**ME 257/357: Propulsion System and Gas-Turbine Analysis**

**Course Overview:** Propulsion systems convert some form of stored energy or energy that is freely available in the environment into kinetic energy to produce thrust. Since the energy involved is used to do work, the study of propulsion systems is based on concepts from thermodynamics. The course thus begins with a review of essential aero- and thermodynamics, which we then use to analyze thermodynamic cycles that form the basis of propulsion systems. Specific focus of this course is on the design analysis of gas-turbine engines. Beginning by examining an ideal Brayton cycle, we will perform component analyses of combustor, turbine and compressor, thereby increase the level of physical description to account for relevant processes. These investigations are performed by considering a turbofan gas-turbine engine that is representative of a small business aircraft. As part of a series of homework assignments, a computer program will be developed that allows us to perform essential performance studies of this aircraft engine.

**Objectives:** The goals of this class are to:

1. Review elementary principles of aircraft performance and thermodynamic analysis as applied to propulsion systems
2. Provide an introduction to combustion, chemical kinetics, and equilibrium chemistry
3. Provide a working knowledge of and tools for component analysis and design of gas-turbine engines

**Outcome:** By the end of the course you should:

1. Have understanding about classical thermodynamic concepts and state relations.
2. Be able to perform thermodynamic cycle analysis, including characterization of thermal efficiency, net work, and other performance criteria, as applied to a gas-turbine cycle.
3. Perform a basic design of a gas-turbine engine, with relevance to jet engines and turbofans.
4. Have a basic understanding about environmental challenges (associated with pollutant formation, fossil fuel combustion, and noise emissions) and technological issues of advanced propulsion systems.

**Course Prerequisites:** ENGR 30, ME 70, ME 131B, CME 100

Lectures: 380-380X

10:30 – 11:50am Tuesday, Thursday

Instructor: Matthias Ihme

Office: Building 500, Room 500A

Office-hours: Monday: 4:30pm – 6:00pm, and open door

Email: [mihme@stanford.edu](mailto:mihme@stanford.edu)

Phone: (650) 724-3730

Grading: Homework 50% Problem sets are due before the beginning of the class at submission day, late work is accepted with a loss of 15% per day for a maximum of 3 days (including weekend days). Valid excuses are not penalized but must be discussed (at least 3 days) in advance with the instructor.

Midterm Exam 20% Thursday, *May 24th*, 10:30-11:50 am (tentative)

Final Project 30% Due: Tuesday, *June, 12th* (tentative)

Course webpage: <https://canvas.stanford.edu>

Teaching Assistant: Qing Wang (desk: 500-501N2)

Office hours: Bldg. 500, Room 501A

Tuesday 4:30 – 6:00pm

Wednesday 4:00 – 6:00pm

Email: [wangqing@stanford.edu](mailto:wangqing@stanford.edu)

Textbook:

Mattingly, J. D., “Elements of Propulsion: Gas Turbines and Rockets.” AIAA Ed. Series.

Supplementary reading material: Since this course covers different subject areas (including aerodynamics, thermodynamics, and gas turbines), we are using supplementary material from different sources. For this, a course reader has been developed that is available from coursework.

Additional resources will be provided as handouts, lecture notes, presentations, or supplementary reading.

Below is a list of complementary reading for this course; all books are on reserve at the library:

* Hill, P. and Peterson, C., “Mechanics and Thermodynamics of Propulsion.” Addison-Wesley.
* Saravanamuttoo, H. I. H., Rogers, G. F. C., Cohen, H., and Straznicky, P. V., “Gas Turbine Theory.” Pearson.

Other useful resources:

* Thermodynamics:
  + Cengel & Boles: Thermodynamics: An Engineering Approach, McGraw-Hill
  + Reynolds & Perkins: Engineering Thermodynamics, McGraw-Hill
* Aerodynamics:
  + Anderson, Introduction to Flight, McGraw-Hill
  + Anderson, Modern Compressible Flow, McGraw-Hill
* Gas Turbine Engines:
  + Lefebvre: Gas Turbine Combustion, Taylor & Francis
  + Farokhi: Aircraft Propulsion, Wiley
  + Cumpsty: Jet Propulsion – A Simple Guide to the Aerodynamic and Thermodynamic Design and Performance of Jet Engines, Cambridge University Press
  + Dixon & Hall: Fluid Mechanics and Thermodynamics of Turbomachinery, Butterworth-Heinemann; also available as online resource: <http://www.sciencedirect.com/science/book/9780124159549>
  + Rolls Royce: The Jet Engine – A complete overview of the modern gas turbine
  + Online resource to Jane’s aero engines: <https://janes.ihs.com>

Lecture policy:

* All material covered in class and provided as lecture notes may be on a test
* No open laptops and computers during class, except for taking notes
* No emailing or other electronic/social network media allowed during lecture

Guidelines for problem-sets:

* Problem solutions must be submitted in neat, professional, and legible form
* Stanford Honor Code applies to all problem sets, midterms, and projects
* You are encouraged to work in groups to discuss your solution approach on a *conceptual level*; however, every student has to submit her/his own write-up and non-trivial code
* Problem sets will include mathematical derivations, for which partial credit is given. Therefore, unless otherwise stated, *symbolic* *software packages* (such as MAPLE, Mathematica, Matlab-symbolic tool-box, …) are not allowed for solving the HW-problems.
* A main emphasis of this lecture is on the development of a computer program of a turbofan engine that can be utilized for basic engine-design analysis

**Course Schedule**

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| --- | --- | --- | --- | --- |
| **Week** | **Weekdays** | **Topic** | **Recommended Reading Material[[1]](#footnote-1)** | **PSets** |
| 1 | 4/03; 4/05 | Introduction and problem formulation; review of aerodynamics and aircraft performance |  |  |
| 2 | 4/10; 4/12 | Thrust equation and engine performance | M: 1; 2; 5.7 | PSet #1 posted |
| 3 | 4/17; 4/19 | Specific turbofan concepts and parametric turbofan analysis | HP: 5 | PSet #1 due  PSet #2 posted |
| 4 | 4/24; 4/26 | Combustor, low NOx, alternate fuels, LPP design, theory of flameout limits | HP: 6  M: 10.6; 10.7; 10.8  SRCS: 6 |  |
| 5 | 5/01; 5/03 | Multistage compressor, velocity triangles, stall margins, surge | HP: 7  SRCS: 5 | PSet #2 due  PSet #3 posted |
| 6 | 5/08; 5/10 | Blade twist, radial equilibrium, stage design |  |  |
| 7 | 5/15; 5/17 | Matching turbine and compressor, equilibrium running line, envelope | HP: 8.7  M: 8  SRCS: 9; 10.4 | PSet #3 due  PSet #4 posted |
| 8 | 5/22; 5/24 | Off-design performance charts, transient engine operation |  |  |
| 9 | 5/29; 5/31 | Special topics |  | PSet #4 due |
| 10 | 6/05 | Special topics |  | Project due |

Travel:

5/17

6/05

1. Literature reference to recommended reading material:

   P: Hill & Peterson

   M: Mattingly

   SRCS: Saravanamuttoo, Rogers, Cohen, & Straznicky [↑](#footnote-ref-1)