FKFS Academy

FKFS
RESEARCH IN MOTION.

ELECTRIFICATION OF MOBILITY

Lecturer: Prof. Giorgio Rizzoni, The Ohio State University

COURSE OUTLINE
DAY 1:

Module 1: Electrification of Mobility

- History of e-mobility
- Energy considerations
  - Primary energy sources
  - Well-to-tank energy and emissions analysis – electricity and non-petroleum-based fuels are not necessarily carbon-free
- Vehicle energy use and regulatory environment
- Understanding vehicle energy consumption
- Impact of electrification
- Some observations on world vehicle markets

Module 2: xEV architectures

- Benefits of electrification
- xEV architectures
- HEV and PHEV development over the past 25 years; case study: the Toyota Hybrid Systems
- BEV Architectures
- Regenerative Braking

Module 3: Electric Machines, Electric Drives and Power Converters

- Basic operating characteristics of electric machines
- DC machines
- AC Machines operating principles
- AC Induction machines
- Permanent Magnet Synchronous Machines
- Basic introduction and operating principles of Power Converters
- Control of electric drives
- Introduction to Modeling and Design of Electric Drives and Power Converters

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DAY 2:

Module 1: Introduction to Energy Storage Systems	**Module 2: Introduction to Energy Management Systems**
• Introduction to energy storage systems for automotive applications • Notation and definitions • Overview of li-ion battery technology: operating principles, properties of electrode materials, state of the art, materials for next-generation cells • Battery cell modeling • System integration principles for modules and packs • Battery Management Systems (BMS), state of charge, power and health estimation, balancing, other safety and protection features • Thermal Management Systems (TMS), solutions for passive and active cooling • Battery charging standards, service equipment • Battery life: State of Health (SoH) and Residual Useful Life (RUL) • Test Protocols to Characterize Degradation in Cells	• Review energy management concepts for hybrid electric powertrains • Introduce principles of optimal control, including Dynamic Programming, the Minimum Principle, and Equivalent Consumption Minimization Strategy (ECMS) • Case studies and design and calibration of optimal energy management strategies with emissions, battery aging and drive quality contraints

Module 3: Electric Propulsion Technology in Motorsports
• A little history of electric motorsports, from 1899 to 1999 • Electric land speed records • xEV technology in motorsports today

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DAY 3 (HALF DAY): COMPUTATIONAL LABORATORY

Module 1: BEV laboratory, with focus on regenerative braking	Module 2: HEV laboratory, with focus on optimal energy management
The day starts with a laboratory in which the participants will explore the simulated performance of a BEV using a simulator that is capable of simulating many important aspects of a battery electric vehicle including regenerative braking. Demonstrations and exercises in simulation focus on understanding the interaction of electromechanical regenerative braking with friction braking, with consideration of braking performance, energy recuperation and vehicle stability.	The course closes with a laboratory in which the participants will use a detailed simulation model of a PHEV to explore the design and calibration of energy management strategies. Matlab/Simulink-based code will be provided to the participants.

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HYDROGEN FOR MOBILITY – MOTIVATION & TECHNOLOGY OUTLOOK

Lecturer: Prof. André Casal Kulzer, IFS University of Stuttgart

& Hans-Jürgen Berner, FKFS Stuttgart

COURSE OUTLINE

Introduction	**Production**
• Hydrogen properties (thermodynamical/chemical) • Comparison with other energy carriers (molecular/electro-chemical) • Regulation regarding sustainable mobility • Hydrogen in mobile applications	• Production methods • Electrolysis • Hydrogen as a strategic secondary energy source
Storage & Transportation	**Fuel Cell Electric Vehicles (FCEV)**
• Storage types & storage losses • Hydrogen carriers • Infrastructure • Applications	• FCEV Architecture • Fuel Cell Types • Balance of Plant • Operation strategies • Thermal Management • Applications • Potential and limitations
Internal Combustion Engine Vehicles (ICEV)	**Life Cycle Analysis & Technology Assessment**
• ICEV architecture • Special requirements using hydrogen • Operation strategies • Exhaust gas aftertreatment • Applications • Potential and limitations	• Definition • Tools and assumptions • Assessment of various mobility concepts regarding LCA and cost • Hydrogen in future mobility concepts

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VEHICLE AERODYNAMICS AND AEROACOUSTICS

KNOW-HOW IN THEORY, MEASURING TECHNIQUE AND TESTING

Lecturer: Dr.-Ing. Daniel Stoll, IFS, University of Stuttgart

COURSE OUTLINE

Module 1: Basis of Vehicle Aerodynamics

- Physical principles and basic equations of aerodynamics
- Aerodynamic forces, moments and coefficients
- Drag components
- Influence of vehicle design and vehicle parts on drag and lift
- Influence of drag and lift on vehicle performance

Module 2: Aeroacoustics

- Physical basics of acoustics
- Acoustic measurement techniques
- Acoustic analysis procedures
- Physics of aeroacoustics
- Test and measurement setup
- Main sources in aeroacoustics
- Noise reduction techniques
- Psychoacoustic aspects incl. unsteadiness

Module 3: Numerical Methods

- Basics of computational fluid dynamics (CFD)
- Common codes used for CFD
- CFD-application on particular flow situations
- Basics of computational aeroacoustics (CAA)
- Calculation of aeroacoustically effective turbulent fluctuations
- Calculation of sound sources as well as sound transmission

Module 4: Aerodynamic Testing and Measuring Techniques

- Aerodynamic measuring techniques
- Wind tunnel types
- Specific wind tunnel effects
- Comparison of road and wind tunnel situation
- Full road simulation in wind tunnel
- Measuring pressures and velocities in wind tunnel flows
- Methods for flow visualization

Module 5: Aeroacoustic Practical Training

- Aeroacoustic measurement and analysis techniques
- Evaluation of various aeroacoustic weak spots of the test vehicle (measurement and analysis)
- Psychoacoustic analysis and rating
- Subjective listening in the vehicle compartment

Module 6: Aerodynamic Practical Training

- Testing procedures and cycles in aerodynamic wind tunnels
- Influence of vehicle design and vehicle parts on drag and lift
- Wind tunnel set up for full road simulation
- Wind tunnel correction methods
- Measurement of wheel ventilation drag

Module 7: Introduction to Soiling Measurements	Module 8: Active Aerodynamics
• Wind tunnel set up for soiling tests • Different types of soiling • Qualitative and quantitative assessment of vehicle soiling • Possibly visit of thermal wind tunnel	• Potentials and challenges • Aerodynamics and design • Effects on driving dynamics and range • Examples and different features