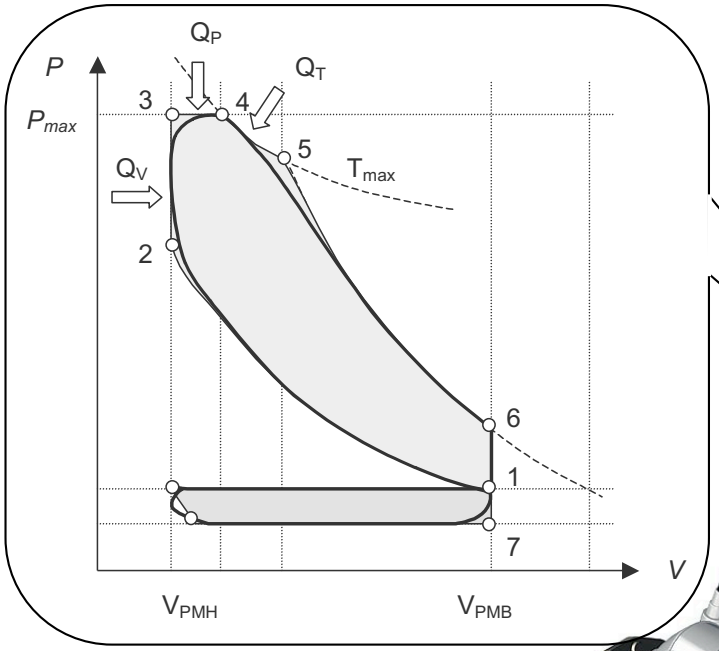
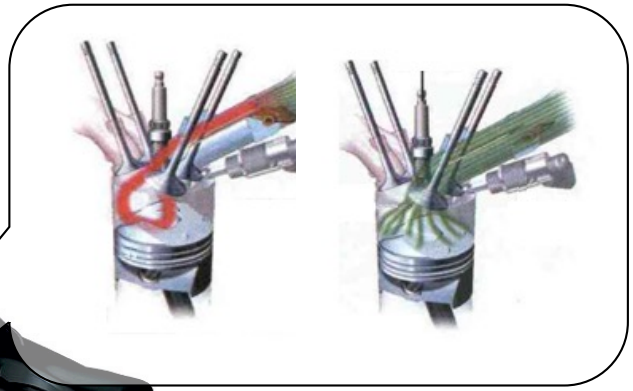
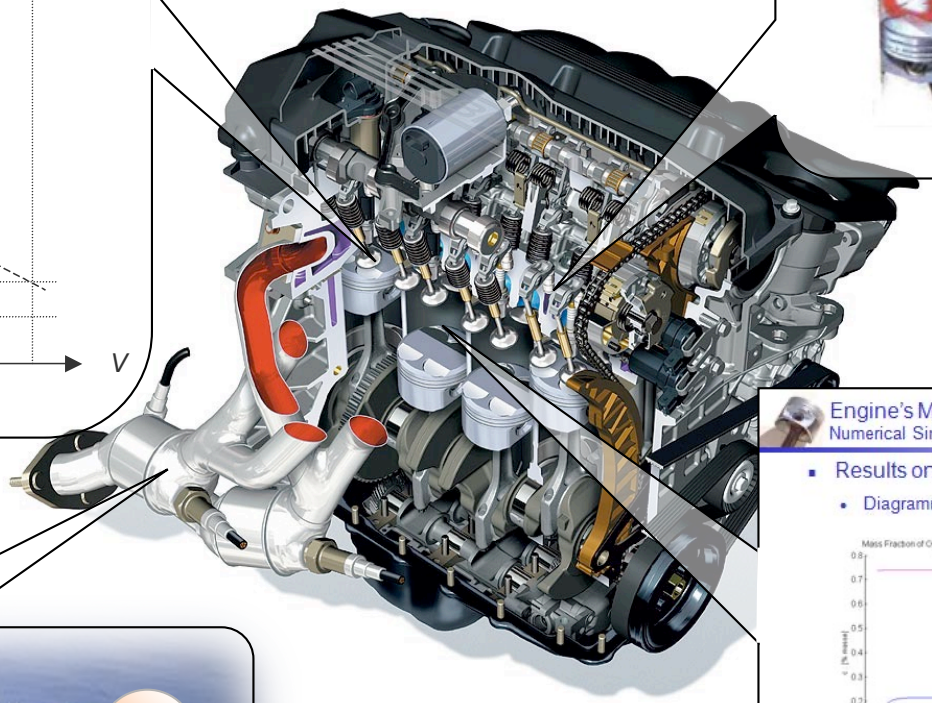
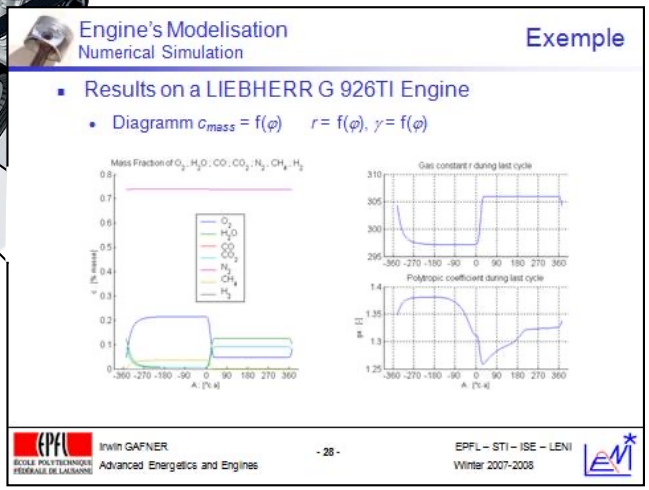
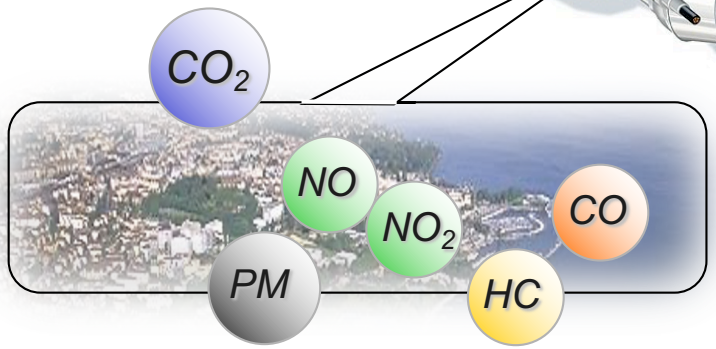
Engines


P
V
Q_P
Q_T
Q_V
P_{max}
T_{max}
1
2
3
4
5
6
7
V_{PMH}
V_{PMB}






Engine's Modelisation
Numerical Simulation
Exemple
Results on a LIEBHERR G 926TI Engine
Diagramm c_{mass} = f(φ) r = f(φ), γ = f(φ)
Irwin GAFNER
Advanced Energetics and Engines
- 28 -
EPFL – STI – ISE – LENI
Winter 2007-2008


CO_2
NO
NO_2
CO
PM
HC

Engines – preamble

- Reference books:

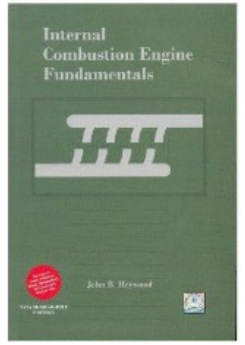
  A) Thermodynamique & Energétique 1, *L. Borel / D. Favrat*

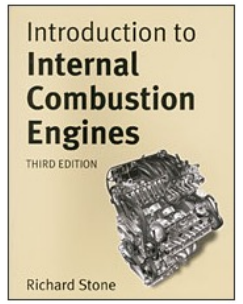
  B) Internal Combustion Engine Fundamentals, *John B. Heywood* (1988)

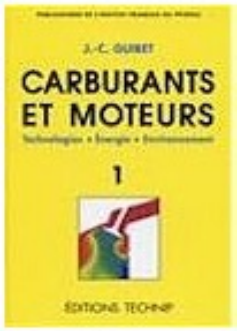
  C) Introduction to Internal Combustion Engines, *R. Stone* (SAE, 2012)

  D) Carburants & moteurs (2 books), J-C Guibet (Ed. Technip, IFP)

  E) V Ganesan, IC Engines, 4th Ed. McGraw Hill, 2016



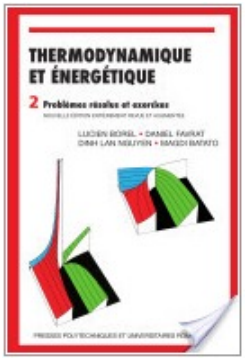




- Prerequisite:

  Thermodynamique & Energétique I & II

  (Sophia Haussener, Jan Van herle)



Contacts :
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Hangyu.Yu@epfl.ch
Martin.Gay@epfl.ch

Engines – preamble

- Course support – moodle:
  - Slides (ppt/pdf)
  - Animation videos
  - Exercises
  - Video recording of lectures
  - Formulae mementos (=> exam in January session)

- Potential invited seminar(s) – *depending on external lecturers*
  - Dr Jean-François Tissot (Acceleron, Baden (AG) : diesel engines, turbochargers)
  - Liebherr Motors (Bulle, FR)
  - Dr Mardit Matian (EH Group, Nyon (VD) : fuel cell mobility)
  - Prof Dr David Hart (E4Tech, Lausanne : consulting studies fuel cells/electrolysis/H2)

- Exam:

  January 2024, written (3h), 50% Engines, 50% Fuel Cells : calculation exercises. All material is allowed (open book). 60% of the final grade.

  ⇒ Week 10 (Nov13): theory test on Engines (45'). Closed book. 1/6th of final grade.

  ⇒ Week 14 (Dec18): theory test on Fuel Cells (45'). Closed book. 1/6th of final grade.

Why ‘fuel cells’ & ‘engines in a shared course ?

Similarities	Differences
Both use chemical fuel input (gas or liquid)	Engines : combustion (=>pollutants!) FC : direct electrochemical conv.
Application: Mobility	ICE cars, trucks, ships, trains FC electric (hybrid) cars, buses,…
Application: Stationary	Cogeneration engines : 0.1-10 MWe FC cogeneration units : 1-1000 kWe
Complex, pluridisciplinary	Engines: mech. eng. focus FC: chem.eng + mat.sci. focus

Engines - Objectives

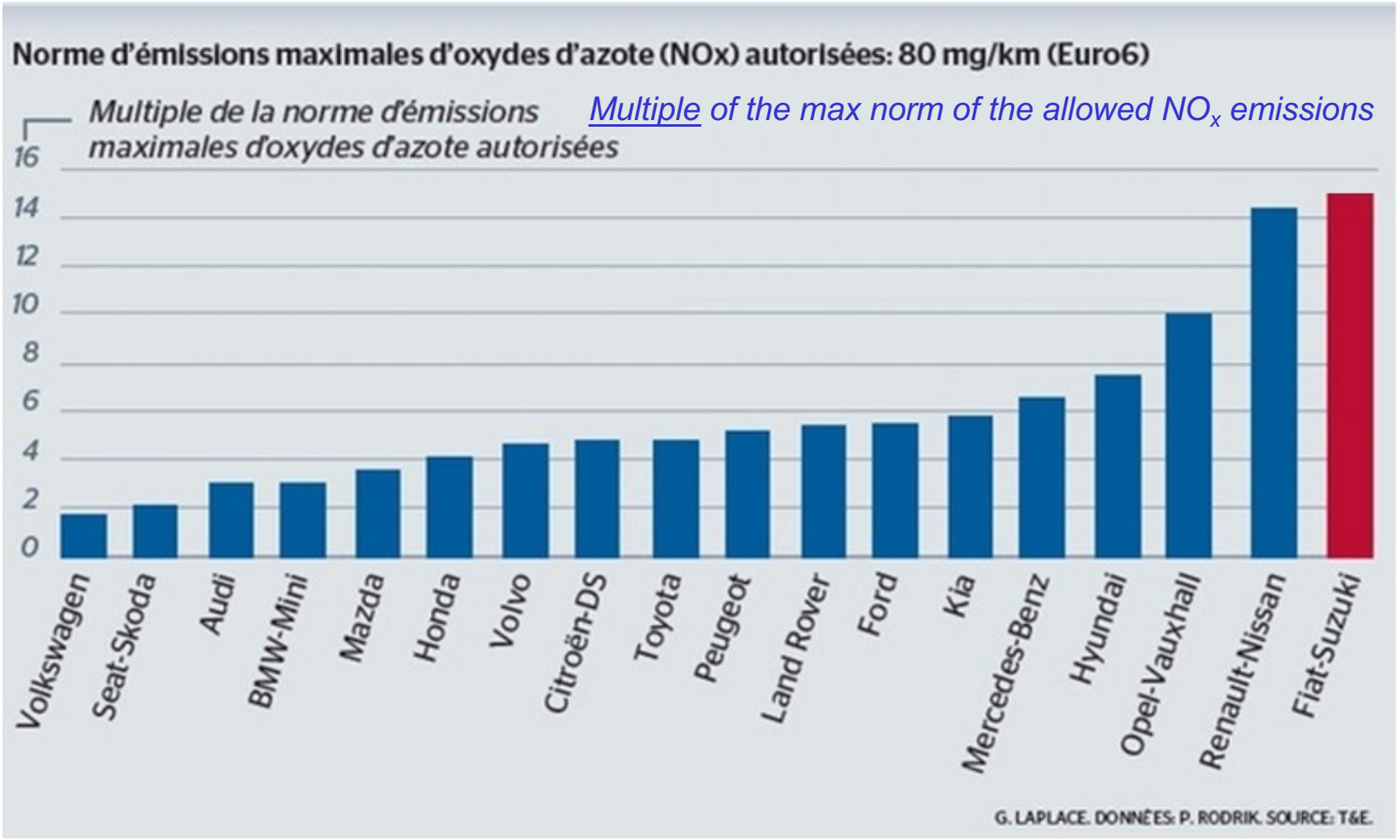
- Main objectives and targeted knowledge:

  ⇨ introduction to Internal Combustion Engines for transport and cogeneration applications

  ⇨ understand the main technological and methodological **options** in the design and use of internal combustion engines and exhaust gas treatment systems

  ⇨ understand the main technological **challenges** (trade-off) between mechanical, thermal, economical and environmental constraints

‘Dieselgate’



Source: Article «24 heures», 20.09.2016

Engines – Course content (1/2)

Week 1) Introduction to Internal Combustion Engines

- Description of the main components
- Operation principle (2 and 4-stroke, Diesel & Otto)
- Mechanical principles (incl. movies showing engine assemblies in 3D)
- Main material flows in an engine

11 sept

Week 2) Thermodynamic Cycles

- Reminder of thermodynamic fundamentals
- Theoretical and real cycles

18 sept

Week 3) Terminology and key values

- Engine cycle representation
- Engine operating characteristics
- Key factors and typical relations
- Efficiency definitions (from combustion to effective mech. power)
- Full load and operating map representation

25 Sep

Engines – Course content (2/2)

Week 4) Compression-Ignition Engines (CI *or* Diesel Engines)

2 oct

- Fuel properties and combustion process
- Noise analysis and prevention
- Load regulation & supercharging
- Energy distribution

Week 5) Spark-Ignition Engines (SI *or* Otto Engines)

9 oct

- Fuel properties and combustion process (ignition, knock limit)
- Load regulation
- New combustion concepts (mixed systems, direct gasoline injection)

Week 6 : Invited seminar Dr Jean-François Tissot, Acceleron (Turbochargers) — 16 oct

Week 7) Emission treatment systems

30 oct

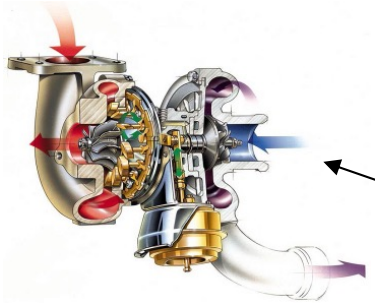
- Characterization of combustion gases and origin of pollutants
- Pollutant formation
- Emission standards (On & Off-road engines)
- Upstream methods and means of emissions reduction
- Downstream methods (3 way-cat, SCR, DPF, NOx trap)

Engines - course plan

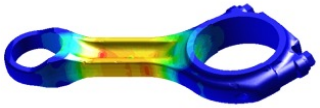
Week	Date	Content	Hours	
			Course	Exercise
1	Sep-11	Preambel Week 1: General Introduction Exercise 0 : simple num. examples of engine parameters	2-3	(intro)
2	Sep-18	Week 2 : Themodynamic cycles Exercise 1 :Thermodynamic cycle	2	1
3	Oct-25	Week 3 : Therminology and Definitions Exercise 2 : Gas engine	2	1
4	Oct-02	Week 4 : Diesel Engines Exercise 3 : Energy and exergy balance of a Diesel engine	2	1
5	Oct-09	Week 5 : Otto Engines Exercise 4 : Idle regulation of a S.I. Engine	2	1
6	Oct-16	*Week 6 : Invited lecture Dr J-F Tissot, Acceleron*	2	-
7	Oct-23	Semester break		
8	Oct-30	Week 7: Emission Treatment Systems Exercise 5 : Selection of a cogeneration engine	2	1
10	Nov-13	**45' theoretical exam on Engines part (closed book)**	1 Fuel cells	1 Fuel cells

Engines

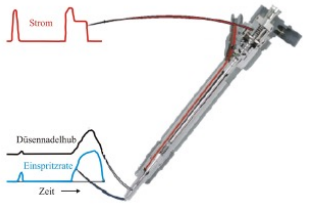
- Connection with other mech.eng. courses:



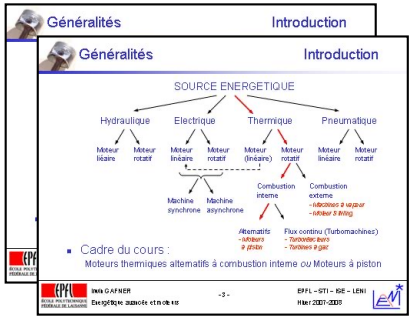
Thermal Turbomachines

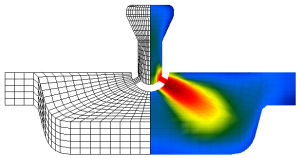


structural mechanics



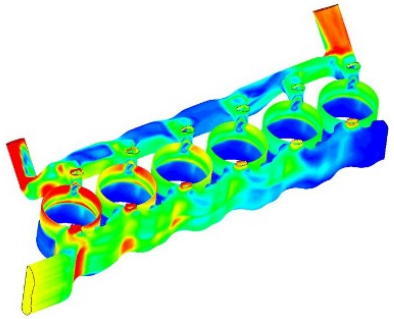
Identification and control





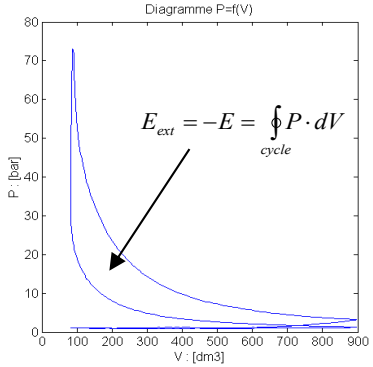
Numerical flow modelling

Mechanical design

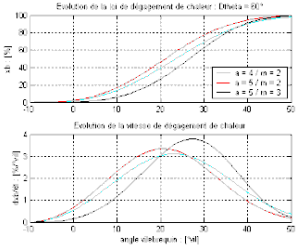


Heat transfer

Thermodynamics



Modelling and optimization of energy systems



$$(a1)\quad \frac{dP}{P} - \frac{dT_u}{T_u} + \frac{dV_u}{V_u} = -\frac{dM_b}{M_u} + \frac{dr_u}{r_u}$$

$$(a2)\quad \frac{dP}{P} - \frac{dT_b}{T_b} - \frac{dV_u}{V_b} = +\frac{dM_b}{M_b} - \frac{dV}{V_b} + \frac{dr_b}{r_b}$$

$$(a3)\quad M_u \cdot \frac{du_u}{dT} \cdot dT_u + P \cdot dV_u = (u_u - h_u) \cdot dM_b + dQ_{u,parois}$$

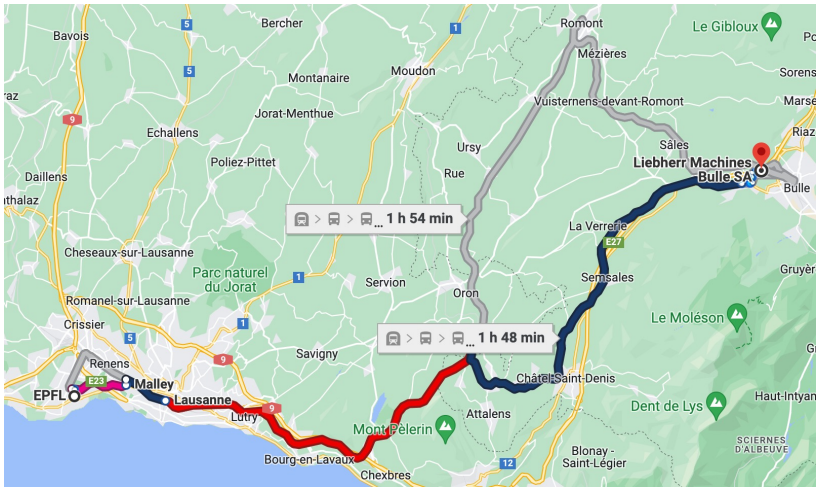
$$(a4)\quad M_b \cdot \frac{du_b}{dT} \cdot dT_b - P \cdot dV_u = (h_u - u_b) \cdot dM_b - P \cdot dV + dQ_{b,parois} + dQ_{comb}$$

Excursion during semester ?

- to Liebherr Engines factory, Bulle (FR)

https://youtu.be/yc2l0Azbgjk

Possible on Tue/Wed/Thu
Morning or afternoon
November or December
Max. 25 participants
Depends on personal interest



Past master semester projects at GEM

- 79. (JAN2020) Development of a pressure damping device for an evaporator coupled with a SOE
- 82. (JUN2020) PEFC electrochemical stack model
- 87. (JAN2022) Design exploration of a SOFC-battery hybrid supply for 50 pax electric aircraft
- 91. (JUN2022) Multi-objective optimization and economic analysis of SOFC-EV charging station
- 92. (JUN2022) Cooling strategies of a PEM fuel cell using CFD
- 96. (JUN2022) Anionic membranes screening and analysis / gas crossover
- 114. (JAN2024) Degradation analysis of single-cell accelerated stress tests via electrochemical impedance spectroscopy and distribution of relaxation time methods
- 115. (JAN2024) Minimizing Environmental Impact in Hydrogen Production Systems through Optimal Stack Module Sizing and Replacement Strategy
- 116. (JAN2024) Investigation of multiple scenarios for the exploitation of a SOFC-mGT system.
- 122. (JUN2024) Solid Oxide Electrolysers fault conditions footprint by using Electrochemical Impedance Spectroscopy (EIS) and Total Harmonic Distortion (THD)
- 123. (JUN2024) Performance and stability of metal-supported Solid Oxide Electrolysis Cells

Past master thesis projects at GEM (1)

- 48. (SEP2020) **CGN-Lausanne**, Layout of a H_2-electrical propulsion for a 1.8 MW ship
- 49. (SEP2020) Using NH_3 in SOFC for Heavy Duty Transport (*publication*)
- 50. (MAR2021) **Retrofuture-EV** (F), Integration study of an energy converter to an electric traction system in an automotive retrofit.
- 51. (MAR2021) **RUAG** (CH), Trade-off, Design and Model-Based Performance and Safety Analysis of Energy Storage Subsystems for Spacecrafts.
- 53. (MAR2021) Etude de faisabilité et conception d'un banc d'essai moteur à hydrogène
- 56. (AUG2021) **Swisshydrogen**, Development of compact FC range extender for automotive application
- 59. (JAN2022) Modeling and experimental investigation of critical conditions in reversible solid oxide cells using State-of-Health online monitoring
- 60. (JAN2022) Design and optimisation of a heat exchanger network for an integrated reversible SOFC system
- 61. (FEB2022) **Stadler**, Development of a simulation tool to optimize the design of hybrid propulsion systems on railway vehicles, and application in a case study on shunting locomotives

Past master thesis projects at GEM (2)

- 67. (AUG2022) **Michelin**, Modélisation d'une pile à combustible à membrane polymère PEMFC
- 68. (AUG2022) **Engie**, Thermodynamic modeling of Hydrogen Refueling Station
- 69. (SEP2022) **Liebherr**, THERMOMECHANICAL FATIGUE DAMAGE MODEL FOR ICE EXHAUST MANIFOLDS
- 74. (FEB2023) Two-Phase Simulation of AEM Electrolyser Flow Channels ***(=> Patent)***
- 75. (FEB2023) MEMBRANE ELECTRODE ASSEMBLY SIMULATION OF AEMEL
- 77. (MAR2023) **EH Group**, Modelling and dimensioning of a PEMFC active humidifier
- 80. (AUG2023) **Safran**, Instrumentation de pile à combustible PEMFC
- 81. (AUG2023) **Liebherr**, Engine Design modelling combining Statistical Approaches and AI
- 82. (AUG2023) **Stadler**, Electrical Modelling of the Auxiliary Consumptions in Trains
- 84. (Mar2024) **Garrett**, Design of a cooling system for a FS eMotor
- 89. (AUG2024) **Neology**, Optimization of an ammonia to hydrogen generation system
- 90. (AUG2024) **Beyond Aerospace**, Aviation Energy Efficiency: Hybridization Strategies for Battery and Fuel Cell Systems
- 91. (AUG2024) **SolydEra**, CFD modeling and analysis of ejectors for the recirculation of fuel in a SOC system
- 93. (AUG2024) Operating strategy of SOFC system for lifespan extension and performance optimization
- 94. (AUG2024) Characterisation and analysis of PEMFC cells and stacks