FACULTY OF **ENGINEERING**

DEGREE COURSE: **INDUSTRIAL ENGINEERING**

MASTER DEGREE: **INDUSTRIAL ENGINEERING / ENERGY**

SUBJECT: AERODYNAMICS AND GASDYNAMICS

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OBJECTIVES

The course aims at providing the basic knowledge of Aerodynamics and Gas Dynamics. The main objective is the acquisition of knowledge about the phenomena that characterize incompressible and compressible flows, measurement technologies and conceptual design of the aerodynamic surfaces.

CONTENTS

Introductory concepts
1. History of aerodynamics and flight
2. Fundamental variables in aerodynamics
3. Similarities and Buckingham theory
4. Aerodynamic forces and aerodynamic coefficients

Fundamental equations
1. Algebra of Vectors and Tensors
2. Control Volume Analysis
3. Substantial Derivative
4. Conservation of Mass and of Momentum

Kinematics of fluids
1. Stream-lines, path-lines trajectories, smoke-lines and other visualization techniques
2. Angular velocity of the particle, strain rate and shear stress
3. Vorticity and circulation
4. Velocity Potential Function
5. Stream function

Inviscid and Incompressible Flows
1. Incompressibility
2. Low speed wind tunnel
3. Pitot tube and speed measurement
4. Potential Flows in 2D and Laplace equation
5. Inviscid flow on a circular cylinder
6. Generation of lift and Kutta-Joukowsky theorem
7. D'Alembert's paradox

Incompressible flow around airfoils
1. Geometry of a wing airfoil
2. Characteristics of airfoils, NACA 4 and 5 digits
3. Vortex Sheet and analytical solution of the flow around an airfoil
4. Kutta condition
5. Starting and Stopping Vortex
6. Circulation and Kelvin theorem
7. Theory of thin profiles, symmetric and cambered cases
8. The phenomenon of stall

Incompressible flow around a wing of finite extension
1. Downwash and induced drag
2. Vortex filaments in 3D, Biot-Savart law and Helmholtz theorem
3. Prandtl theory of the lifting line
4. Numerical solution of flow over finite wing: Vortex Lattice Method
5. Winglets

Viscous Flows
1. Fundamental Principles of viscous flows
2. Navier-Stokes equations
3. Couette and Poiseuille Flow
4. Boundary layer equations
5. Blasius solution for flows over flat plate
6. Polhausen Integral solution of momentum equation
7. Boundary layer control strategies: Suction and Blowing
8. The laminar airfoil, NACA 6 digits and Wortmann airfoils

Flaps, Slats and static longitudinal stability of the aircraft
1. Flaps, Slats and high lift devices
2. Longitudinal Static Stability of the aircraft
3. Example of calculation

Aerodynamics of bluff bodies and cars
1. Aerodynamics of bluff bodies and aerodynamic interference
2. Wakes
3. Aerodynamics of transportation cars
4. Aerodynamics of racing cars
5. NACA duct

Rotating wings aerodynamics the case of wind turbines
1. Conservation of the angular momentum
2. Aerodynamics of turbomachinery
3. The case of the rotary wing
4. Aerodynamics of wind turbines
5. Airfoils for wind turbines

Gasdynamics Compressible flows: introductory concepts
1. Elements of thermodynamics
2. Compressibility definition
3. The speed of sound

4. Equations of compressible flows
5. Stagnation conditions
6. Phenomenological aspects of shock waves

One-dimensional gas dynamics
1. Simplified Equations
2. Flows in nozzles and diffusers
3. The convergent-divergent nozzle
4. Lock sonic flow
5. Wind tunnels supersonic

Normal shock waves, oblique and expansion waves
1. Equations of the normal shock waves
2. Upstream and downstream properties in a shock wave
3. Equations of oblique waves
4. compressible flows of cones and pyramids
5. Shock waves separated on bluff bodies
6. Relations expansion Prandtl-Meyer

Compressible flow over airfoils
1. The velocity potential
2. The Compressibility correction of Prandtl-Glauert
3. Critical Mach Number
4. The barrier of sound and the rule of the Area
5. The supercritical airfoils

Turbulence and Introduction to CFD (Computational Fluid Dynamics)
1. Concept of Turbulence
2. Reynolds' Averaged Equations for turbulent flows
3. CFD Simulation, discretization of equation and domain
4. Techniques to differences in volume and finite element
5. Approaches DNS LES and RANS simulation of turbulence

Elements of Environmental Aerodynamics
1. The environmental boundary layer
2. Aerodynamics of buildings
3. Environmental Wind tunnels

LEARNING OUTCOMES

At the conclusion of the course, students will have acquired the necessary tools to model aerodynamic phenomena and to perform the calculation or measurement of the forces exerted by the air on solid surfaces.

ASSESSMENT

Written exam: multiple-choice tests and open-ended questions

RECOMMENDED TEXTBOOKS

- J.D. Anderson Jr. "Fundamentals of Aerodinamics" Mc Graw Hill

- E.L. Houghton, P.W. Carpenter "Aerodynamics for engineering students" Butterworth Heinemann
- R. Aris "Vectors Tensors and the Basic Equations of Fluid Mechanics" Dover Books
- Milton Van Dyke "An album of fluid motion" The Parabolic Press