Aerospace propulsion: complement II

Academic Year: (2017 / 2018) **Review date: 25-01-2018**

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

Coordinating teacher: RAIOLA , MARCO

Type: Electives ECTS Credits : 6.0

Year : 4 Semester : 2

STUDENTS ARE EXPECTED TO HAVE COMPLETED

Fluid Mechanics
Aerospace propulsion
Aerodynamics
Thermal Engineering

COMPETENCES AND SKILLS THAT WILL BE ACQUIRED AND LEARNING RESULTS.

The student will acquire knowledge of turbomachinery and propellers and their applications to aerospace propulsion. This course is intended to provide the core of the 'aerospace propulsion minor' syllabus to students that followed the 'aerospace vehicles minor'. This complemented syllabus will give students a more solid background for continuing Master studies in Aerospace Engineering.

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.

The Propeller
-Geometry and characteristics of propellers
-Momentum and blade element theory
-Propeller propulsive efficiency
-Compressibility tip loss
-Propeller testing
-Design of optimum propellers

Turboprop and Turboshaft Engines
-Cycle analysis of conventional-free-turbine turboprop engine
-Installation issues
-The impact on regional aviation
-The Unducted Fan

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 60% the end-of-term exam mark and 40% the mark of the continuous evaluation).

% end-of-term-examination:	60
% of continuous assessment (assigments, laboratory, practicals…):	40

BASIC BIBLIOGRAPHY

- Dixon S, Hall C Fluid Mechanics and Thermodynamics of Turbomachinery, Butterworth-Heinemann, 2013
- Greatrix DR Powered Flight, The engineering of Aerospace Propulsion, Springer, 2012
- Lewis RI Turbomachinery Performance Analysis, John Wiley & Sons Inc. , 1996
- Richard Von Mises Theory of flight, Dover, 2012