Informazioni generali

- Anndi corso: 1
- Semestre: 2
- CFU: 6
- Insegnamento tenuto in lingua **INGLESE**

Docente responsabile

Vincenzo MULONE

Obiettivi

The course provides advanced knowledge for the design of fluid machines, in particular dynamic (turbo) compressors and turbines. Once the fluid dynamics equations are briefly introduced, the phenomenological aspects of vorticity transport, of boundary layer and of compressibility effects of the fluid are studied in depth for the design of dynamic (turbo) machines for industrial, aerospace and automotive applications. The fundamentals of integrated turbomachinery design with the systems connected to them are also described.

Programma

- Equations of fluid machinery
- Description of stress/strain models.
- Material and non-material description of the motion. Reynolds Transport theorem.
- Integral and continuity differential equations, momentum (Navier-Stokes), energy in mechanical and entropic therma-transient form. Relative motion. Inertial forces.
- Dynamics of vorticity. Rotational and irrotational flows. Actions on wing profiles. Kelvin's theorem. Examples of potential flow calculation around aerodynamic profiles.
- Boundary layer: local and global parameters, turbulent laminar transition, hints on control.

- General information on turbomachinery design and operation parameters
- Dimensionless parameters
- Classification and choice of turbomachines through dimensionless parameters
- Influence of viscosity, size effects and cavitation.
- Similarity in thermal turbomachinery.
- Operating(characteristic) curves.

- Transformations in turbomachinery

- Efficiency, loss coefficients.
- Euler work, integral equation of moment of momentum.
- One-dimensional analysis of a stage, graphic representation.
- Degree of reaction of a stage.
- Dimensionless analysis of a stage.
- Repeated stage, normal stage.

- Flow analysis in turbomachinery
- Coordinates and reference systems; schematic of the flow field.
- Geometry, cascades, cascade performances.
- 2D cascade, radial cascade.
- Radial equilibrium, free and forced vortex.
- Secondary flows, profile losses and mixing effects.
- General theory of diffusers, efficiency, pressure recovery coefficient.

- Axial compressors
- General description.
- Velocity diagrams, efficiency, degree of reaction, optimization of the stage.
- Comparison between stages with different degrees of reaction. IGV.
- Main profiles used. Pressure and speed distribution around the profile. Calculation of optimal incidence angles.
- Main design correlations. Load criteria for axial cascade. Profile losses. Design of the main aerodynamic profiles used for compressors.
- Off-design behavior of cascades.
- Transonic stages and proifles. Supersonic compressors.
- Ring losses, secondary losses.
- Axial fans and propellers.
- Outline of the 3D design methodologies of complex blades.
- Outline of matching in multi-stage compressors.
- Design of an axial multistage compressor.

- Centrifugal compressors
- General description.
- Actual operation of centrifugal compressors.
- Load reduction coefficient (slip-factor). Stodola theory, main correlations.
- Design of the impeller. Meridian channel, number of blades, efficiency, incidence, vaneless and vaned diffusers. Volute casing. Main types of losses.
- Notes on centrifugal fans.

- Abnormal operation of compressors.
- Stall, surge: generalities.
- Elementary theory of the rotating stall.

- Elementary surge theory.
- Compressor instability.

- Analysis of system-machine coupling.
- External characteristic curve, match with the machine characteristic curve.
- Machines and systems for compressible and incompressible fluids.
- Complex branched circuits.
- Cavitation for incompressible fluid machines
- Flow rate control in circuits: throttling, bypass and speed control strategies. Flow control in compressible fluid machines.

- Axial and radial turbines.
- General aspects, velocity coefficient
- Smith diagrams
- Choice of aerodynamic profile
- Basic design strategies for radial turbines.

Eventuali propedeuticità

The student should have already attended the basic courses of calculus, geometry, physics, heat transfer, energy conversion and fluid mechanics.

It is required that the student has good skills with regard to the differential and integral calculus, the matrix calculation and the linear algebra, the basics of thermodynamics and heat transfer.

Testi di riferimento

- Course powerpoint slides
- Osnaghi, Teoria delle Turbomacchine, Esculapio
- N.A. Cumpsty, Compressor Aerodynamics, Krieger
- Saravanamuttoo Rogers, Gas Turbine Theory, Pearson
- Sandrolini Naldi, Macchine voll. 1 e 2, Pitagora
- Dixon and Hall, Fluid Mechanics and Thermodynamics of Turbomachinery, Elsevier
- Albin, Compressori centrifughi e assiali, Liguori
- Karassik et al., Pump handbook, McGraw Hill

Per ulteriore approfondimento:

- Tweedt, Daniel Lawrence, The aerodynamics of a baseline supersonic throughflow fan rotor (1993). Retrospective Teses and Dissertations. 12194. http://lib.dr.iastate.edu/rtd/12194.
- Arthur Kantrowitz. The supersonic axial compressor. NACA Report 974.
- Ayse G Gungor, Yvan Maciel, Mark P Simens and Julio Soria. Analysis of a Turbulent Boundary Layer Subjected to a Strong Adverse Pressure Gradient (2014).Journal of Physics: Conference Series 506,012007.
- Takahiro Tsukahara, Yohji Seki, Hiroshi Kawamura,Daisuke Tochio.DNS OF TURBULENT CHANNEL FLOW AT VERY LOW REYNOLDS NUMBERS. Technical report Tohoku University.
- Bo Song, Wing F. Ng. Performance and Flow Characteristics of an Optimized Supercritical Compressor Stator Cascade. ASME J Turbomachinery (2006).
- Lasse Mueller, Zuheyr Alsalihi, Tom Verstraet.Multidisciplinary Optimization of a Turbocharger Radial Turbine. ASME J Turbomachinery (2013).
- Simon J. Gallimore,John J. Bolger, Nicholas A. Cumpsty, Mark J. Taylor, Peter I. Wright,James M. M. Place. The Use of Sweep and Dihedral in Multistage Axial Flow Compressor Blading—Part II: Low and High-Speed Designs and Test Verification. ASME J Turbomachinery (2002).
- H. Ji-ang, G. Jian, Z. Jingjun, Y. Chenguang. Effect of Vane Opening on Aerodynamic Performance of the Ram-rotor Test System. Journal of Thermal Science Vol.25, No.3 (2016) 207-215.
- Sara Ling and Ted Sönne. VGV optimization for performance. MSc. thesis, University of Lund (2014).

Modalità d'esame

The student's assessment is carried out with a project test and an oral one.

In the project test students are grouped by three, working on a topic proposed by them and agreed with the instructor. Groups must develop the topic, implementing models to characterize innovative systems and related components. Results must be provided in form of a 10 page scientific paper, providing the background, the model details, results, conclusions and a reference list. The project test is evaluated with a grade between 0 and 10. Access to the oral exam is given once the design test is done with a grade of at least 5.

In the oral exam the student will have to demonstrate sufficient knowledge about machine design, operation, control and functioning. The learning outcomes of the student will be verified with respect to advanced aspects of the design and operation of the machines, through questions initially about the basic principles of operation, discussing the operating and simplifying hypotheses and the effect of the variability of the operating parameters on the machine performance.

The final grade is determined by 1/3 of the grade obtained in the project and by 2/3 by the grade (out of scale of 20) obtained at the end of the oral test.

Scheda insegnamento

 Scheda insegnamento Fluid Machinery Design and Modeling (188 kB)