AME 415 Fall 2020 Syllabus

- Course Title**: Turbine Design and Analysis**
- No prerequisite courses. Familiarity with Matlab is necessary for project assignments.
- Instructor: Bogdan Marcu
    - Office: Online. Office hours are worked via email interaction with a response time of 24 hours or less for the questions sent via email.
    - Email: marcu@usc.edu,

Introduction and Purposes

AME 415 is an introductory course focusing on the hands-on design and analysis of industrial equipment. Using axial turbines as the work example, the course is introducing the mechanical and aerospace engineering students to the typical approaches used in the industry. After laying the fundamental principles derived from thermodynamics, the course introduces techniques of performance modeling based on empirical test data correlations, design parameterization, and advanced Computational Fluid Dynamics analysis. All concepts and techniques learned are applied to the design of an axial turbine conforming to industry standards.

Utilized in propulsion, power generation and other applications, turbines of various configurations constitute a type of machinery essential for modern industrial economies. In a straightforward and applied manner, the class project allows the student to understand the physics associated with turbine operation and train into the complete chain of design and analysis tasks associated with the development of turbine hardware. Starting with writing design code, continuing with conceptual design, and advancing through detailed geometry definition and advanced CFD analysis, the class project addresses every segment of typical development processes currently employed in the industry.

Given the special format of the course, a detailed description of the home work and project work is provided below.

Homework

A series of 5 homework assignments will be given before the actual project is started. Each homework is a small project designed to introduce and familiarize the student with the science, and algorithms and the work methodology to be later used for the main project

1. Compressible flows and iterative calculations of thermodynamic parameters
2. Simple performance calculations, 1-D approximation of turbine flow physics and design reasoning
3. Working on NASA turbine reports: extraction of turbine performance from standard maps, understanding of similarity principles and scaling.
4. Three dimensional design concepts with verification of work distribution per radius.
5. Example Computational Fluid Dynamics analysis of a 2-D airfoil

Project

The structure of the class project mimics the development work performed in industry with equal emphasis on both academic understanding of the fundamental flow physics and the engineering rigor expected in the non-academic fast paced development programs. Tested on previous pilot courses, the project structure proved to be the most effective mean of learning how to integrate i)academic knowledge, ii)algorithm development and coding, iii)design reasoning, iv)design methodology and v)advanced analysis tools in order to define an engineering product in complete detail. The stages of the project progress as follows:

- Define the concept of the required product in the context of existing experience. Selection of main parameters
- 1-D analysis. Develop analysis algorithms, code, validate and apply to the design at hand. Turbine sizing.
- Generate 2-D airfoil geometry. Understand cascade flow physics, design criteria and utilization of design tools. Application of empirical loss correlations. Turbine geometry definition at mean diameter.
- Advanced CFD analysis of geometry generated. Interpretation of results, design iterations and successive improvement.
- Extend design to 3-D. Design reasoning, establish methodology and apply to the 2-D baseline design already developed.
- Extract the overall machine performance
- Communication: The project will be graded based on 3 reviews at the end of the course. These reviews mimic the typical reviews carried in the industry during a development program: i) Conceptual, ii)Detail and Final (Critical) reviews. Chart package design, organization of information flow, verbal presentation, peer scrutiny and evaluation.

Course Requirements and Grades

- Text-book/Reading material: hand-out notes.
- Grading :
    - 35% Homework
    - 65% Project

Course and Project Schedule

Week 1. General background for turbomachines. Turbine types and configurations. Thermodynamics associated with turbine analysis. Euler Equation. Fluid Properties.

- HW 1 Assignment. Power calculations and balance between a pump and driving turbine. Application of Euler equations.

Week 2. Short review of compressible flows equations.
Introduction to turbines: configurations, detailed enthalpy-entropy diagrams, efficiency, non-dimensional performance parameters and performance maps and reporting.

- HW 2 Assignment Calculation of flow parameters through a channel between adjacent airfoils. Stator-rotor flow angle and pressure calculations. Application of Euler equation, and calculation of efficiency

Week 3. The axial flow turbine. Elements of turbine geometry, vane and blade airfoils. Airfoil cascade performance. Degree of reaction. 3-D stage design based on radial equilibrium.

- HW 3 – Extract turbine performance information from test reports, calculate massflow, torque and power for given DESIGN POINT operating conditions.

Week 4. Training session 1.

- Airfoil design. Training for the airfoil design tool. Airfoil CFD analysis.
- CFD Session 1: Training for CFD analysis (StarCCM+/ANSYS CFX)
- HW 4 – Design an airfoil and perform CFD analysis for a given set of conditions.

Week 5. Training session 2.

- CFD Session 2: Training for CFD analysis using (StarCCM+/ANSYS CFX).
- Project team formation: students organize themselves in teams of 3 members.
- HW5 - Extract turbine performance information from test reports, calculate massflow, torque and power for given OFF-DESIGN POINT operating conditions

Week 6. The axial flow turbine design: 1-D sizing. Turbine sizing, analysis at meanline diameter and dimensioning of the turbine flow path, airfoil heights, flow areas, flow angles. Baseline turbine example with detailed numerical results.

- Project task 1: Coding your own 1-D turbine design code

Week 7. The axial-flow turbine loss system. Turbine Empirical Performance. Detailed numerical calculations of the losses for the Baseline Turbine Example.

- Student project review for Task 1, discussion and guiding
- Project Task 2: Validate your own loss system code. Adapt loss calculations to your turbine code.

Week 8. Working session 1 one on one with each student team hands-on, code debugging, algorithm corrections.

Week 9. Working session 2 one on one with each student team hands-on, code debugging, algorithm corrections.

- Turbine sizing code verification against instructor’s coding for each team.

Week 10. Working session 2 one on one with each student team hands-on, code debugging, algorithm corrections.

- Final turbine sizing students' code verification against instructor's coding for each team.
- Project CFD analysis – discussions, guiding, verification, recommendation.

Week 11. Project Phase I – Turbine Stage Conceptual Design Review (Co-DR): 1-D sizing, and preliminary performance.

- Graded Review. Class presentation

Week 12. Project Phase II – Detailed Design Review (PDR): Refined 1-D sizing and performance. Preliminary design of stators and rotors and associated CFD analysis.

- Graded Review. Class presentation

Week 13. Project Phase III – Critical Design Review (CDR). Finalized turbine stage performance. Finalized airfoil geometries for rotors and stators. Detailed CFD analysis.

- Graded Review. Class presentation, peer-review, discussion of results, wrap-up

Miscellaneous notes

- Late work policy: homework and project phase assignments must be completed in time, no late work accepted.
- Participation is not evaluated, however, the students are strongly encouraged to attend the lecture given the hands-on nature of the course work.
- Bibliography

    - Ronald. H. Aungier, Turbine Aerodynamics, ASME Press 2009, ISBN 0-7918-0241-8
    - David Japikse and Nicholas C. Baines, Introduction to Turbomachinery, Oxford University Press, 1997, ISBN 0-933283-10-5.
    - J.H. Horlock, Axial Flow Turbines, Krieger Publishing 1985 (reprint), ISBN-10: 0882750976, ISBN-13: 978-0882750972

Students with Disabilities

Any student requesting academic accommodations based on a disability is required to register with Disability Services and Programs (DSP) each semester. A letter of verification for approved accommodations can be obtained from DSP. Please be sure the letter is delivered to me (or to TA) as early in the semester as possible. DSP is located in STU 301 and is open 8:30 a.m.–5:00 p.m., Monday through Friday. The phone number for DSP is (213) 740-0776.

Academic Integrity

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