



COURSE: **Macchine & Sistemi Energetici**

ACADEMIC YEAR: 2016/2017

TYPE OF EDUCATIONAL ACTIVITY: Characterizing

TEACHER: Bonfiglioli A. (6 CFU) e Magi V. (3 CFU)

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Language: italian

ECTS: 9

n. of hours: 90

Campus: Potenza
School: Engineering
Program: Ingegneria Meccanica

Semester: second

EDUCATIONAL GOALS AND EXPECTED LEARNING OUTCOMES

The course aims to provide knowledge on the architecture and operation of volumetric fluid machines and turbomachines, both power absorbing and power generating, operating with both incompressible and compressible fluids. These include: turbo-pumps, volumetric compressors, water, steam and gas turbines and internal combustion engines. Such knowledge is aimed at providing the skills necessary to appropriately choose and operate fluid machines within an industrial environment.

The main knowledge provided will be:

1. basics of applied thermodynamics and fluid dynamics;
2. knowledge of the main types of fluid machines, power absorbing and power generating, volumetric and turbomachinery;
3. Fundamental characteristics of centrifugal turbo pumps, volumetric compressors, hydraulic and thermal turbines, internal combustion engines;
4. Basic knowledge to address the study of energy systems that use fluid machinery, including: aircraft engines, hydroelectric, gas turbine engines, pumping stations;

The main skills (ie the ability to apply their knowledge) will be:

1. to analyze existing fluid machinery, in order to identify their operating conditions;
2. evaluate the most suitable types of machines that meet the given design requirements.

PRE-REQUIREMENTS

You must have acquired and assimilated the following knowledge provided by the courses of "Analisi I", "Fisica I", "Meccanica dei Fluidi" e "Fisica Tecnica":

1. Knowledge of differential calculus in one independent variable;
2. Knowledge of kinematics and dynamics of a material point;
3. Knowledge of basic concepts of thermodynamics, in particular those relating to the 1st and 2nd law of thermodynamics, entropy, ideal gases: equation of state, internal energy and enthalpy, specific heat, entropy, polytropic transformations;
4. In-depth knowledge of steam thermal plants;
5. Knowledge of basic concepts of fluid dynamics, in particular those relating to: fluid system and control volume; the principle of conservation of mass and momentum from both a Lagrangean and an Eulerian viewpoint; the transport theorem; Bernoulli's theorem; knowledge of the fundamental characteristics of laminar and turbulent flows, the boundary layer concept.

It is strongly encouraged, but not strictly required, that the student has passed the exam of Fisica Tecnica, before he/she takes the exam of Macchine & Sistemi Energetici.

SYLLABUS

1. **Classification: volumetric and turbomachines**



2. **Review of thermodynamics:** (11 hours theory + 2 hours of tutorials)
 1. First and second principle of thermodynamics;
 2. Eulerian and Lagrangean viewpoint;
 3. Stationary and inertial reference frame;
 4. Hydraulic and thermal fluid machinery;
 5. Positive Displacement (or Volumetric) machines and turbomachines;
 6. Thermodynamic cycles: efficiency
 7. Calorically and thermally perfect gases;
 8. Pressure-volume and entropy-temperature thermodynamic planes;
 9. Isentropic, isobaric, constant temperature, constant volume transformations;
 10. Specific heat: definition and graphical interpretation;
 11. Polytropic processes;
 12. Compression and expansion efficiencies.
 3. **Q1D flow of a compressible fluid:** (9 hours theory + 2 hours of tutorials)
 1. Hypothesis and limitations
 2. Isentropic flow;
 3. Total and critical properties;
 4. Area law;
 5. Mass flow;
 6. Converging and converging-diverging nozzles.
 7. Velocity triangles: Euler's formula
 4. **Work-absorbing fluid machines:** (8 hours theory + 2 hours of tutorials)
 1. Classification
 2. Centrifugal pumps:
 1. Importance of the centrifugal forces;
 2. Impeller;
 3. Slip factor;
 4. Diffuser;
 5. Hydraulic and geometric similarity;
 6. Characteristic curves;
 7. Cavitation: Net Positive Suction head (NPSH);
 8. Multistage centrifugal pumps;
 9. Pump specific speed: criteria for selecting a pump.
 5. **Positive Displacement (or Volumetric) compressor:** (12 hours theory + 4 hours of tutorials)
 1. Components;
 2. Ideal, real and conventional cycle;
 3. Power control;
 4. Multi-stage compressors.
 6. **Power-generating turbomachinery:**
 1. Hydraulic turbines: (13 hours theory + 5 hours of tutorials)
 1. Classification
 2. Turbine specific speed;
 3. Pelton wheel:
 1. Components;
 2. Velocity triangles;
 3. Torque, power and efficiency;
 4. Maximum head.
 4. Francis turbine:
 1. Components;
 2. Velocity triangles;
 3. Degree of reaction;
 4. Turbine specific speed;
 5. Power control.
 5. Kaplan turbine:
 1. Components;
 2. Velocity triangles: free vortex;
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3. Power control;
 4. Diffuser;
 5. Cavitation.
 2. Axial and radial flow thermal turbines (3 hours theory + 4 hours of tutorials)
7. **Turbogas power plant:** (6 hours theory + 2 hours of tutorials)
 1. Baseline cycle:
 1. ideal and real cycles;
 2. efficiencies.
 2. Complex cycles: re-heated, inter-refrigerated
8. **Reciprocating engines** (10 hours theory + 4 hours of tutorials)
 1. Generalities
 1. Classifications
 2. Working cycle
 3. Machine layout
 2. Main Operation Parameters
 1. Geometric parameters
 2. Work, power and mean pressure
 3. Cycles and thermodynamic efficiencies
 4. The mechanical efficiency
 3. The ideal cycle
 1. heat supply
 2. heat release
 4. Typical Cycles
 5. Calculation of the ideal cycle
 1. Compression
 2. Heat supply
 3. Expansion Phase
 4. Heat release
 6. The limit cycle
 1. Suction phase
 2. Compression Step
 3. Combustion Phase
 4. Expansion Phase
 5. Exhaust Phase
 6. Initial Compression Temperature
 7. Calculation example
 8. Comparison between the ideal and limit Otto cycle
 9. Comparison between the ideal and limit Sabathè cycle
 7. Real engine operation
 1. The indicated efficiency
 2. Charge and exhaust in 4-stroke engines
 1. Pressure inside the cylinder
 2. Exhaust Temperature
 8. Volumetric efficiency
 1. the engine rotation speed and related phenomena
 2. Pressure and suction temperature in the environment
 3. Pressure and temperature of the exhaust gases
 9. Expression of p_{me}
 10. Change in performance under varying ambient conditions
 11. Engine Tuning
 12. Performance Curves

TEACHING METHODS

The course consists in 90 hours of teaching, split between classroom lectures and numerical tutorials; the latter cover roughly 25% of the 90 hours of teaching. The course might be supplemented by technical tours and/or seminars held by external (eg. industrial) experts.



EVALUATION METHODS

The aim of the examination is to test the level of achievement of the previously mentioned educational goals. The exam sessions consist in a **written test** followed, one week later (four days in the case of July's session), by an **oral examination**.

A reservation for the written test is mandatory and must be made through the Web Services Teachers / Students (ESSE3) software accessible from the home page of the University.

The modalities and the written test evaluation are as follows:

1. The instructor will assign each student, randomly, a seat in the classroom.
2. Each student will receive the trace of the written test and two signed protocol sheets.
3. Each student will be required to sign the attendance register.
4. The data present in the tracks depend on an integer N (student variable student) whose numerical value is marked on the exam sheet.
5. It is not allowed to use notes and / or books, but students must bring the Mollier diagram (on paper).
6. Each student will have to use only the protocol sheets that have been distributed, for both the "bella" copy and, eventually, "brutta" copy.
7. If a student needs additional sheets, he will have to ask the instructor in the classroom another protocol sheet already signed.
8. The student who needs to temporarily leave the classroom will have to put all the sheets and the exam papers on the desk.
9. Each student, whether he/she decides to hand in the exam papers, or to give up the correction, must return all the papers he/she has received (including the track and any "brutta" copy), making sure (in the former case) to report the results in the appropriate spaces available on track.
10. Before leaving the classroom, the student must sign the appropriate register in the column "To be checked" or "not to be checked".
11. The written test normally lasts three (3) hours.
12. "blank" exam sheets will be handed by the instructor only in the last half hour and only to those who are leaving the classroom.
13. The written exam consists of 3 exercises, regarding the practical / applied aspects covered in the course; each of these exercises is worth 10 points. The candidate will be admitted to the oral test in the event that the written test has been marked as follows:

> = 12/30, and two or more exercises have been solved with sufficient voting, for example: 6,6,0.

> = 16/30 in the case where only one of the exercises is sufficient, for example: 10,5,1 or 6,5,5.

The oral examination follows the written test in about a week. The oral examination must be taken in the same session in which the written test was sustained. Those who fail to appear at the oral test, despite having passed the written test, will have to retake the written exam. A reservation for the oral exam is mandatory; it can be done once having read (using the ESSE3 software) the written test results.

14. The oral test consists of:
 1. three questions concerning the theoretical contents of three different topics covered during the course that the student randomly draws and to which it responds in writing;
 2. an interview with at least one of the members of the examination board.

The marks of the written and oral part of the test provide the final grade; the final grade will not be lower than the arithmetic average of the marks obtained in the written and oral tests.

TEXTBOOKS AND ON-LINE EDUCATIONAL MATERIAL

The course material consists of the following book:

- Elementi di macchine operatrici a fluido. Luciano A. CATALANO, Michele NAPOLITANO, 2001/2, 208 pagine, ISBN 88-371-1241-6, Editore Pitagora.

The remaining course material, which is necessary and sufficient for the preparation of the examination, is available



on a cloud server hosted by the University, which is accessible from the instructor's web page via the link: "Materiale Didattico"

In particular, the up-to-date version of the syllabus ("esercizi_e_programma.pdf", the date of the last update is shown on the cover page) can be found in the "Materiale_didattico_UniBAS" folder; details concerning the chapters of the textbook and / or notes used by the instructor for the different topics addressed during the course can be found in that file.

The "esercizi_e_programma.pdf" file also contains exercises (some solved, others with only the numerical solution) useful for the preparation of the written exam.

The Video_ed_Immagini.zip file contains the audio-visual material used by the instructor during the course.

Previous exam papers can be found in the instructor's web page under the heading: "Risultati delle prove di esame e tracce di esame."

INTERACTION WITH STUDENTS

At the beginning of the course, after describing the objectives, program and methods of verification, the instructor provides students educational materials (shared folders, website, etc). Meanwhile, the instructor collects the list of students who wish to attend the course, together with their name, serial number and email.

The instructor receives at his office from Monday to Friday, from 8:30 to 12:30, in line with his other institutional commitments. The actual availability can be verified by the students using the following link: <http://oldwww.uni-bas.it/utenti/bonfiglioli/ricevimento.html>

Students who wish to meet the instructor in the afternoon can make a request via the contacts (email, phone service) listed above or available on the University phone book.

EXAMINATION SESSIONS (FORECAST)¹

25/11/2016, 30/1/2017, 24/3/2017, 19/5/2017, 24/7/2017, 22/9/2017, 24/11/2017

SEMINARS BY EXTERNAL EXPERTS YES X NO

FURTHER INFORMATION

¹ Subject to possible changes: check the web site of the Teacher or the Department/School for updates.