Università degli Studi della Basilicata
Scuola di Ingegneria

COURSE: Fundamentals of Turbomachinery Fluid Mechanics			
ACADEMIC YEAR: 2017-2018			
TYPE OF EDUCATIONAL ACTIVITY: Characteristic			
TEACHER: Aldo Bonfiglioli			
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Language: italian			
ECTS: 6	n. of hours: 54	Campus: Potenza School: Engineering Program: Mechanical Engineering (II level)	Semester: first

EDUCATIONAL GOALS AND EXPECTED LEARNING OUTCOMES

The course aims at providing knowledge on the equations that govern the one-dimensional, steady and unsteady, and quasi-one-dimensional steady flow of a compressible fluid. Such knowledge is aimed at providing the skills required to appropriately analyze the thermo-dynamical behaviour of those devices and fluid machines that operate with a compressible fluid. These include: combustion chambers, nozzles, shock tubes, reciprocating engines and pipelines.

The main knowledge provided will be:

1. in-depth knowledge of the one-dimensional Euler equations, both steady and unsteady;
2. in-depth knowledge of the techniques needed to solve the Euler equations, including the treatment of shock waves and contact discontinuities;
3. in-depth knowledge of Fanno, Rayleigh and pipeline flows;
4. elements of acoustic theory.

The main skills (I.e. the ability to apply their knowledge) will be:

1. to identify the most appropriate mathematical model that is capable to describe the flow through a given fluid device or machinery;
2. solve the aforementioned equations to determine the kinematic and thermodynamic properties of the fluid at all sections;
3. apply the theoretical models to the study of those devices and fluid machines that operate with a compressible fluid.

PRE-REQUIREMENTS

Students must have acquired and assimilated the following knowledge typically provided by the courses of “Analisi II”, “Fisica Matematica”, “Meccanica dei Fluidi” and “Fisica Tecnica”:

1. Knowledge of differential calculus in two independent variable; directional derivative, gradient; transport equation; wave equation; the divergence theorem.
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. 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

view-point; the transport theorem; Bernoulli's theorem.

SYLLABUS

Numbers in square brackets refer to the references in section TEXTBOOKS AND ON-LINE EDUCATIONAL MATERIAL

1. Compressible, quasi-one-dimensional flows (Q1D) [1, §1.2]; [7 ore di didattica frontale]
2. Compressibility and the speed of sound [1, §1.3]; [1 ora di didattica frontale]
3. Quasi-one-dimensional steady flows: [8 ore di didattica frontale + 4 ore di esercitazioni numeriche]
   a) Isentropic flow [1, §2.1];
   b) Total and critical quantities [1, §2.2];
   c) The area rule [1, §2.3];
   d) Mass flow [1, §2.4];
   e) Normal shocks [1, §2.5],[2];
   f) Converging nozzles [1, §2.6];
   g) Converging-diverging (De Laval) nozzles [1, §2.7];
   h) Applications of Converging-diverging (De Laval) nozzles [1, §2.8]; [3] the companion movie [4]).
4. One-dimensional, non-isentropic, steady flows: [5 ore di didattica frontale + 5 ore di esercitazioni numeriche]
   a) Fanno Flow [1, §3.1];
   b) Constant temperature pipeline flow [1, §3.2];
   c) Rayleigh Flow [1, §3.3].
5. One-dimensional unsteady flows [12 ore di didattica frontale + 10 ore di esercitazioni numeriche]
   a) Introduction [1, §8.1];
   b) Moving normal shocks [1, §8.2];
   c) Reflected shock waves [1, §8.3];
   d) Linear convection equation [5, §1.1-1.3];
   e) Characteristic formulation of the Euler equations [6, §3.1-3.4] e [7];
   f) Simple waves [6, §3.5] e [7];
   g) Expansion waves [1, §8.6];
   h) Shock tube relations [1, §8.7];
   i) Finite compression waves [1, §8.8].
   j) Elements of acoustic theory: [1, §8.4] e [8, §11.1-11.5].

TEACHING METHODS

The course consists in 54 hours of teaching, split between classroom lectures and numerical tutorials; the latter cover roughly 40% of the 54 hours of teaching. The course might be supplemented by 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**. The 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 a sheet with the test questions and two signed protocol sheets.
3. Each student will be required to sign the attendance register.
4. The data present in the quesions depend on an integer N whose numerical value is marked on the exam sheet.
5. It is not allowed to use notes and / or books, but students are allowed to bring the "NACA report 1135" [2] and can make use of the “Comprop” software.

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 pass the exam if she/he receives a mark of at least 18/30.
14. This is a “modular” course, made of two parts; a unique grade will however be given for the whole course, which is worth 15 ECTS. The final grade will be the ECTS-weigthed average of the two grades.

TEXTBOOKS AND ON-LINE EDUCATIONAL MATERIAL

Bibliography

1) M. Napolitano. Corso di gasdinamica. http://climeg.poliba.it/\verb1~1gasdinamica.
2) Ames Research Staff. Equations, tables, and charts for compressible flow. Technical report, NASA Ames Research Centre, 1953. NACA Report 1135, http://naca.larc.nasa.gov/reports/1953/naca-report-1135/.
3) Donald Coles. Channel flow of a compressible fluid. Online, 1968. http://web.mit.edu/hml/ncfmf/08CFCF.pdf.
4) Ascher Shapiro. National committee for fluid mechanics films (ncfmf). Online, 2008. http://web.mit.edu/hml/ncfmf.html.
5) Aldo Bonfiglioli. Lecture 1: linear advection. Online, 2010. http://oldwww.unibas.it/utenti/bonfiglioli/www.html.
6) Aldo Bonfiglioli. Lecture 3: the euler’s equation. Online, 2010. http://oldwww.unibas.it/utenti/bonfiglioli/www.html.
7) Aldo Bonfiglioli. Characteristic formulation of the un-steady 1d euler’s equation of gasdynamics. Online, 2010. http://oldwww.unibas.it/utenti/bonfiglioli/www.html.
8) I. G. Currie. Fundamental Mechanics of Fluids. McGraw-Hill, Inc., 1974. Disponibile in aula tutorato.
9) John L. Lumley. Eulerian and lagrangian descriptions in fluid mechanics. Online, 1968. http://web.mit.edu/hml/ncfmf/01ELDFM.pdf.
10) P.H. Oosthuizen and W. E. Carscallen. Compressible Fluid Flow. McGraw-Hill series in Aeronautical and Aerospace Engineering. McGraw-Hill, 1997. Disponibile presso la biblioteca interfacoltà (PZ).
11) R. W. Fox and A. T. McDonald. Introduction to Fluids Mechanics. John Wiley & Sons, 1978.
12) I. H. Shames. Mechanics of Fluids. McGraw-Hill series in Mechanical Engineering. McGraw-Hill, 1992. Disponibile presso le biblioteche di PZ e MT.
13) J. Anderson. Modern Compressible Flow: With Historical Perspective. McGraw-Hill Science/Engineering/Math; 3 edition (July 19, 2002), 2002. Disponibile presso la biblioteca ex-DIFA.

The course material 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 (“ProgrammaEserciziAppunti.pdf”, the date of the last update is shown on the cover page) can be found in the “EserciziEdAppunti/Bonfiglioli” 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 “EserciziEdAppunti/Bonfiglioli” file also contains exercises (some solved, others with only the numerical solution) useful for the preparation of the written exam.
The “AudioVideo.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, along with their name, serial number and email.
The instructor receives at his office on Tuesday, from 8:30 to 10:00, in line with his other institutional commitments. Students who wish to meet the instructor in a different time slot can make a request via the contacts (email, phone service) listed above or available on the University phone book.

EXAMINATION SESSIONS (FORECAST)[1]
07/02/2018, 13/03/2018, 16/05/2018, 24/07/2018, 25/09/2018, 28/11/2018

SEMINARS BY EXTERNAL EXPERTS YES □ NO X

FURTHER INFORMATION

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