Advanced Topics in Internal Combustion Engines and Biofuels

Course Syllabus: Thermodynamic and thermochemical fundamentals for the analysis of internal combustion engines. Advanced study of ideal and real cycles, including models with air-fuel mixture and chemical equilibrium. Exergy analysis and availability destruction as a diagnostic and optimization tool. Modeling of intake, compression, combustion (spark-ignition and compression-ignition), expansion, and exhaust processes, with emphasis on finite heat release and heat transfer. Pollutant formation mechanisms and thermodynamic strategies for emission control. Computational thermodynamic modeling of cycles (zero-dimensional and quasi-dimensional) and Low-Temperature Combustion model. Critical comparison between textbook theory and recent research articles.

Prerequisites:

- Undergraduate-level thermodynamics.
- Basic knowledge of internal combustion engine components and operation.
- Familiarity with Python or similar computational tools.

Course Duration: 60 hours.

Learning Objectives: Modeling ideal and fuel-air engine cycles to predict performance and efficiency. Evaluate the thermodynamic factors controlling combustion in spark-ignition and compression-ignition engines. Utilize computational tools to simulate and optimize internal combustion engine processes.

Teaching Content:

1) Internal Combustion Engines Mechanical Cycles. Engines Performance Parameters. Thermodynamic Property Relations.
2) Ideal Engine Cycles. Thermodynamic Modeling of Otto, Diesel, Dual and Miller Cycles Using Air-Standard Assumptions. Four-Stroke Processes and Residual Fraction.

3) Finite Energy Release. Thermodynamic Properties for Ideal Gas Mixtures. Stoichiometry. Low-Temperature Combustion Modeling.
4) Thermochemistry Of Fuel-Air Mixtures. Enthalpy Of Formation, Heating Values, And Adiabatic Flame Temperature.
5) Fuel-Air Cycle Models. Step-By-Step Progression from Air-Standard to Fuel-Air Cycles, Incorporating Real Gas Properties, Dissociation, And Combustion Chemistry for Greater Accuracy.
6) Intake And Exhaust Flow Dynamics, Valve Timing, Volumetric Efficiency, Manifold Tuning and Charging Concepts.
7) Combustion In Spark-Ignition Engines. Thermodynamic Analysis of Flame Propagation, Turbulent Flame Structure, And Cyclic Variation in Combustion.
8) Combustion In Compression-Ignition Engines. Fuel Spray Dynamics, Autoignition, Premixed/Diffusion Burning Phases, And Heat Release Rate Analysis.
9) Heat Transfer and Friction. Modes And Magnitude of In-Cylinder Heat Transfer; Engine Friction Components and Their Impact on Performance.
10) Advanced Thermodynamic Modeling I. Introduction to Zero-Dimensional and Quasi-Dimensional Modeling for Engine Cycle Simulation, Linking Theory to Practice.
11) Advanced Thermodynamic Modeling II. Second Law Analysis of Engines and Exergy-Based Design Optimization.
12) Final Project Presentations & Course Wrap-Up. Students Present Their Modeling or Analysis Project

Assessment: Assignments (20%): End-of-chapter problems in textbooks to reinforce concepts. Midterm Examination (25%): An exam covering the fundamentals of engine thermodynamics and cycle analysis. Project (30%): A computational project using Python to model a fuel-air engine cycle and perform parametric study of key variables. Final Examination (25%): An exam covering the advanced aspects of engine thermodynamics modeling.

Methodology: Lectures and Problem Based Learning.

Textbooks:

- Ferguson, Colin R., and Allan T. Kirkpatrick. Internal Combustion Engines: Applied Thermosciences. 3rd ed., Wiley, 2015.
- Heywood, John B. Internal Combustion Engine Fundamentals. McGraw-Hill, 1988.