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Introduction to Hybrid and Electric Vehicle Engineering
BSME Senior Course
Syllabus

Course Description

This course presents fundamentals in hybrid electric, hybrid hydraulic and electric vehicle engineering with specific applications to commercial vehicles, including highway and terrain trucks, buses, mining and forestry machinery, farm tractors and construction equipment, combat and tactical military vehicles, unmanned ground vehicles, planet rovers.

The course focuses on mechatronic system and component design of HEV based on the requirements to power flow management, power conversion and thus to vehicle dynamics and energy/fuel efficiency. Mechanical drivetrain engineering problems are considered in conjunction with electric drive design and then mechatronic wheel-electric drive, suspension and locomotion System design are presented. The course discusses design of batteries and energy storages and vehicle power electronics and also introduces plug-in hybrid electric vehicles.

Additionally to regular lectures, the course provides (i) hands-on experience in testing vehicles on the 4x4 vehicle chassis dynamometer with individual wheel control, (ii) laboratory works of hydraulically-controlled systems, (iii) computer workshops on simulating vehicles and wheel-electric drive control and (iv) practical knowledge in testing and controlling dynamics of an electric unmanned ground vehicle.

Number of credits: 2.5cr lectures and 0.5cr labs and computer workshops

Course Topic Outline

Week/ Sessions	Topic
Week 1. Two Sessions: 1h15min + 1h15min	**1. Hybrid and Electric Vehicles (HEV): History Overview and Modern Applications** 1.1. Ground vehicles with mechanical powertrain and reasons for HEV development 1.2. HEV configurations and ground vehicle applications 1.3. Advantages and challenges in HEV design 1.4. Course objectives
Week 2. Two Sessions: 1h15min + 1h15min	**2. Power Flow and Power Management Strategies in HEV** 2.1. Mechanical power: generation, storage and transmission to the wheels 2.2. Electric power: generation, storage and conversion to mechanical power 2.3. Hydraulic power: generation, storage and conversion to mechanical power 2.4. Energy storage/conversion and thermodynamic relations 2.5. Laboratory Work. FESTO Hydraulic Station: Generation and Conversion of Hydraulic Power (Actuation of linear motion)
Week 3. Two Sessions: 1h15min +	**3. Vehicle Dynamics Fundamentals for HEV Modeling and Computer Simulation (MATLAB/Simulink)** 3.1. Various strategies for improving vehicle energy/fuel efficiency 3.2. Vehicle chassis mathematical model in various operation conditions (steady motion, acceleration, regenerating braking, coasting, moving up and down a hill)

1h15min	3.3. Series HE powertrain mathematical model 3.4. Computer model of the HEV
Week 4. Two Sessions: 1h15min + 1h15min	**3. Vehicle Dynamics Fundamentals for HEV Modeling and Computer Simulation (MATLAB/Simulink) - continuation** 3.5. Computer Workshop. Fuel efficiency evaluation of a series HEV in city and high-way cycles: study and analyze two strategies for ICE/Battery power split **4. Vehicle Testing Laboratory Works** 4.1. 4x4 Vehicle Chassis Dynamometer: Power Curve Test
Week 5. Two Sessions: 1h15min + 1h15min	**4. Vehicle Testing Laboratory Works - continuation** 4.2. 4x4 Vehicle Chassis Dynamometer: Programmed Force Test **5. Mechanical Drivetrain Engineering** 5.1. Driving axle designs and characteristics 5.2. Automatic transmission designs and characteristics
Week 6. Two Sessions: 1h15min + 1h15min	**5. Mechanical Drivetrain Engineering - continuation** 5.3. Planetary gear sets in transmission designs 5.4. Vehicle applications at different modes of operation
Week 7. Two Sessions: 1h15min + 1h15min	**6. Electric Drives** 6.1. DC-Brushed and brushless drives: principles of design, operation, math modeling and control ➢ Shunt Drives ➢ Series Drives ➢ Compound Drives
Week 8. Two Sessions: 1h15min + 1h15min	**6. Electric Drives - continuation** 6.2. Thermal analysis of electric drives in various vehicle applications
Week 9. Two Sessions: 1h15min + 1h15min	**7. Wheel-Electric Drive, Suspension System Design** 7.1. Gear trains in wheel-electric drives 7.2. Mechatronic design of wheel-electric drives 7.3. Suspension design for wheel-electric drives
Week 10. Two Sessions: 1h15min + 1h15min	**7. Wheel-Electric Drive, Suspension System Design - continuation** 7.4. Wheel/Tire-terrain interactive dynamics 7.5. Inverse dynamics-based control 7.6. Computer Workshop. Inverse dynamics-based control of a tire-surface interactive dynamics (NI LabVIEW)

Week 11. Two Sessions: 1h15min + 1h15min	**Midterm Examination (one session)** **8. Batteries and Energy Storages** 8.1. Battery characterization, math modeling and designs 8.2. Battery sizing for various vehicle applications
Week 12. Two Sessions: 1h15min + 1h15min	**8. Batteries and Energy Storages – continuation** 8.3. Battery monitoring and charging control 8.4. Combination of batteries and ultracapacitors 8.5. Fuel cells: principles of operation, design, modeling 8.6. Fuel cell storage system 8.7. Strategy for controlling hybrid fuel cell system
Week 13. Two Sessions: 1h15min + 1h15min	**8. Batteries and Energy Storages – continuation** 8.8. Flywheel energy storage characterization 8.9. Hydraulic accumulator characterization 8.10. Laboratory Work. FESTO Hydraulic Station: Control development and implementation for a three-way spool valve
Week 14. Two Sessions: 1h15min + 1h15min	**9. Power Electronics in Hybrid Electric Vehicles** 9.1. Rectifiers 9.2. Buck convertor 9.3. Voltage source inverter 9.4. Current source inverter 9.5. DC-DC convertor **10. Plug-in Hybrid Electric Vehicles** 10.1. PEV configurations 10.2. Power management problems 10.3. Component sizing
Week 15. Two Sessions: 1h15min + 1h15min	**11. Electric Unmanned Ground Vehicle: Computer Modeling and Physical Tests** 11.1. Autonomous wheel power management for vehicle dynamics control 11.2. UGV tests