Stuttgart International Summer School 2013

Mobility

System Competence in Electric, Hybrid and Combustion Powertrains, Electrochemical Energy Conversion, Aerodynamics and Aeroacoustics

Course 1.1: Energy Analysis and Modeling of Hybrid Electric Vehicles
Course 1.2: Simulation of Hybrid Electric Vehicles
Course 2.1: Introduction to Control and Optimization of Hybrid Electrical Vehicles
Course 2.2: Deep Dive in the Development and Implementation of Energy Management Strategies in PHEVs
Course 3.1: Introduction to Batteries and Fuel Cell Systems for Automotive Applications
Course 3.2: Analysis, Modeling and Control of Batteries and Fuel Cell Systems for Automotive Applications
Course 4: Introduction to Electromechanical Energy Conversion for Electrical Vehicle Applications
Course 5: Aerodynamics and Aeroacoustics

- Educational program for working engineers from the automotive field
- Attendants: Engineers from R&D departments of automotive companies
- Small groups, at most 20 persons/course
- Modular course participation possible

In cooperation:

Universität Stuttgart
Ohio State University
CAR
e-mobil BW

Research in motion
Course 1.1:
Energy Analysis and Modeling of Hybrid Electric Vehicles

Lecturer:
Prof. Giorgio Rizzoni
The Ford Motor Company Chair in Electromechanical Systems, Professor of Mechanical and Aerospace Engineering, Professor of Electrical and Computer Engineering, Director, Center for Automotive Research, The Ohio State University

Target Group:
This course is targeted to professionals working or interested in the area of energy conversion and utilization at the vehicular level, and more specifically towards hybrid electric vehicles (HEV).

The course focuses on the fundamentals of hybrid electric vehicles, covering reasons for hybridization, energy analysis, architectures and components, unified energy modeling, vehicle simulation, energy optimization strategies, and supervisory control of HEVs.

Course Objectives:
Objective 1: Evaluate energy consumption in road vehicles. Relate energy usage to fuel economy and exhaust emissions. Understand the concept and potential benefits of drivetrain hybridization strategies.
Objective 2: Develop and use mathematical models of energy conversion and mechanical transmission sub-systems used in conventional vehicles.
Objective 3: Develop and use mathematical models of energy conversion, and of mechanical transmission subsystems used in hybrid vehicles. Develop a methodology for constructing general models of energy storage and power flow processes in hybrid vehicles.
Objective 4: Develop and use mathematical models of electro-chemical, mechanical and hydraulic energy storage systems.
Objective 5: Learn principles of optimal energy management and supervisory control strategy for optimal energy storage in hybrid electric vehicles. Study HEV design and optimization of fuel economy in a simulation environment.

Course Outline:
Module 1: The power consumption side of vehicles
- Forces acting on a vehicle, road load equation
- Inertial load, aerodynamic losses, rolling resistance losses, transmission losses, accessories losses, idling losses
- Overall vehicle energy budget
- Drive cycles and their impact on energy use
- Energy analysis of conventional vehicles and motivation for hybrids

Module 2: Conventional vehicles, IC engines and transmissions
- Heat engine types: spark-ignited, Diesel, etc.
- Basic engine operating parameters and characteristics, control parameters
- Emissions characteristics
- Manual transmission (manual and automated)
- Automatic transmissions and torque converters
- Continuously variable transmissions
- Torque splitters/epicycloidal gear trains
- Motivation behind hybrid electric vehicles, energy efficiency and emissions

Module 3: Overview of electro-mechanical/chemical energy conversion
- Classification and basic principles of operation of electric machines
- DC, AC induction, PM synchronous and switched reluctance machines
- Electric machine drives and power converters
- Modeling the efficiency of electric machines
- Fuel cell types, basic principles and characteristics

Module 4: On-Board energy storage
- Fuels as a form of on-board chemical energy storage: liquid and gaseous fuels, well-to-wheel analysis
- Batteries: charge/discharge characteristics, specific energy, energy density, specific power, power density; modeling the performance of batteries
- Ultra-capacitors, efficiency considerations
- SOC estimation
- Mechanical on-board energy storage devices (flywheels, hydraulic accumulators), efficiency considerations

Module 5: Principles of energy management of HEV/PHEVs
- Need for energy management strategy in HEVs
- Equivalent fuel consumption minimization
- Case Study: FutureTruck 2000
- Plug-in Hybrid Electric Vehicles
- Case Study: OSU EcoCAR 2011

Objective 3: Develop and use mathematical models of energy conversion, and of mechanical transmission subsystems used in hybrid vehicles. Develop a methodology for constructing general models of energy storage and power flow processes in hybrid vehicles.
Course 1.2: Simulation of Hybrid Electric Vehicles

Lecturer:
Prof. Giorgio Rizzoni
The Ford Motor Company Chair in Electromechanical Systems, Professor of Mechanical and Aerospace Engineering, Professor of Electrical and Computer Engineering, Director, Center for Automotive Research, The Ohio State University

Target Group:
This course is intended to teach the advanced use of simulation tools to analyze the behavior of hybrid electric vehicles (HEVs). The course teaches the development of Matlab/Simulink™ codes to model HEVs using modular techniques, and to calibrate and validate the simulator using vehicle design data and experimental data.

The course will be mostly conducted in a computer laboratory; students will have access to the necessary software. Students are expected to have working knowledge of Matlab/Simulink. This course is not an introduction to Matlab/Simulink. It can be taken stand-alone or as a sequence to “Energy Analysis and Modeling of Hybrid Electric Vehicles”.

Course Objectives:

Objective 1: Review basic principles of vehicle energy consumption and of hybrid powertrains in the context of a computer simulation. Introduction to Matlab/Simulink environment, and to the modular development of simulation codes.

Objective 2: Development of simulator modules: driving cycles, vehicle, engine, mechanical transmission, electric drives, energy storage, accessories, supervisory controller.

Objective 3: Construction of simulator from modules, simulator debugging and testing.

Objective 4: Development of simple supervisory controller; use of the simulator to perform energy and performance analyses.

Course Outline:

Module 1:
- Review of hybrid electric vehicles
- Case study: analysis of Ohio State University EcoCAR PHEV
- Introduction to Matlab/S environment
- Steps in the development of the simulator:
  - Identify objectives
  - Develop simulator structure
  - Constructing, testing and debugging modules
  - Assembling modules into a system simulation
  - Generating outputs
  - Testing, debugging and validating a system simulation

Module 2:
- Develop vehicle module:
  - Driving cycles
  - Vehicle longitudinal dynamics structure
  - Calculating vehicle energy consumption and potential for recuperation: output blocks
  - Assemble, debug and validate basic vehicle simulator, with ideal powertrain
- Develop conventional powertrain module:
  - Engine, transmission block
  - Insert conventional powertrain
  - Assemble, debug and validate basic vehicle simulator, with ideal powertrain

Module 3:
- Develop hybrid powertrain module:
  - Electric drive blocks
  - Energy storage blocks
  - Mechanical coupling between e-drives and conventional powertrain
  - Update vehicle energy consumption module
  - Assemble, debug and validate basic vehicle simulator, with hybrid powertrain

Module 4:
- Develop supervisory controller and test and validate:
  - Develop simple rule-based supervisory controller using Stateflow™
  - Integrate controller in vehicle simulator
  - Use vehicle simulator and generate automated reports
Course 2.1: Introduction to Control and Optimization of Hybrid Electric Vehicles

Lecturer:

Simona Onori
Ph.D., Research Scientist, Center for Automotive Research, Lecturer, Department of Mechanical and Aerospace Engineering, The Ohio State University

Target Group:

This course is targeted to professionals engineers and graduate engineering students who are interested in gaining an exposure to advanced control development in advanced propulsion automotive systems. In that, this course complements the introductory course “Energy Analysis and Modeling of Hybrid Electric Vehicles” and it aims at providing general tools and methods for designing supervisory controllers in hybrid electric vehicles.

This course will cover the basis of design optimization and energy management control in hybrid vehicles and will discuss modeling, simulation, control and optimization approaches exploited today to design energy management strategies in hybrid vehicles.

The course will describe in detail the state of the art in the field of energy management development and will introduce the students to the most relevant R&D topics in the field of control design and optimization in hybrid vehicles discussing the main challenges faced today by automotive engineers.

This course can be taken in sequence to “Energy Analysis and Modeling of Hybrid Electric Vehicles”.

Course Objectives:

Objective 1: Introduce design optimization methods with application to hybrid electric vehicle drivetrain architectures.

Objective 2: Simulate and model hybrid electric vehicles: high-level control vs. low level control, backwards vs. forward modeling, dynamic vs. quasi-static simulators.

Objective 3: Review principles of optimization and optimal control. Cast the energy management problem within a constrained optimization problem and formulate optimal control problems for energy management in HEVs and PHEVs.

Objective 4: Solve the optimal control problem for charge sustaining HEVs through: Dynamic Programming, rules-based strategy, Pontryagin’s Minimum Principle (PMP) and Equivalent Consumption Minimization Strategy (ECMS) and overall comparative study.

Course Outline:

Module 1: Design optimization of hybrid electric vehicles

- Class organization, introduction and overview of hybrid electric vehicles
- Nature of the optimization problem for HEVs and PHEVs
- Defining optimization criteria
- Hierarchy of optimization problems for HEV
- Link between design and control
- Examples of design optimization problems

Module 2: Vehicle modeling and simulation

- Model-based control: backward vs. forward vehicle simulator; dynamic vs. quasi-static
- Control signals vs. physical signals: high level and low level control
- Vehicle components modeling in a hybrid vehicle energy-based simulator
- Battery models; battery SOC/SoE
- Well-to-wheel energy analysis
- Motivation to the use of optimal control to the solution of energy management problem

Module 3: Principles of optimization and optimal control

- The need for mathematical optimization tools
- Formulation of optimization problems
- Formulation of constraints
- Formulation of the optimal control problem for energy management in HEVs and PHEVs

Module 4: Solution methods for the optimal control problem in HEVs: non-implementable strategies

- Energy management strategies:
  1. Dynamic Programming (DP)
  2. Pontryagin’s Minimum Principle (PMP)
  3. Equivalent Consumption Minimization Strategy (ECMS)
- Comparative study of energy management strategies

Module 5: Solution methods for the optimal control problem in HEVs: on-board implementable strategies

- Energy management strategies: rule-based and adaptive-ECMS
- Comparative study of energy management strategies implemented on a forward vehicle simulator
Course 2.2: Deep Dive in the Development and Implementation of Energy Management Strategies in PHEVs

Lecturer:
Simona Onori
Ph. D., Research Scientist, Center for Automotive Research,
Lecturer, Department of Mechanical and Aerospace Engineering, The Ohio State University

Target Group:
This advanced course builds upon the general concepts presented in the introductory course on “Introduction to Control and Optimization of Hybrid Electric Vehicles” and provides an in-depth description of the optimal control design development and implementation process. The target audience of this course is composed by researchers and professional engineers working on hybrid vehicles, who are seeking to get hands-on experience with the development and implementation of energy management strategies in hybrid vehicles.

Course Objectives:
Objective 1: In-depth analysis of the forward PHEV simulator: 1) driving cycle/driver, 2) powertrain modules. Procedure to designing and implementing a supervisory controller module.
Objective 2: Introduction to optimization routines and software tools in Matlab/Simulink environment to be use in the development of a supervisory controller.
Objective 3: Implementation of optimal control methods, PMP and ECMS, on the vehicle forward simulator. Implementation of penalty functions to guarantee feasible operation. Tuning optimal strategies via shooting method.
Objective 5: Benchmarking strategies according to performance-based and fuel economy-based metrics.

Course Outline:

Module 1: Forward PHEV simulator
• Modeling and implementation of vehicle simulator modules: 1) driving cycle/driver, and 2) powertrain modules.
• Where to start from when designing a supervisory controller?
• Analysis of supervisory controller input/output signals, feedback loops, and actuator constraints limitations
• Definition of the main steps to designing and implementing a supervisory controller module

Module 2: Software routines for optimization problems
• Introduction to optimization tools in Matlab/Simulink environment for solving general optimization problems
• Implementation of optimization routines in Matlab/Simulink for solving energy minimization problems in hybrid vehicles

Module 3: Implementation of optimal (non-realizable) control methods
• Implementing PMP and ECMS on the forward PHEV simulator
• Enforcing constraints through penalty functions
• Strategies tuning via shooting method implementation

Module 4: On-board implementable strategies
• Development and implementation of:
  - CS/CD (charge-depleting/charge-sustaining) strategy
  - Adaptive-PMP/ECMS on the forward PHEV simulator to achieve minimum fuel consumption and maximum performance

Module 5: Benchmarking
• Comparative analysis of on-board implementable strategies according to the following metrics:

<table>
<thead>
<tr>
<th>Performance</th>
<th>Acceleration 0 – 100 km/h [s]</th>
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<tbody>
<tr>
<td></td>
<td>Acceleration 70 – 120 km/h [s]</td>
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<td></td>
<td>Acceleration 0 – 1000 m on 4% slope [s]</td>
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<td></td>
<td>Braking distance from 100 km/h [m]</td>
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<tr>
<th>Energy and economy</th>
<th>Total energy use (fuel + electricity) [MJ/km]</th>
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<tbody>
<tr>
<td></td>
<td>Fuel consumption [MJ/km]</td>
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<td></td>
<td>Well-to-wheel CO₂ emissions [kg/km]</td>
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<tr>
<th>Computational performance</th>
<th>Processor use [simulation time]</th>
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<tr>
<td></td>
<td>Memory use [MB]</td>
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# Course 3.1: Introduction to Batteries and Fuel Cell Systems for Automotive Applications

## Lecturers:

**Prof. Marcello Canova**  
Ph.D., Assistant Professor of Mechanical and Aerospace Engineering; Associate Fellow, Center for Automotive Research, The Ohio State University

**Prof. Yann Guezennec**  
Ph.D., Professor of Mechanical and Aerospace Engineering; Senior Fellow, Center for Automotive Research, The Ohio State University

## Target Group:

The course is specifically targeted to industry professionals who are interested in gaining exposure to the areas of hybrid, plug-in and electric vehicles, and related propulsion and powertrain technologies. Particular attention will be devoted to the challenges faced by automotive engineers for the integration of batteries and fuel cells in automotive systems, ranging from energy storage/charging, packaging, control, performance, optimization and costs. The course is an excellent complement to the introductory course "Energy Analysis and Modeling of Hybrid Electric Vehicles".

## Course Objectives:

This course will cover the basic operating principles of batteries and fuel cell systems, describe in detail the state of the art and introduce the most relevant R&D topics in the field of design, system integration, performance modeling and system-level control.

**Objective 1:** Basic operating principles, performance metrics and terminology.

**Objective 2:** Overview on the types of automotive fuel cells and energy storage systems.

**Objective 3:** Introduce and apply basic modeling principles.

**Objective 4:** System design and integration, energy management and control principles.

## Course Outline:

### Module 1: Introduction to battery cells for automotive applications

- Basic concept and terminology
- Components and operation of a cell
- Overview of basic operating principles
- Charging/discharging performance curves
- Overview of batteries for automotive applications (PbA, NiMH, Li-ion)
- Advanced battery technologies (Li-air, Li-S)

### Module 2: Introduction to fuel cell stacks and systems

- Types of fuel cells (PEM, SOFC, other)
- Analysis of fuel cell stacks, polarization curves
- Influence of operating parameters on stack characteristics (temperature, pressure, humidity, gas composition, etc.)
- Characteristics and energy analysis of fuel cell stacks, efficiency
- Fuel cell stacks vs. fuel cell systems
- Characteristics of complete fuel cell systems
- Stack and system efficiency

### Module 3: Introduction to battery systems integration and control

- Battery systems integration and packaging
- Safety consideration
- Battery management and thermal management systems
- State of charge estimation: problem and methods
- Battery equalization and balancing
- Overview of battery aging and battery life estimation methods

### Module 4: Principles of modeling of batteries and fuel cells

- Classification of battery models
- Equivalent electrical circuit models
- Dynamic models of PEM fuel cell systems

### Module 5: Integration into automotive systems and energy management

- “Hybridization” of automotive powertrain
- Traction vs. APU systems
- Fuel cell hybrid vehicles
- Principles of supervisory control (energy management) of battery and fuel cell vehicles
- Case study: energy management strategy and sizing of a hybridized fuel cell vehicle
# Course 3.2: Analysis, Modeling and Control of Batteries and Fuel Cell Systems for Automotive Applications

## Lecturers:

**Prof. Marcello Canova**  
Ph.D., Assistant Professor of Mechanical and Aerospace Engineering; Associate Fellow, Center for Automotive Research, The Ohio State University

**Prof. Yann Guezennec**  
Ph.D., Professor of Mechanical and Aerospace Engineering; Senior Fellow, Center for Automotive Research, The Ohio State University

## Target Group:

The target audience of this course is composed by researchers and engineers who are seeking to gain knowledge of the fundamental physiochemical processes in battery and fuel cell systems performance, together with modeling and simulation, experimental characterization and applied control and estimation. This advanced course builds upon the material presented in the introductory course on battery and fuel cell systems.

## Course Objectives:

The material in this course focuses on experimental and analytical methods that are today in use for characterizing and predicting the performance of electrochemical energy conversion and storage systems for automotive use.  

**Objective 1:** Principles of electrochemistry, thermodynamics, heat and mass transfer.  

**Objective 2:** Laboratory instrumentation and testing procedures.  

**Objective 3:** Modeling of electrochemical systems for battery and fuel cells.  

**Objective 4:** Applications of control theory to fuel cells and battery systems.

## Course Outline:

### Module 1: Principles of applied electrochemistry

- Basic Concept and Terminology  
- Components and Operation of a Cell  
- Potentials and Thermodynamics of Cells  
- Kinetics and Electrode Reactions  
- Principles of Mass Transport/Diffusion  
- Determination of Cell Terminal Voltage  
- Analysis of Heat Generation and Thermal Effects in Electrochemical Cells

### Module 2: Experimental methods for batteries and fuel cell characterization

- Introduction to Experimental Procedures and Instrumentation  
- Electrochemical Characterization Methods (Cyclic Voltammetry, Electrochemical Impedance Spectroscopy, Chronopotentiometry, Polarography)  
- System-Level Testing Procedures, Post-Processing and Analysis of Results  
- USABC Testing Protocols for Performance Characterization and Aging

### Module 3: Modeling of battery cells and packs

- Introduction and Definitions  
- Classification of Battery Models  
- Physics-Based Electrochemical Cell Models  
- Parameters Identification Techniques and Data Acquisition Procedures  
- Overview of Heat Generation and Cell Thermal Models  
- Case Study: Design and Identification of Equivalent Circuit Model for Li-ion Cell  
- Case Study: Design and Calibration of Single Particle Model for Li-ion Cell

### Module 4: Modeling of fuel cell stacks and systems

- General modeling approaches, purpose of modeling  
- Concept of (quasi-)static and dynamic modeling  
- Modeling of fuel cell stacks and systems  
- Case Study: Modeling and Simulation of PEM Fuel Cell System

### Module 5: Estimation and control problems in battery and fuel cell systems

- Introduction to Battery Management Systems  
- Battery State of Charge Estimation: Problem Description and Technical Solutions  
- Aging and Degradation in Batteries  
- Battery Prognosis, State of Health Estimation  
- Case Studies:  
  - State of Charge Estimation Methods for Battery Packs  
  - Parameter Extraction from Cell Aging Studies  
  - State of Health Estimation in Li-ion Batteries
Course 4: Introduction to Electromechanical Energy Conversion for Electrical Vehicle Applications

Lecturer:

Prof. Dr.-Ing. Nejila Parspour
Professor of Electrical Energy Conversion, Director of the Institute of Electrical Energy Conversion (IEW) at the University of Stuttgart

Target Group:

This course is targeted to professionals working or interested in the area of electromechanical energy conversion. It addresses all interested in drive systems for electrical vehicles.

This course can be taken stand-alone or as a sequence to the introductory courses 1.1, 2.1 and 3.1.

Course Objectives:

The material in this course will be focused on electrical machines. Further permanent magnet excited synchronous machine and drive components will be analyzed.

Objective 1: Understand the principles of electromechanical energy conversion.
Objective 2: Introduction to the most common electrical machines used in electrical vehicles.
Objective 3: Understand the principles of synchronous machines.
Objective 4: Learn rotor field oriented control of permanent magnet excited synchronous machines.
Objective 5: Practical experiences on a drive system.

Course Outline:

Module 1: Basics of electromagnetism

- Magnetic field
- Magnetic materials
- Force and voltage generation in electrical machines
  - Faraday’s law
  - Amper’s law
  - Lorentz’s force
- Drive systems
  - Components of electrical drive systems
  - Energy flow
  - Motor and generator mode
- Losses in electrical machines

Module 2: Basics of electrical machines

- Classification and overview of electrical machines
  - Direct current machine
  - Asynchronous machine
  - Synchronous machine
- Introduction to direct current machines
  - Theory: Principles of function
  - Lab course

Module 3: Principles of synchronous machines

- Stator and magnetic field generation
- Different types of rotor
- Principle of function
- Equivalent electrical circuit
- Torque generation
- Torque/speed characteristic
- Torque/load angle characteristic

Module 4: Advanced topics on synchronous machines

- Permanent magnet excited synchronous motor
- Space vector theory
- Modeling of synchronous machines
  - Rotor field oriented model
  - Important parameters
- Buildup of a rotor field oriented synchronous machine drive
  - Theory
  - Exercise

Module 5: Lab course: Advanced topics on synchronous machines

- Example of a synchronous machine
  - Parameter identification
  - Modeling
- Introduction to the test bench with a high torque motor
- Operation of a high torque motor at the test bench

Target Group:

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Module 5: Lab course: Advanced topics on synchronous machines

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- Operation of a high torque motor at the test bench
Course 5: Vehicle Aerodynamics and Aeroacoustics

Lecturers:
Prof. Jochen Wiedemann
Institute for Combustion Engines and Automotive Engineering Stuttgart (IVK), Chair in Automotive Engineering, Member of the Managing Board of the Research Institute of Automotive Engineering and Vehicle Engines Stuttgart (FKFS)

Co-lecturers: Dr. Reinhard Blumrich, FKFS, Head of Computational Acoustics and Aeroacoustics, Nils Widdecke, IVK/FKFS, Head of Aerodynamics and Thermal Management, Dr. Timo Kuthada, FKFS, Head of High Performance Computing

Target Group:
This course is targeted to professionals working or interested in the area of vehicle aerodynamics and aeroacoustics. The course is intended for technicians or engineers who either are newcomers or simply wish to learn more about these topics. It focuses on the fundamentals of aerodynamics and aeroacoustics, covering ongoing measurement techniques as well as computational approaches and optimization strategies. The various facets of the course content are presented as both theoretical lectures and wind tunnel practical training.

Course Objectives:
The course is designed to enable the participants to effectively perform aerodynamic and aeroacoustic development work at car manufacturers and suppliers under consideration of the various interfaces to other disciplines.

Objective 1: Understand basic aerodynamic physics and relationships; apply fundamental aerodynamic equations on standard flow situations; assess aerodynamic coefficients and aerodynamic results; influences on vehicle drag and lift.

Objective 2: Understand the principal acoustic and aeroacoustic physics; choose the adequate measurement instrumentation and setup; getting expertise to assess acoustic analyses and results.

Objective 3: Understand the approaches when implementing computational methods in aerodynamics and aeroacoustics; being able to assess the possible field of application and the advantages and disadvantages concerning the various numerical methods realistically.

Objective 4: Plan and conduct aerodynamic and aeroacoustic investigations under experimental conditions in modern wind tunnel facilities and evaluate the measured data.

Course Outline:

Module 1: Basics of vehicle aerodynamics
- Physical basics of aerodynamics
- Key figures in aerodynamics
- 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
- Aeroacoustic analogies
- Kirchhoff integral theorem
- Linearized Euler equations
- Fluid-structure interaction
Course 5: Vehicle Aerodynamics and Aeroacoustics

Course Outline:

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
- Simulation of vehicle soiling

Module 5: Aeroacoustic practical training
- 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 full and model scale wind tunnels
- Influence of vehicle design and vehicle parts on drag and lift
- Wind tunnel set up for full road simulation
- Influence of ground simulation on drag and lift

Module 7: Demonstration of soiling measurements
- Wind tunnel set up for soiling test
- Different types of soiling
- Qualitative and quantitative assessment of vehicle soiling

Biographical sketch of Prof. Dr.-Ing. Jochen Wiedemann, University of Stuttgart

In 1977 Professor Wiedemann received his Diploma Degree in mechanical engineering from Ruhr-Universität, Bochum, Germany. After carrying out aerodynamic research at the von Karmán Institute for Fluid Dynamics in Belgium and Ruhr-University Bochum, in 1983 he received the doctoral degree (Dr.-Ing.) for his work on aerodynamic drag reduction. In 1984 Professor Wiedemann joined Audi AG where he held several managing positions. He was involved in many vehicle projects in aerodynamics, aeroacoustics and driving dynamics. His final position at Audi was Project Manager of the newly built Audi Windtunnel-Center.

In 1998 Jochen Wiedemann was appointed Chair Professor of Automotive Engineering at the Institute for Internal Combustion Engines and Automotive Engineering, (IVK) at the Stuttgart University, Germany and he also became a Member of the Board of Managing Directors of FKFS. His research work is largely associated with aerodynamics/aeroacoustics, road load and vehicle dynamics. In 2004 Professor Wiedemann was appointed a “Visiting Professor” at Tongji University where he gives lectures in vehicle dynamics. In appreciation for his achievements Professor Wiedemann was awarded the City of Shanghai’s Magnolia Silver Award for merits in the social and economic development of Shanghai.
Biographical sketch of Prof. Giorgio Rizzoni, The Ohio State University

Giorgio Rizzoni, the Ford Motor Company Chair in ElectroMechanical Systems, is a Professor of Mechanical and Aerospace Engineering and of Electrical and Computer Engineering at The Ohio State University (OSU). He received his B.S. (ECE) in 1980, his M.S. (ECE) in 1982, his Ph.D. (ECE) in 1986, all from the University of Michigan. Since 1999 he has been the director of the Ohio State University Center for Automotive Research (CAR), an interdisciplinary university research center in the OSU College of Engineering. Dr. Rizzoni’s research interests are in future ground vehicle propulsion systems, including advanced engines, electric and hybrid electric drivetrains, energy storage systems, and fuel cell systems. He is author or co-author in over 400 journal and conference papers, and three books. He is a Fellow of SAE (2005), a Fellow of IEEE (2004), a recipient of the 1991 National Science Foundation Presidential Young Investigator Award, and of several other technical and teaching awards.

Biographical sketch of Simona Onori, Ph. D., The Ohio State University

Simona Onori is a Research Scientist at the Ohio State University Center for Automotive Research (CAR) and lecturer at the Mechanical and Aerospace Engineering Dept. at the OSU. She received her Laurea degree, Summa Cum Laude in ECE from University of Rome ‘Tor Vergata’ (Italy), her M.S. in EE from University of New Mexico (USA), and her Ph.D. in Control Engineering from University of Rome ‘Tor Vergata’ in 2003, 2004 and 2007, respectively. She serves as an Associate Editor for the ASME, and Guest Editor for the Int. J. of Powertrain. Her research is in control system theory and applications. She focuses on model-based control design in advanced propulsion systems, energy management control and optimization in HEVs and PHEVs, fault diagnosis and prognosis for automotive system applications, aging, characterization, modeling and identification of advanced batteries.

Biographical sketch of Marcello Canova, Ph. D., The Ohio State University

Marcello Canova is an Assistant Professor of Mechanical and Aerospace Engineering at the Ohio State University. Since 2006, he is affiliated with the Center for Automotive Research. He received his Diploma di Laurea Cum Laude in Mechanical Engineering from the Institut National des Sciences Appliquées in Lyon, France in 1979, and his Ph.D. in 2006 in Mechanical Engineering, all from the University of Parma, Italy. Dr. Canova conducts research in the broad area of fluid and thermal sciences and energy systems, with emphasis on modeling, optimization and dynamic systems and control problems associated to future ground vehicle propulsion systems, advanced powertrains, electrochemical energy conversion and storage systems. His research has been funded by, among others, Ford, General Motors, Chrysler, Cummins, the National Science Foundation and the US Department of Energy.

Biographical sketch of Prof. Yann Guezennc, Ph. D., The Ohio State University

Yann Guezennc is a Professor of Mechanical and Aerospace Engineering at the Ohio State University, and affiliated with the Center for Automotive Research. He got his Diplome d’Ingénieur summa cum laude in Mechanical Engineering from the Institut National des Sciences Appliquées in Lyon, France in 1979, and his Ph.D. in Mechanical and Aerospace Engineering from the Illinois Institute of Technology in 1985. Since 1986. His research and teaching activities are in the area of advanced automotive powertrains with focus on advanced internal combustion engines, after-treatment systems, hybrid electric vehicles, and fuel cell systems for automotive applications. In the past 5 years he has developed significant research activities in the area of modeling of advanced batteries, battery aging experiments and diagnostics for HEV and PHEV applications.

Biographical sketch of Prof. Dr.-Ing. Parspour, University of Stuttgart

Nejila Parspour is Professor of Electrical Energy Conversion at the University of Stuttgart and head of the Institute of Electrical Energy Conversion (IEW). She received her Master in Electrical Engineering in 1991 and her Ph.D. (Summa Cum Laude) in 1995, both from Technical University of Berlin. Before joining the University of Stuttgart she collected 5 years of industrial experience at Philips and 6 years of scientific experience at the University of Bremen. Her research and teaching activities are in the field of electrical machines and drives with a focus on machine design as well as in the field of contactless energy transfer with a focus on inductive charging systems. In the field of electromobility, Nejila Parspour has acquired profound knowledge, particularly in developing position-tolerant inductive charging systems and high efficiency electrical motors. She has been awarded several prizes for her achievement, including the “Technology Award” of the federal state of Bremen and the “Überrorgenmacher” of the federal state of Baden-Württemberg.
Gesamt Fahrzeugsimulation eines batterieelektrischen Fahrzeugs

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Projektziele:

Registration: Stuttgart International Summer School

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Course 1.1 Energy Analysis and Modeling of Hybrid Electric Vehicles 2 1/2 Days 24. - 26.06.2013
Course 1.2 Simulation of Hybrid Electric Vehicles 2 1/2 Days 26. - 28.06.2013
Course 2.1 Introduction to Control and Optimization of Hybrid Electric Vehicles 2 1/2 Days 26. - 28.06.2013
Course 2.2 Deep Dive in the Development and Implementation of Energy Management Strategies in PHEVs 2 1/2 Days 01. - 03.07.2013
Course 3.1 Introduction to Batteries and Fuel Cell Systems for Automotive Applications 2 1/2 Days 01. - 03.07.2013
Course 3.2 Analysis, Modeling and Control of Batteries and Fuel Cell Systems for Automotive Applications 2 1/2 Days 03. - 05.07.2013
Course 4 Introduction to Electromechanical Energy Conversion for Electrical Vehicle Applications 2 1/2 Days 03. - 05.07.2013
Course 5 Aerodynamics and Aeroacoustics 3 Days 24. - 26.06.2013

1 Day 1 & 2: 8:30 – 17:30, Day 3: 8:30 – 12:30 2 Day 1: 14:00 – 18:00, Day 2 & 3: 8:30 – 17:30 3 Day 1 to 3: 8:30 – 17:30

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Each course is a non-credit graduate level seminar, offered through lectures consisting of twenty hours of instruction with a comprehensive set of notes (provided).

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