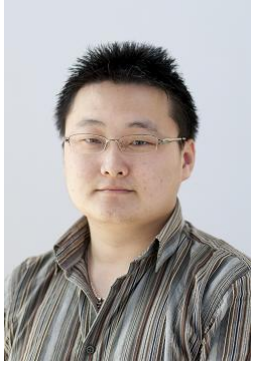
Fuel Cell Technology for Automotive applications

Instructor: Fei Gao

Chairman of fuel cell modeling axis of the Federation for Fuel Cell Research CNRS FCLAB in France, and the head of the energy production division of the energy and environment department.



The fuel cell is a potential candidate for energy storage and conversion in our future energy mix. Indeed, a fuel cell is able to directly convert the chemical energy stored in fuel (e.g. hydrogen) into electricity, without undergoing different intermediary conversion steps. Among the different fuel cell types, the proton exchange membrane (PEM) fuel cell has shown great potential in automotive applications, due to its low operating temperature, solid-state electrolyte, and compactness. Many experts consider the PEM fuel cells to be one of the potential embarked energy candidates for terrestrial transportation.

This eLearning course will mainly focus on the proton exchange membrane (PEM) fuel cell technology which has been used specially in automotive applications. The PEM fuel cell fundamentals, such as its physics, structure, power characteristics, efficiency, will be presented and discussed. The fuel cell system with its key ancillary components, such as air compressor, hydrogen tank, power converter, will also be introduced. Different powertrain configurations with fuel cells in automotive applications will be discussed and shown with real examples around the world. An emphasis on the fuel cell economic aspects and a short introduction to hydrogen economy will be given at last.

Topics:

Module 1: Fuel cell principals

In this first module of a five modules series eLearning course, the basic physics in the proton exchange membrane (PEM) fuel cells and their material/structural composition, such as Bipolar plates, gas diffusion layer, catalyst layer and proton exchange membrane (electrolyte), will be introduced and explained. In addition to the PEM fuel cell technology, a short review of other fuel cell technologies will also be given.

Topics:

- Introduction to fuel cells
- PEM fuel cell operating principals
- Bipolar plates and gas channels
- Gas diffusion layers (electrodes)

- Catalyst sites (electrodes)
- Electrolyte – Polymer membrane
- Cooling channels
- Other fuel cell technologies – SOFC, DMFC, PAFC, AFC and MCFC

Module 2: Fuel cell power characteristics, efficiency and life span
In this second module, the PEM fuel cell static and transient power characteristics will be firstly discussed based on the physical phenomena introduced in the first module. A focus on the fuel cell "theoretical" and "practical" efficiency and their physical meanings will be discussed secondly. At last, different phenomena related to the fuel cell aging/degradation will be briefly introduced.

Topics:

- PEM fuel cells polarization curve and electrical/thermal power
- PEM fuel cells transient power characteristics
- Efficiency – energy change during electrochemical reactions
- Efficiency – final efficiency with associated voltage losses
- Impacts of PEM fuel cells parameters on fuel cell output voltage
- Introduction to fuel cell aging/degradation phenomena

Module 3: Fuel cell system components
In this third module, the fuel cell system key ancillary components and the state-of-the-art of their technologies will be introduced and discussed. A special focus will be given to the PEM fuel cell air compressor, as it is the largest parasitic power consumption component in the fuel cell system.

Topics:

- Air supply and air compressor
- Hydrogen supply and storage
- Cooling circuit
- Power converter
- Fuel reformer (optional)

Module 4: Fuel cell applications
In this fourth module, different PEM fuel cells applications in vehicles, such as main power generator, range extender, auxiliary power unit, will be presented and discussed. Different hybrid fuel cell powertrains will be introduced and a brief introduction to other energy storage components will be given. Some real world fuel cell vehicle example will be shown.

Topics:

- Fuel cell propulsion and hybrid powertrains
- Advantages of fuel cell hybridization
- Fuel cell auxiliary power units
- Real world fuel cell vehicles examples

Module 5: Introduction to hydrogen economy and fuel cell economic aspects
In this last module, a short introduction to "hydrogen economy" will be given at first. The actual hydrogen production and perspectives will be discussed and a "well to wheel" efficiency analysis

example will be discussed for fuel cell vehicles compared with conventional vehicles and electric/hybrid vehicles. The European vision of fuel cell vehicle market around 2020 and 2050 and the associated economic aspects will be presented at last.

Topics:

- Hydrogen on earth
- Hydrogen production and perspectives
- “well to wheel” efficiency for hydrogen fuel cell vehicles
- Fuel cell vehicle vs. electric/hybrid vehicles
- Different visions on fuel cell vehicles development

About the Instructor

Dr. Fei Gao is currently an associate professor in the energy and environment department of the University of Technology of Belfort-Montbeliard (UTBM), Belfort, France. He received respectively the Master's degree in electrical and control system engineering in 2007, and the PhD degree in renewable energy with university youth doctor reward in 2010, from the UTBM. His main research interests include fuel cells and their applications in transportation, multiphysics modeling and real time applications. He is also the chairman of fuel cell modeling axis of the Federation for Fuel Cell Research CNRS FCLAB in France, and the head of the energy production division of the energy and environment department. He serves as an editor for the IEEE Transportation Electrification Newsletter and an active reviewer for IEEE Transactions on Vehicular technology, Power Electronics and Industrial Electronics.

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