Course guide
295811 - 295HY032 - High Temperature Solid Oxide Cells

Last modified: 26/06/2025

Unit in charge: Barcelona East School of Engineering
Teaching unit: 729 - MF - Department of Fluid Mechanics.

Degree: ERASMUS MUNDUS MASTER IN HYDROGEN SYSTEMS AND ENABLING TECHNOLOGIES (HYSET) (Syllabus 2024). (Optional subject).
MASTER'S DEGREE IN MECHANICAL TECHNOLOGIES (Syllabus 2024). (Optional subject).

Academic year: 2025 **ECTS Credits:** 6.0 **Languages:** English

LECTURER

Coordinating lecturer: MIGUEL MORALES COMAS

Others: Primer quadrimestre:
MIGUEL MORALES COMAS - Grup: T1

PRIOR SKILLS

Basic knowledge in materials and chemical engineering; process engineering; thermodynamics

LEARNING RESULTS

Knowledges:
K.03. Recognise the process and product design principles and methods that apply to smart manufacturing systems.
K.02. Identify the fundamental equations governing physical phenomena associated with complex problems in mechanical engineering.
K03. Demonstrate an understanding of the hydrogen value chain, including hydrogen production processes and technologies, hydrogen storage technologies, hydrogen transport/logistics/infrastructure, hydrogen end uses (stationary, mobility, industrial and residential, including fuel cells), hydrogen safety, codes and standards, and all socioeconomic issues related to the energy transition, partly driven by the use of hydrogen.
K02. Demonstrate in-depth knowledge of standards related to the safety of working with hydrogen, the integration of systems related to hydrogen technologies, and market potential.
K.06. Identify the most appropriate techniques, components and materials for the development of advanced applications in mechanical engineering.
K.05. Identify emerging technologies, both in the mechanical domain and in the field of new information and communication technologies, that can be applied to mechanical engineering projects.

Skills:
S.02. Correctly apply the analytical, computational and/or experimental techniques best suited to the analysis of a case or project in the mechanical field.
S.01. Comprehensively apply experimental techniques, calculations, evaluations, appraisals, expert reports, studies, work plans and related tasks in the development of mechanical engineering projects, applying compulsory specifications, regulations and standards at each stage of the process.
S01. Communicate effectively with others orally, in writing and graphically about learning, thought processes and decision making, and participate in discussions, using interpersonal skills such as active listening and empathy that support teamwork.
S02. Work in the field as well-trained, enthusiastic professionals with a broad multidisciplinary knowledge of hydrogen technologies and systems, educated in an international and multicultural environment to promote global cooperation in meeting the complex challenges of the energy transition.
S.08. Integrate knowledge from different areas of the mechanical field in the design and development of projects, systems and engineering solutions.
S.04. Incorporate sustainability and energy efficiency criteria into the design, planning, execution and operation phases of engineering projects.

Competences:
C.03. Manage the acquisition, structuring, analysis and visualisation of data and information in the mechanical field and critically evaluate the results of this process.
C.01. Recognise the complexity of the economic and social phenomena typical of a welfare society in order to relate welfare to globalisation and sustainability, and use techniques, technology and principles of economics and sustainability in a balanced and compatible way.
C.05. Propose advanced scientific and technological solutions to complex industrial challenges in the field of mechanical engineering.
C05. Propose advanced scientific and technological solutions to complex industrial challenges in the field of energy, with a focus on the use of hydrogen as a vector.
C01. Recognise the complexity of the economic and social phenomena typical of a welfare society in order to relate welfare to globalisation and sustainability, and use techniques, technology and principles of economics and sustainability in a balanced and compatible way.
C03. Manage the acquisition, structuring, analysis and visualisation of data and information in the field of energy transition and critically evaluate the results of this process.
C.02. Work as part of a multidisciplinary team, whether as a team member or in a leadership role, to contribute to the development of projects with pragmatism and a sense of responsibility, undertaking commitments with due regard to the resources available.

TEACHING METHODOLOGY

- Lectures and conferences: knowledge exposed by lecturers or guest speakers.
- Participatory sessions: the collective resolution of exercises, debates, and group dynamics, with the lecturer and other students in the classroom; classroom presentation of an activity individually or in small groups.
- Theoretical/practical supervised work: classroom activity, carried out individually or in small groups, with the advice and supervision of the professor.
- Homework assignment of reduced extension: carry out homework of reduced extension, individually or in groups.
- Homework assignment of broad extension (PA): design, planning, and implementation of a project or homework assignment of broad extension by a group of students, and writing a report that should include the approach, results, and conclusions.

LEARNING OBJECTIVES OF THE SUBJECT

- To develop scientific and technical skills to design and test high-temperature fuel and electrolyzer cells, and to set up the basis for their implementation, optimization and/or modification.
- To develop technical criteria to define and select a high-temperature fuel and electrolyzer cell system with the participation of other energy devices (fuel processing, hybridization with other fuel cells, or other energy technologies).
- To identify the challenges and weaknesses of Solid Oxide Cells materials, cells, devices, and systems, and to provide engineering solutions.
- To develop scientific skills to implement new ideas related to high-temperature fuel and electrolyzer cells.

STUDY LOAD

Type	Hours	Percentage
Hours large group	21,0	14.00
Self study	108,0	72.00
Hours small group	21,0	14.00

Total learning time: 150 h

CONTENTS

Topic 1. Introduction

Description:
Fuel and electrolyzer cells fundamentals and operating principles.

Full-or-part-time: 3h 30m
Theory classes: 1h
Self study : 2h 30m

Topic 2. Thermodynamics and electrochemical kinetics

Description:
Operating characteristics of cells. Thermodynamic and electrochemical losses. Electrical efficiency and heat rejection. Cell performance variables.

Full-or-part-time: 7h 10m
Theory classes: 2h
Self study : 5h 10m

Topic 3. Cell types

Description:
Molten Carbonate Fuel Cell (MCFC). Solid Oxide Cell (SOC). Protonic Ceramic Fuel Cell (PCFC).

Full-or-part-time: 21h 25m
Theory classes: 6h
Self study : 15h 25m

Topic 4. Cell components

Description:
Electrolyte materials. Anode materials. Cathode materials. Interconnect materials. Seal materials.

Full-or-part-time: 21h 25m
Theory classes: 6h
Self study : 15h 25m

Topic 5. Cell and stack designs

Description:
Planar and tubular design. Cell fabrication. Single-cell performance. Stack performance. Stack scale-up.

Full-or-part-time: 32h 10m
Theory classes: 6h
Laboratory classes: 3h
Self study : 23h 10m

Topic 6. Operation conditions of cells and stacks

Description:
Testing electrodes. Testing cells and stacks. Area-specific resistance (ASR). Comparison of test results on electrodes and on cells. Non-activated contributions to the total loss. Inaccurate temperature measurements. Cathode performance. Impedance analysis of cells. The problem of gas leakage in cell testing. Assessment of the size of the gas leak.

Full-or-part-time: 32h 10m
Theory classes: 6h
Laboratory classes: 3h
Self study : 23h 10m

Topic 7. Systems

Description:
Fuel processing. Power conditioning. Balance of Plant (BoP). System optimization. System designs. Hybrids.

Full-or-part-time: 32h 10m
Theory classes: 6h
Laboratory classes: 3h
Self study : 23h 10m

GRADING SYSTEM

Continuous assessment (2 exams; 30% each written exam), laboratory reports (20%), and final group project (20%).

EXAMINATION RULES.

Written exams are individual. Laboratory and projects are carried out in groups.

BIBLIOGRAPHY

Basic:

- Fuel cell handbook. Seventh edition. Virginia: National Energy Technology Laboratory, [2016]. ISBN 9781365101137.
- Morales, Miguel; Segarra, Mercè. "Materials issues for solid oxide fuel cells design". Handbook of clean energy systems. 2015, p. 1-17.
- Singh, Mandeep; Zappa, Dario; Comini, Elisabetta. "Solid oxide fuel cell: decade of progress, future perspectives and challenges". International journal of hydrogen energy [on line]. Vol. 46, Issue 54, p. 27643-27674 [Consultation: 05/09/2024]. Available on: https://www.sciencedirect.com/science/article/pii/S0360319921021704.- Irshad, Muneeb. "A brief description of high temperature solid oxide fuel cell's operation, materials, design, fabrication technologies and performance". Applied Sciences [on line]. Vol. 6, núm. 3, p. 75 [Consultation: 10/09/2024]. Available on: https://www.mdpi.com/2076-3417/6/3/75.

Complementary:

- Mahato, Neelima; Banerjee, Amitava; Gupta, Alka; Omar, Shobit; Balani, Kantesh. "Progress in material selection for solid oxide fuel cell technology: A review". Progress in materials science [on line]. Vol. 72, p. 141-337 [Consultation: 10/09/2024]. Available on: https://www-sciencedirect-com.recursos.biblioteca.upc.edu/science/article/pii/S0079642515000195.- Mogensen, M. B. "Reversible solid-oxide cells for clean and sustainable energy". Clean energy [on line]. 2019, Vol. 3, núm. 3, p 175-201 [Consultation: 10/09/2024]. Available on: https://doi.org/10.1093/ce/zkz023.- Shen, Minghai; Ai, Fujin; Ma, Hailing; Xu, Hui; Zhang, Yunyu. "Progress and prospects of reversible solid oxide fuel cell materials". iScience [on line]. 2021, Vol. 24, Issue 12, 103464 [Consultation: 10/09/2024]. Available on: https://www-sciencedirect-com.recursos.biblioteca.upc.edu/science/article/pii/S2589004221014358.- Mendonça, Catarina; Ferreira, António; Santos, Diogo M. F. "Towards the commercialization of solid oxide fuel cells : recent advances in materials and integration strategies". Fuels [on line]. 2021, 2(4), 393-419 [Consultation: 10/09/2024]. Available on: https://www.mdpi.com/2673-3994/2/4/23.- Shabri, Hazrul Adzfar. "Recent progress in metal-ceramic anode of solid oxide fuel cell for direct hydrocarbon fuel utilization : A review". Fuel processing technology [on line]. 2021, Vol. 212, 106626 [Consultation: 10/09/2024]. Available on: https://www-sciencedirect-com.recursos.biblioteca.upc.edu/science/article/pii/S0378382020309176.- Shen, Minghai; Zhang, Panpan. "Progress and challenges of cathode contact layer for solid oxide fuel cell". International journal of hydrogen energy [on line]. 2020, Vol. 45, Issue 58, p. 33876-33894 [Consultation: 10/09/2024]. Available on: https://www-sciencedirect-com.recursos.biblioteca.upc.edu/science/article/pii/S0360319920335874.