Turbomachinery Design

Academic Year: (2021 / 2022) **Review date: 09-06-2021**

Department assigned to the subject: Department of Bioengineering and Aerospace Engineering

Coordinating teacher: DISCETTI , STEFANO

Type: Electives ECTS Credits : 6.0

Year : 4 Semester :

REQUIREMENTS (SUBJECTS THAT ARE ASSUMED TO BE KNOWN)

Fluid Mechanics
Thermal Engineering

OBJECTIVES

The goal of this course is to introduce students to the basic principles and methodologies of turbomachinery design. The students are expected to achieve a fundamental and applied knowledge of the working principles and design guidelines of axial and radial turbomachines.

Link to document

DESCRIPTION OF CONTENTS: PROGRAMME

Introduction. Dimensional Analysis
- Definition of a turbomachine. Different kinds and applications.
- Main defining variables, dimensions and fluid properties. Units.
- Dimensional analysis and performance laws. Compressible flow analysis. Specific speed: machine selection. Model testing.

Fluid mechanics and thermodynamics equations
- Equations in integral form.
- Euler equations for turbomachines.
- Definition of Rothalpy.
- Definition of adiabatic / polytropic efficiency. Enthalpy-entropy diagrams.
- Equations in differential form.

Two-dimensional cascades
- Introduction. Definition of streamsurface, m¿-¿ plane, blade-to-blade analysis.
- Cascade nomenclature for compressors and turbines.
- Cascade kinematics: velocity triangles. Cascade dynamics: forces, momentum. Cascade entalphy and entropy change: losses.
- Compressor cascade performance. Compressor characteristics: enthalpy rise, pressure recovery, deflection, deviation and loss. Blade loading: surface velocity distribution, diffusion factor. Compressor cascade correlations: optimum solidity, polar curve. Diffusor efficiency.
- Turbine cascade performance. Turbine characteristics: turning angle, Zweifel coefficient. Surface velocity distribution: Back Surface Diffusion parameter. Turbine cascade correlations: loss, optimum pitch-chord ratio.
- Cascade wind tunnel testing. Description of tunnels, measurements. Unsteadiness.

Axial flow turbines: two-dimensional stage theory
- Dimensional analysis of a single turbine stage. Velocity triangles, loading and flow parameters, reaction. Repeating stage hypothesis.
- Thermodynamics of a turbine stage. Total-to-total stage efficiency. Row loss-stage efficiency relation
- Reaction. Effect on efficiency. Optimum reaction
- Smith chart. Empirical versus reversible.
- Flow characteristics of a multistage turbine.
- Stress/Cooling/Detailed design. Design criteria.

Axial flow compressors and fans: two-dimensional stage theory
- Dimensional analysis of a single compressor stage. Velocity triangles, loading and flow parameters, reaction. Repeating stage hypothesis.
- Thermodynamics of a compressor stage. Total-to-total stage efficiency. Row loss-stage efficiency

relation.
- Loading-Flow coefficient chart. Reaction choice. Lift and Drag in terms of ¿ and ¿. Diffusion Factor and solidity selection. Estimation of compressor efficiency. Simplify off-design performance.
- Blade element theory.
- Stall and surge phenomena.

Three-dimensional flow in Axial Turbomachines
- Theory of radial equilibrium. The indirect problem: free-vortex flow, forced-vortex flow, general whirl distribution. The direct problem.
- Compressible flow through a blade-row.
- Constant specific mass flow.
- Off-design performance of a stage (free-vortex turbine).
- Actuator disc approach. Blade-row interactions. Computer methods solving through-flow problem.
- Secondary flows. Loss, angles and helicity.
- Three-dimensional losses. Types and models.
- Three-dimensional design features. Lean, sweep and bow.

Centrifugal compressors, fans and pumps
- Introduction and definitions. Centrifugal compressor parts.
- Theoretical analysis of a centrifugal compressor. Dimension-less performance parameters. Inlet, impeller and diffuser equations.
- Optimum design of a centrifugal compressor inlet.
- Radial flow turbo-machine blading design/selection
- Slip factor. Correlations.
- Performance of centrifugal compressors.
- Diffuser system. Vane and vane-less diffusers.
- Chocking in centrifugal compressor stage.

Radial turbines
- Introduction. Types of inward flow radial turbine.
- Thermodynamics of the 90 degrees IFR turbine
- Basic rotor design. Rotor efficiency definition. Mach number relations. Loss coefficients.
- Optimum efficiency considerations. Minimum number of blades.
- Design criteria. Pressure ratio limits.

LEARNING ACTIVITIES AND METHODOLOGY

Theory sessions.
Problem sessions working individually and in groups.
Lab-sessions.

ASSESSMENT SYSTEM

In order to pass the subject, two requirements need to be met:

1) to have a MINIMUM mark of 4.0/10 in the end-of-term exam;
2) to have a minimum overall mark of 5.0/10 (weighing 75% the mark of the continuous evaluation and 25% the end-of-term exam mark).

The continuous evaluation includes 2 partial exams (each one corresponding to 15% of the final mark) and reports of laboratory practices (corresponding to 45% of the final mark).

% end-of-term-examination:	25
% of continuous assessment (assigments, laboratory, practicals…):	75

BASIC BIBLIOGRAPHY

- R. I. Lewis Turbomachinery Performance Analysis, John Wiley & Sons Inc, 1996
- S Larry Dixon, Cesare Hall Fluid Mechanics and Thermodynamics of Turbomachinery, Seventh Edition, BH (Butterworth-Heinemann), 2013

ADDITIONAL BIBLIOGRAPHY

- Budugur Lakshminarayana Fluid Dynamics and Heat Transfer of Turbomachinery, John Wiley & Sons Inc, 1995
- Korpela,S.A. Principles of Turbomachinery, Wiley&Sons, 2011
- Saeed Farokhi Aircraft Propulsion, John Wiley & Sons Inc, 2008