Heat transfer and combustion

Lecturer
Alessandro PARENTE (Coordinator)

Course mnemonic
MECA-H418

ECTS credits
4 credits

Language(s) of instruction
English

Course period
Second term

Course content

Combustion science will play a major role in the future quest for sustainable, secure and environmentally friendly energy sources. Two thirds of the world energy supply relies on combustion of fossil and alternative fuels today, and all scenarios indicate that combustion will mantain a crucial role in the future energy scenarion, for the conversion of renewables cources as well as CO2-free or neutral energy carriers. Given the present and future role of combustion in our society, this course aims at extending the combustion basics presented in the thermodynamic bachelor courses and extend them to cover advanced topics in chemical kinetics, premixed and diffusion flames, laminar and turbulent reacting systems, ignition and stabilization and, importantly, pollutant formation and control. The latter aspect is covered in detail, by presenting the most up-to-date technologies for the reduction of pollutants, e.g. NOx, such as flameless combustion. Finally, the heat transfer modes are analysed in the framework of combustion processes with special emphasis on radiation (the less covered aspect in the bachelor thermodynamic courses), pointing out the complexity of turbulence-radiation interactions and introducing the approaches for treating combustion in the simulation of practical combustion systems. []

In details the course includes the following chapters:

- Rehearsal on combustion thermodynamics (adiabatic flame temperature and equilibrium).
- Combustion kinetics (detailed and reduced mechanisms).
- Coupling thermal and chemical analyses of reacting systems (Reactor models). Premixed and diffusion flames (laminar and turbulent).
- Ignition and flame stability.
- Formation and control of pollutants in combustion processes.
- Introduction to the numerical modelling of turbulent combustion systems using state-of-the-art simulation software.
- Radiative heat transfer in combustion systems: radiative transfer and radiation/turbulence interactions, radiative properties and solution methods for numerical simulations.

Objectives (and/or specific learning outcomes)

The objective of the present course is to i) gain insight in combustion physics; ii) become familiar with industrial combustion parameters; iii) understand the main assumptions associated to the numerical modeling of combustion systems (choice of the combustion model and kinetic mechanism).

The assessment of the course is based on a group project based on the numerical simulation of a given combustion system using state-of-the art Computational Fluid Dynamics (CFD) software (Ansys FLUENT). The project objective is to understand the main physics behind the combustion process under investigation, identify strength and limitations of simulation tools and to propose potential improvements/perspectives for future work.

The final outcome of the course is the preparation of a short scientific article and of a presentation outlining the main results of the project.

Specific learning objectives include being able to:

- Compute the adiabatic flame temperature of multicomponent gas mixtures with infinitely fast chemistry, chemical equilibrium and simplified reactor configurations.
- Distinguish between global, semi-global and elementary reaction mechanisms.
- Compute the structure and characteristics of a premixed flame, including flame speed, thickness, quenching distance and minimum ignition energy.
- Compute the structure and characteristics of a diffusion flame, including the height, lift-off distance and blow-off limits.
- Estimate the formation of pollutants, especially NO^x, from combustion processes.
- Understand the behaviour and operation of industrial combustion systems, including ignition and stabilization issues.
- Use advanced computer codes to model combustion systems, by simulating the detailed flame structures.

Teaching method and learning activities

Lectures, exercises under supervision, project, personal work.

Contribution to the teaching profile

This teaching unit contributes to the following competences:

- In-depth knowledge and understanding of exact sciences with the specificity of their application to engineering
- In-depth knowledge and understanding of the advanced methods and theories to schematize and model complex problems or processes
- Reformulate complex engineering problems in order to solve them (simplifying assumptions, reducing complexity)

- Conceive, plan and execute a research project, based on an analysis of its objectives, existing knowledge and the relevant literature, with attention to innovation and valorization in industry and society
- Correctly report on research or design results in the form of a technical report or in the form of a scientific paper
- Present and defend results in a scientifically sound way, using contemporary communication tools, for a national as well as for an international professional or lay audience
- Collaborate in a (multidisciplinary) team
- Develop, plan, execute and manage engineering projects at the level of a starting professional
- Think critically about and evaluate projects, systems and processes, particularly when based on incomplete, contradictory and/or redundant information
- A creative, problem-solving, result-driven and evidence-based attitude, aiming at innovation and applicability in industry and society
- A critical attitude towards one's own results and those of others
- Consciousness of the ethical, social, environmental and economic context of his/her work and strives for sustainable solutions to engineering problems including safety and quality assurance aspects
- The flexibility and adaptability to work in an international and/or intercultural context
- An attitude of life-long learning as needed for the future development of his/her career
- Has a broad scientific knowledge, understanding and skills to be able to design, produce and maintain complex mechanical, electrical and/or energy systems with a focus on products, systems and services.
- Has an in-depth understanding of safety standards and rules with respect to mechanical, electrical and energy systems.

References, bibliography and recommended reading

- I. Glassman, R. Yetter, Combustion, Elsevier Science and Technology, 2008.▪ K. Kuo, Principles of combustion, John Wiley, 2005.▪ C. K. Law, Combustion Physics, Cambridge University Press, 2006.▪ N. Peters, N. Peters, Cambridge University Press, 2001.▪ T. Poinsot, D. Veynante, Theoretical and Numerical Combustion, R.T. Edwards, Inc., 2001.▪ S. R. Turns, An Introduction to Combustion: Concepts and Applications, McGraw-Hill, New York, NY, 2012.▪ J. Warnatz, U. Maas, R. W. Dibble, Combustion. Physical and chemical fundamentals, modeling and simulation, experiments, pollutant formation, Springer, Berlin, 2001.

Other information

Contact(s)

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Evaluation method(s)

Other

Evaluation method(s) (additional information)

Oral examination.

The oral examination will focus on the presentation of the project. Moreover, a selected jury will be present to ask question related to the project, aiming at assessing, for each member of the group, the level of understanding of physical and theoretical matters behind the numerical modeling.

Determination of the mark (including the weighting of partial marks)

The final grade is composed based on the following categories:

Criteria for evaluation

- Clarity of presentation (written and oral), 40%. The written paper must be provided 3 days before the presentations. A presentation of 20 minutes shall be prepared, showing the main steps of the work and how each member of the group contributed to the project.
- Understating of the theoretical concepts, 30%. You will have questions concerning the work performed and you will be also evaluated for the ability of making connections between the practical work and the theory.
- Critical assessment, 30%. You will need to justify your results taking into account the experimental observations and the theoretical limitations of the models used.

Main language(s) of evaluation

English

Programmes

Programmes proposing this course at the Brussels School of Engineering

MA-IREM | Master of science in Electromechanical Engineering | finalité Professional/unit 1