



Faculty of Engineering

COURSE OUTLINE

MECH459/558 Fundamentals of Hybrid Vehicles

Term – FALL 2015 (201509)

Instructor

Dr. Zuomin Dong
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Office Hours: Tuesdays, 3:00-4:30 pm

Office Hours

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|-----------|-----------------------|--------------|
| Days: | Tuesdays | Wednesdays |
| Time: | 6:30-7:50 pm | 5:30-6:50 pm |
| Location: | Cornett Building A221 | |

Course Website - <http://www.engr.uvic.ca/~mech459> (un and pw of the controlled portion will be provided.)

Course Objectives

The course is designed to provide the background knowledge for students and UVic Formula Hybrid team participants to learn and to carry out model-based design of hybrid propulsion systems for green vehicles and ships, and to have a better understanding on mechatronics systems.

The course materials are from technical references, research literatures and training materials. After the “introductions” and “examples”, many self-directed “labs” will be needed to get familiar with various modeling and simulation tools. The project will be on new green vehicle powertrain or subsystem design with supporting simulation results, or a focused study on advanced hybrid electric propulsion system for green vehicles and ships.

Learning Outcomes

- 1) Specify the key components of a vehicle propulsion system and their functions
- 2) Qualitatively identify the advantages and limitations, and comment and critique on key aspects of various hybrid electric powertrain systems and vehicles
- 3) Select appropriate hybrid electric powertrain architecture
- 4) Determine appropriate type and size of hybrid electric powertrain components and ESS
- 5) Chose appropriate vehicle driving cycles for vehicle performance testing
- 6) Design hybrid electric powertrain system by combining appropriate powertrain architecture, key powertrain components, and energy storage system
- 7) Build vehicle performance evaluation model using hybrid electric powertrain modeling tools
- 8) Perform vehicle operation performance and energy efficiency evaluation for given driving cycle, powertrain design, and vehicle data through computer simulation
- 9) Identify feasible hybrid electric powertrain system designs and areas for improvement for a given application using vehicle performance and energy efficiency simulation and analysis
- 10) Apply the learnt modeling, simulation and analysis methods to similar transportation applications.

Syllabus

Background of Hybrid Electric Vehicle (HEV) Powertrain Technologies; Vehicle Power Plants, Electric Propulsion Systems, Transmissions, and Energy Storage System; Vehicle Performance Modeling and Simulation Using Advanced Powertrain Modeling Tools; Design and Optimization of HEV Powertrain System; Other Key Issues in HEV Design and Developments; HEV Related Design Project and Case Study.

A-Section(s): A01 / CRN 12329/12333
TA: Rui Cheng (Email: ruicheng@uvic.ca)
Time: 3:00-5:30 pm

B01 (Lab): Tue 14:30-17:20 pm
Days: Tuesdays
Lab: ELWB228; or Office Hours: EOW526

References: (course website)**Course Projects:**

| Midterm and Final Projects | Contents | % | Due Dates |
|-------------------------------------|---|----|--------------|
| Midterm Report I & Presentation | HEV Modeling and Design Using ADVISOR/... Presentations: Oct 13 and Oct 14 | 30 | Oct 13, Tue |
| Midterm Report II | Review on Hybrid Propulsion Technologies | 20 | Nov 3, Tue |
| Final Project Report & Presentation | HEV Powertrain Technology Research Project Presentations: Nov 25, Dec 1 and Dec2 | 50 | Nov 25/Dec 1 |

Note: Failure to pass the Midterm (I&II) and Final projects will result in a failing grade for the course.

Projects will be done in a group of 3 (MECH459) and 2 (MECH558).

The final grade obtained from the above marking scheme for the purpose of GPA calculation will be based on the percentage-to-grade point conversion table as listed in the current Undergraduate Calendar.

There will be no supplemental examination for this course.

Note to Students:

Students who have issues with the conduct of the course should discuss them with the instructor first. If these discussions do not resolve the issue, then students should feel free to contact the Chair of the Department by email or the Chair's Secretary to set up an appointment.

Accommodation of Religious Observance

See entry in current Undergraduate Calendar

Policy on Inclusivity and Diversity

See entry in current Undergraduate Calendar

Standards of Professional Behaviour

You are advised to read the Faculty of Engineering document Standards for Professional Behaviour in current Undergraduate Calendar, which contains important information regarding conduct in courses, labs, and in the general use of facilities.

Cheating, plagiarism and other forms of academic fraud are taken very seriously by both the University and the Department. You should consult entry in current Undergraduate Calendar for the UVic policy on academic integrity.

Course Lecture Notes

Unless otherwise noted, all course materials supplied to students in this course have been prepared by the instructor and are intended for use in this course only. These materials are NOT to be re-circulated digitally, whether by email or by uploading or copying to websites, or to others not enrolled in this course. Violation of this policy may in some cases constitute a breach of academic integrity as defined in the UVic Calendar.

The password protected portion of the course materials were provided by our industrial and DOE sponsors. These materials are made available to Student Competition teams. To access the cutting edge industrial HEV powertrain design and modeling tools, students need to be signed up as Formula Hybrid team members for the term (Software License Requirement).

LIST OF TOPICS

I. MathWorks Multiphysics Modeling and Simulation Tools

1. Introduction and Overview

- Course Organization
- UVic EcoCAR Program, Success, Facilities, Plan and New Formula Hybrid Development
- Introduction to MATLAB and Simulink
- Modeling, Control and System Optimization Using MATLAB and Simulink
- Siemens AUTONOMIE & Data Acquisition Workshop (Oct. 8 & 9, Thur & Fri)

II. Introduction of Hybrid Powertrain Technology

2. Development of Vehicle Technology

- ICE Vehicles
- Electrical Vehicles
- Vehicle Performance Measurement
 - Maximum speed, gradeability and acceleration
 - Fuel economy
 - Emission
 - Braking performance
- Driving Cycles
- Vehicle Testing Facilities and Techniques

- Toyota Prius
- Ford Escape
- GM hybrid
- GM Volt
- UVic EcoCAR1 & EcoCAR2
- Other near future models
- Opportunities and challenges in HEV technology
- Interdisciplinary nature of HEVs
- Advantages of HEV
- Technical challenges of HEV commercialization

3. Overview of Hybrid Electric Vehicles

- Types and Configurations of HEVs
 - Series
 - Parallel
 - THS
 - Two-mode
 - Next generation powertrain systems
- Development of HEV Technology
 - Honda Insight and Civic

4. Other Key Powertrain Issues

- Sizing of HEV powertrains
- Power management
- Vehicle control

5. Onboard Energy Storage System and Their Recent Development

- Battery
- Ultra capacitor
- Fly wheel

III. Modeling, Simulation and Design of Hybrid Electric Powertrain Systems I

6. General Background

- Backward and forward modeling
- Multi-physics model vs. lookup table model
- Vehicle driving cycles
- Load cycles
- Tire model
- Driver model

7. ADVANCED Vehicle Simulator (ADVISOR) from NREL

- Foundation and characteristics of the modeling tool
- Powertrain component modeling
- Vehicle and powertrain system modeling
- Vehicle performance simulation
- Case studies

IV. Overview of Key HEV Powertrain Components

8. **Generic Vehicle Models**
 - Types of Vehicles
 - Key Vehicle Components
 - Vehicle Powertrain
 - Ancillary Systems
 - Vehicle resistances
 - Traction and slip ratio models
 - Vehicle dynamics
9. **Powerplant of HEV**
 - Gasoline Engine
 - Diesel Engine
 - Biofuels and biofuel burning ICE
 - Hydrogen ICE
 - Recent Advances in ICE
 - Electric Powerplant
 - Electric Motor
 - Hydrogen Fuel Cell System
10. **Hydrogen fuel cell system**
 - PEM fuel cells
 - Ancillary devices
 - Power management and control
 - PEM fuel cell system and its modeling
 - Design and optimization of PEM fuel cell system
- Fuel cell vehicle configurations
- Design examples
11. **Study on Well to Wheel Energy Efficiency**
12. **Transmission**
 - Gear transmission
 - Planetary gear systems
 - Continuously variable transmission
 - E-CVT and AMT
 - Static transmission model
 - Power flow model
13. **Electric Propulsion Systems**
 - DC motor drives
 - Induction motor drives
 - Brushless DC PM motor drives
 - SMPM motor and controller
 - Switch reluctant motor drives
 - Starter/alternator
 - Diesel Generator
14. **Power Electronics**
 - DC-DC Converter
 - DC-AC Inverter

Review on Hybrid Propulsion Technologies Report II

V. Modeling, Simulation and Design of Hybrid Electric Powertrain Systems II

15. **AUTONOMIE (Powertrain System Analysis Toolkit) from US Argonne National Lab**
 - Foundation and characteristics of the modeling tool
 - Powertrain component modeling
 - Vehicle and powertrain system modeling
 - Vehicle performance simulation
 - Case studies
16. **UVic EcoCAR (I and II) Work**
17. **Vehicle Powertrain Design Optimization**
 - Design objectives
- Design constraints
- Multiple design objectives
18. **Real-time Optimal Control and Power Management**
 - Plant Model
 - Objective of Control
 - Major Technical Challenges
 - Real time Optimal Power Control for HEVs/PHEVs
 - Real time Optimal Energy Management for PHEVs

19. Design Optimization Tools

- Traditional optimization methods
- MATLAB Optimization Toolbox
- Global optimization schemes
- Computer modeling and simulation based design optimization
- Multi-objective optimization
- Advanced global optimization program tools

20. SimDriveline™ & SimPower™ - MathWorks-Simulink Based Mechanical Driveline and Electrical Power Systems Modeling Tools

- Foundation and characteristics of the modeling tool
- **Sim** series modeling tools
- Powertrain component modeling
- Vehicle and powertrain system modeling
- Vehicle performance simulation
- Case studies

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| HEV Powertrain System Technology Research Project and Presentation |
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Special Topics and Themes

- **Dymola - Dynamic Modeling Laboratory**
 - Foundation and characteristics
 - Modelica multi-physics modeling language
 - Dymola - a Modelica based tool for modeling & simulating integrated/complex systems (automotive, HEV, etc.) from Dassault
 - Powertrain component and system modeling
 - Vehicle performance simulation
- **Mechanical and Suspension System Design: SolidWorks and MCS-ADAMS**
- **Advanced Control:**
 - Vehicle Dynamics Modeling and dSPACE ASM
 - Hardware in Loop (HIL) Testing and dSPACE HIL
- **Electrical Drives**
- **Programming: Infotainment System**

Following Training and Courses

- MECH497 Green Vehicle Technology Project (3 Units);
- MECH499 Technical Project; or MECH498 Honor Thesis (3 Units);
- Formula Hybrid Co-op Term and Formula Hybrid Vehicle Development Team Work;
- Graduate Research.