

ME 5xx: Fuel Cell Vehicles & Hydrogen Infrastructure

Instructors: D. Siegel and A. Stefanopoulou

Course statement: This course covers essential aspects of fuel cell vehicle technology, hydrogen fueling infrastructure, and potential benefits & barriers to the use of hydrogen as a vehicular fuel. Emphasis is placed upon system-level modeling and control issues of polymer electrolyte membrane fuel cells. Although the main emphasis is on vehicle propulsion, engine electrification and vehicular applications of auxiliary power through Solid Oxide FCs are also discussed. Additional attention is given to the principles and design of on board hydrogen storage systems. Hydrogen generation and distribution technologies are introduced, and life-cycle (well-to-wheels) analyses of petroleum consumption, efficiency, and CO₂ reduction are presented. Lectures will be supplemented with fuel cell vehicle demonstrations conducted by local automotive OEMs, and site visits to hydrogen fueling stations.

Does ****not**** require extensive background in fuel cell chemistry and materials.
Matlab and Simulink and other Mathworks toolboxes will be used.

Open to graduate or senior students with a basic background in mechanical, chemical, or electrical engineering. Permission from the instructor is required for senior undergraduate students.

Home Page: use Ctools (<https://ctools.umich.edu/portal>)

Will contain links to basic course information and lecture summary.

Email list: The ctools emailing capability will be used to send you announcements. You can always email me with questions. Attach your working m- or mdl- files if needed. Always use ME5xx in the message subject.

Text: A coursepack will be available. Lecture notes and handouts will be distributed in class or through Ctools.

Optional (reserved in the Library):

1. Fuel Cell Fundamentals (Hardcover) by Ryan O'Hayre, Suk-Won Cha, Whitney Colella, Fritz B. Prinz
2. Fuel Cell Systems Explained, Larminie, and Dirks, Wiley
3. The Hydrogen Economy: Opportunities, Costs, Barriers, and R&D Needs (National Academies Press)
4. Transitions to Alternative Transportation Technologies – A Focus on Hydrogen (National Academies Press)
5. Hydrogen Fuel: Production, Transport, and Storage (R. Gupta, CRC Press)
6. Mobility 2030: Meeting the Challenges to Sustainability (World Business Council for Sustainable Development)

Homework: The lowest homework score will be dropped. You may discuss the homework assignments with each other and with the instructor, but you **must write your own solutions** to the homework which reflect your own understanding of the material.

Grading: TBD (a combination of homework, midterm examinations and a project report)

Office Hours: TBD (in campus) TBD (off-campus)

Course Outline:

Chapter 1: Overview: Fuel Cell Vehicles (FCV) and Hydrogen as a vehicular fuel (2 lectures)

Benefits of a transition to FCV
(Reduced petroleum consumption, energy independence, lower CO₂ emissions...)
Barriers to the commercialization of FCV
(Infrastructure, H₂ production & storage, FC durability, cost...)
Basic architecture of a FCV
(“a FCV is a HEV;” power electronics)

Chapter 2 : Fuel Cell fundamentals (2 lectures)

Types of fuel cells & their applications
Chemistry (Principles)
Physics (Basic Thermodynamics)
DOE Performance and cost Targets
Current technology status

Chapter 2: Polymer Electrolyte Membrane Fuel Cells (3 lectures)

Materials, Structure, Operation
Electrical Behavior, Heat generation, Mass Transport
Degradation

Chapter 3: Control of Polymer Electrolyte Membrane Fuel Cells (3 lectures)

Voltage regulation (Pressure boost & Voltage buck/boost)
Cooling Loop, Startup and Mal-distribution
Air Flow (sizing, pressure selection, stoichiometry, autonomy)
Hydrogen flow (high pressure delivery of pure H₂)
Backpressure & Recirculation loop, Dead-ended
Water management (Nafion membrane properties)
Humidification, Flow control and flooding versus drying
Cathode and Anode manipulation
Impedance diagnostics
Cell-to Cell variability

Chapter 4: Vehicle architecture (1-2 lectures)

Power electronics
Hybridization strategies

Chapter 5: Hydrogen production technologies (2 lectures)

DOE Targets for cost and efficiency
Technologies: Coal, natural gas (steam reforming), nuclear energy, electrolysis, wind and solar energy, biomass and photobiological processes

Chapter 6: Infrastructure for Hydrogen Distribution and Refueling (2 lectures)

Scenarios for the introduction of FCVs and their supporting infrastructure
Distributed hydrogen production vs. production at central stations
Maximum practicable number of vehicles that can be fueled by hydrogen by 2020
Funding and policy actions needed to achieve that goal

Chapter 7: Hydrogen Storage I: Fundamentals (3 lectures)

DOE System-level targets
Types of storage: physical vs. chemical
Chemical storage methods: conventional metal hydrides, complex hydrides, chemical hydrides, sorbents
Capacity

Thermodynamics
Kinetics

Chapter 8: Hydrogen Storage II: Engineering considerations (2 lectures)

Thermal conductivity
Effective media density
Heat management during refill
Control and interface with the FC powerplant

Chapter 9: Hydrogen Safety / Codes & Standards (1 lecture)

Chapter 10: Life-cycle and Well-to-Wheels Analyses of FCV (2 lectures)

Introduction to the Argonne H2A Model
Petroleum consumption
Greenhouse gas emissions (CO₂ reduction)
Energy efficiency/energy use
Cost of ownership
Comparisons with: conventional ICE vehicles, HEV, PHEV, EV