AE 4451 – Jet and Rocket Propulsion

HOURS: 3-0-3

CATALOG DESCRIPTION:

The theories and principles of jet and rocket propulsion. Thermodynamic cycles. The mechanics and thermodynamics of combustion. Turbine engine and rocket performance characteristics. Component and cycle analysis of jet engines and turbomachinery.

PREREQUISITES:

AE 2010 Thermodynamics and Fluids Fundamentals

COURSE OBJECTIVES:

1. Familiarity with common types of aircraft and spacecraft propulsion systems.
2. Use of thermodynamic cycle analysis, including the thermodynamic treatment of chemically reacting systems.
3. Preliminary cycle design and performance analysis of propulsion systems for both aircraft and spacecraft.
4. Working knowledge of the basic operation and design requirements of propulsion turbomachinery components (inlets, compressors, combustors, turbines, afterburners, and nozzles).

LEARNING OUTCOMES:

Students will be able to:

1. Make design choices between jet and rocket propulsion systems based on performance issues
2. Calculate energy release, e.g., adiabatic flame temperatures, and equilibrium composition of gases at known temperature and pressure
3. Analyze the thermodynamic performance of jet engine cycles and compute relevant performance parameters
4. Perform and report preliminary design calculations to size jet engines to meet specific performance goals
5. Analyze the thermodynamic performance of simple chemical and electrical rocket cycles and compute relevant performance parameters
6. Characterize the performance and operating/design constraints for inlets, compressors, combustors, turbines and nozzles

TOPICAL OUTLINE:

1. **Overview**:
    a. Aircraft and spacecraft propulsion systems
    b. General design goals
2. **Mechanics and Thermodynamics of Gases**
    a. **Thermodynamics Review**
        i. Systems
        ii. Conservation/Transport equations
        iii. Momentum conservation and thrust equations
        iv. Properties of perfect gases and perfect gas mixtures
    b. **Equilibrium Chemical Thermodynamics**
        i. Chemical energy/heats of reaction and formation
        ii. Equilibrium composition
    c. **Thermodynamic Cycle Analysis**
        i. Carnot
        ii. Brayton
3. **Airbreathing Propulsion Systems**

a. **Engine Performance Parameters**
    i. Specific thrust
    ii. Specific fuel consumption
    iii. Propulsive, thermal and overall efficiencies
b. **Jet Engine Cycle Analysis and Performance; Cycle Design Optimization**
    i. Ramjets
    ii. Turbojets
    iii. Turbofans (including optimum bypass)
    iv. Turboprops and turboshaft engines

4. **Rocket Propulsion Systems**
    a. **Overview**
    b. **Performance Parameters**
        i. Static thrust
        ii. Equivalent Exhaust Velocity
        iii. Impulse and specific impulse
        iv. Vehicle acceleration and the rocket equation, with mission requirements
    c. **Chemical Rocket Cycle Analysis**
        i. Characteristic velocity and thrust coefficient (example propellant properties and equilibrium and frozen flow calculations)
        ii. Analysis of open and closed liquid rocket cycles (pump requirements, gas generator, staged combustion and expander cycles)
        iii. Solid propellant motor analysis (propellant properties; regression rates; ballistics and stability)
    d. **Electric and In-Space Propulsion**
        i. Power limitations
        ii. Electrothermal; Electrostatic; Electrodynamic propulsion systems
5. **Analysis of Turbine Engine Components**
    a. **Inlet and Nozzle Analysis, Design and Performance**
        i. Subsonic and supersonic diffusers/inlets
        ii. Nozzles and thrust reversers
    b. **Combustor Analysis, Design and Performance**
        i. Combustor configurations
        ii. Stability, flammability operating limits
        iii. Emissions
    c. **Turbomachinery Analysis, Design and Performance**
        i. Axial v. centrifugal configurations
        ii. Euler turbomachinery equations
        iii. Cascade analysis and single-stage performance; blade loading and flow coefficients; off-design performance and maps
        iv. Multistage compressors: startup, operation and surge limits
        v. Turbines – compressor matching
        vi. Turbine materials and cooling: conduction and convection heat transfer analysis