FKFS Academy

11 – 13 June & 16 – 25 July 2024

FKFS
RESEARCH IN MOTION.

VEHICLE AERODYNAMICS AND AEROACOUSTICS

KNOW-HOW IN THEORY, MEASURING TECHNIQUE AND TESTING

11 - 13 June 2024

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

COURSE OUTLINE

Module 1: Basis of Vehicle Aerodynamics	Module 2: Aeroacoustics
• 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	• 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	**Module 4: Aerodynamic Testing and Measuring Techniques**
• 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	• 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	**Module 6: Aerodynamic 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	• 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

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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

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DRIVING DYNAMICS

KNOW-HOW IN THEORY, MEASURING TECHNIQUE AND TESTING

16 - 17 July 2024

Lecturer: Prof. Dr.-Ing. Andreas Wagner, FKFS & IFS University of Stuttgart

COURSE OUTLINE

Module 1: **Basics of Driving Dynamics**	**Module 2:** **Advanced Driving Dynamics**
• Basic tire properties • Vehicle motion in the road plane • Basic driving dynamics characteristics • Roll & pitch motion / vertical dynamics • Suspension properties • Handling performance versus driving comfort	• Key characteristics and driving dynamics DNA • Property based development / systems engineering • Influence of aerodynamics • Influence of drivetrain electrification • Active chassis systems • Dynamics with all-wheel steering
Module 3: Driving Dynamics Characterization	**Module 4: Driving Simulation and Autonomous Driving**
• Measuring equipment and vehicle sensors • Objective characterization • Road testing • Rig testing • Data analysis • Model parameterization	• Driving-simulator basics • Simulation framework • Driving dynamics testing in simulators • Front-loading chassis concepts • Enabler for automated vehicles • Scenario design
Module 5: Practical Training – Stuttgart Driving Simulator	**Module 6: Practical Training – Stuttgart Handling Roadway**

• Practical introduction
  ○ Scenario
  ○ Model implementation
• Workshop
  ○ All-wheel steering strategy
  ○ Suspension setup
	• Practical introduction
	  ○ Basic setup and operation
	  ○ Customizing rig control
	• Workshop
	  ○ Lateral dynamics characterization
	  ○ Vertical dynamics characterization
	  ○ All-wheel steering calibration

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FKFS RESEARCH IN MOTION.

ELECTRIFICATION OF MOBILITY I – MOTIVATION, TECHNOLOGY OUTLOOK, AND MARKETS

Date: 22 July 2024

Lecturer: Prof. Giorgio Rizzoni, The Ohio State University

COURSE OUTLINE

Part 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
- Challenges an dopportunitities

Part 2: Powertrain electrification – Electric Drive Systems

- Introduction to electric drive system
- Properties of traction motors and motor controllers
  Basic principles of operation
  Types of electric machines and power converters
- Torque speed curves and efficiency
- Example of electric drive systems for xEVs

Part 3: Powertrain electrification – Energy Storage Systems

- Basic definitions, including energy and power density and cycle life
- Lithium-ion batteries – state of the art and current challenges
- Li-ion cell formats and performance characteristics
- Materials for Li-ion cells – current and future directions
- Battery pack design and system integration
- Charging systems
- Battery life and lifecycle
- Market and supply chain considerations

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11 – 13 June & 16 – 25 July 2024

FKFS
RESEARCH IN MOTION.

ELECTRIFICATION OF MOBILITY II –

INTRODUCTION TO ELECTRIC DRIVE AND ENERGY STORAGE SYSTEMS

Date: 23-24 July 2024

Lecturer: Prof. Giorgio Rizzoni, The Ohio State University

COURSE OUTLINE

DAY 1: ELECTRIC DRIVETRAINS AND VEHICLE PERFORMANCE

Part 1: Electric machines and power converters	**Part 2: Electrified Drivetrain Architectures and system concepts**
• 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 electric drives • DC vs AC machines and performance and efficiency characteristics of electric drives • Electronic Power conversion principles: DC-AC and DC-DC conversion • Control of electric drives	• BEV architectures • Regenerative braking • Drive Quality • Traction control, stability control and torque vectoring in BEVs
Part 3: Q& A	

DAY 2:

Part 1: Energy Storage Systems	**Part 2: BEV laboratory, with focus on battery performance**
Introduction • 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	The course closes 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 battery electrical and thermal management, power limits, SOC estimation and other important functions.

Battery systems

- System integration principles for modules and packs
- Battery Management Systems and state of charge and power estimation
- Thermal Management Systems (TMS), solutions for passive and active cooling
- Battery charging standards, service equipment. Principle of charge control and balancing
- Definition of State of Health (SOH) and Residual Useful Life (RUL)
- Test protocols to characterize degradation in cells

Part 3: Q& A

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HYDROGEN FOR MOBILITY – MOTIVATION, TECHNOLOGY OUTLOOK, AND MARKETS

25 July 2024

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