MIE 1199 HS – Special Topics in Thermal Science: Thermal Phenomena, Performance and Management of Electric Vehicles (EVs)

Description

This course will describe the thermal phenomena in Electric Vehicles (EVs), including the main circuits associated to the power train, cabin, and battery. A major focus will be on thermal performance and management of power electronics, chargers and batteries, with particular emphasis on Lithium-ion batteries which are expected to be the most used battery for EVs in the next decades. Students in this course are expected to have a basic understanding of electro-chemistry terminologies (e.g., voltage, current, resistance) and undergraduate-level fundamental knowledge of fluid mechanics, thermodynamics and heat transfer.

Course Content

- Introduction of EV Fundamentals
  - Thermal modeling of system- and component-level, electric drivetrain, cabin, and battery
  - Thermal effect on battery performance, range, degradation, safety, SEI, plating, thermal runaway

- Hierarchical Multiscale Thermal Modeling of Lithium-Ion Batteries
  - Trade-off between model computation time, robustness, and fidelity
  - Battery cells: fundamentals, nanoscale modeling (MD, DFT, ML), 2D materials
  - Component-level and computational Fluid Dynamics (CFD) modeling
  - System-level thermal modeling and reduced-order (RO) modeling, digital twins, simulation software

- Battery Cells
  - Overview of Li-ion cells, principles of operation, internal structure, types of batteries, chemistries, and form factors
  - Electrochemical modeling: single-particle zero-dimensional model, one-dimensional model (1D), and detailed three-dimensional model (3D)
  - Characterization and prediction of cell thermophysical properties (e.g., thermal conductivities, heat generation) for cylindrical and pouch cells
  - Inverse heat transfer modeling
  - Thermally-induced stress factors and failure modes: SEI, plating; temperature inhomogeneity

- Battery Thermal Management Systems (BTMS)
  - Techniques for cooling and pre-condition EV batteries; pack- and module-level thermal management, including cooling approaches, coolant delivery modes, and pack architectures

- Aging, Lifetime and Degradation of Li-ion Batteries
    - Aging indicators, calendar and cycling modes, mechanisms, impact of cell chemistry on aging, cell-to-cell variation
    - Predicting aging: data-based models, equivalent circuit models, electrochemical models, electrochemical impedance spectroscopy and incremental capacity
    - Aging and fast charging
    - Mitigating aging

- Thermal Management of Power Electronics, Chargers, Inverters, Electric Motors

- Thermal Management of EV Autopilot & Cabin Electronic Systems