languages: English

Teaching staff

Coordinator: Xavier Trias
Carlos D. Pérez-Segarra

Others: Aleix Baez
Jorge Chiva

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

Total learning time: 125h	Hours large group:	30h	24.00%
	Hours medium group:	0h	0.00%
	Hours small group:	15h	12.00%
	Guided activities:	0h	0.00%
	Self study:	80h	64.00%

Content

Module 1: Introduction-review of the governing equations: Navier-Stokes and energy conservation. Basic concepts. Theory of boundary layer	Learning time: 11h Theory classes: 3h Self study : 8h

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.

Module 2: Introduction to turbulence. Energy spectrum. Averaged Navier-Stokes equations. Average flow and Reynolds tensor terms. Statistical treatment: autocorrelations, PDF ...	Learning time: 29h Theory classes: 6h Self study : 23h

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.

Module 3: Numerical methods for solving the governing equations. Conservative discretisation. Temporary integration of equations. Solvers.	Learning time: 33h Theory classes: 8h Laboratory classes: 4h Self study : 21h

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.

Module 4: Direct turbulence resolution (DNS). Different forms of modelling turbulence: LES and models of regularisation	Learning time: 24h Theory classes: 5h Laboratory classes: 5h Self study : 14h

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.

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	Learning time: 28h Theory classes: 8h Laboratory classes: 6h Self study : 14h

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.

Qualification system

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

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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: 16/11/2016]. Available on: <http://dx.doi.org/10.1007/b137408>. ISBN 3540263160.

Patankar, S.V. Numerical heat transfer and fluid flow. Washington: New York: Hemisphere; McGraw-Hill, cop. 1980. 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.