UNIVERSITÀ DI PISA

COMPUTATIONAL CODES FOR NUCLEAR REACTORS

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CdS	INGEGNERIA NUCLEARE
Codice	1098I
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Moduli	Settore/i	Tipo	Ore	Docente/i
COMPUTATIONAL CODES FOR NUCLEAR REACTORS	ING-IND/19	LEZIONI	60	VALERIO GIUSTI ROSA LO FRANO ANDREA PUCCIARELLI

Obiettivi di apprendimento

Conoscenze

The main objective of the course is to provide the students knowledge of the fundamental (theoretical and practical) aspects of the software codes , currently used in the nuclear engineering field, and of the methodologies and tools they implement, and knowledge of the data analysis techniques.
More in details, tools related to thermal-hydraulics, structural mechanics and neutronic aspects will be addressed during the lectures.

Modalità di verifica delle conoscenze

The students will be involved by the teacher in the resolution of different practical exercises. Ansys Design Modeler, Ansys Meshing, Ansys FLUENT and RELAP5\mod3.3 codes will be used for solving thermal-hydraulics problem. The OpenMC Monte Carlo code will be used to address the neutron transport problems.
Numerical and theoretical study of the finite element method and its application FEM codes (such as MSC.MARC; ANSYS, etc.) will be object of assignments during the oral examination.
Oral examination. In some cases, a short list of written questions can be assigned to let the student take notes and then discuss with the teachers orally.

Capacità

The student will master the use of Computational Fluid Dynamics, System Thermal Hydraulic, Finite Element Model and Neutronics software codes with particular focus on nuclear engineering application. The skills the course provides are:
- understanding of the fundamental (theoretical and practical) aspects of the software codes
- capability to implement proper numerical model for studying simple/complex nuclear plant problems to support plant safety design/operation

Moreover the student will master the basic theory related to turbulence models and balance equations applied in CFD and System Thermal Hydraulic codes. Hints about the theoretical aspects of the Simplified Spherical Harmonics method will be provided. As for FEM, students will be able to perform structural analysis in simple or complex geometry (assessment demand vs. bearing capacity) with suitable EOS.

Modalità di verifica delle capacità

Oral Examination with proposal of problems.

Comportamenti

The student will be gradually introduced to the analyses of systems involving fluid flow, heat transfer and associated phenomena as well as radiation transport by means of computer-based simulations.

Modalità di verifica dei comportamenti

The oral interview will ascertain the personal attitude of the student by proposing questions and problems related to engineering problem related during the course. They will also acquire communicating and questioning attitudes in approaching working principles and tools characterizing the FEM and/or system codes.

Prerequisiti (conoscenze iniziali)

Fundamental notions of analysis and of numerical analysis

Indicazioni metodologiche

Front lessons, with the help of slides and movies. Ansys FLUENT, RELAP5/mod3.3, OpenMC , MSC.MARC or ANSYS codes will be used during the course to solve practical exercises.
Delivery: at the moment it is foreseen to deliver the course in a face-to-face modality but assuring also the online streaming of it. Nevertheless, depending on the pandemic situation, the delivery modality could be changed.

Computer Lab lessons: the availability of Computer Labs must be checked. The teachers will update the students about the chance to have Computer Labs lessons at the beginning of the course.

Programma (contenuti dell'insegnamento)

The course is divided in three main parts, described in the following.
Part 1 – Thermal-Hydraulic teaching units (theoretical aspects):
Continuum hypothesis and definition of the fluid particle; Lagrangian and Eulerian description of motion; the physical meaning of viscosity for gas and liquids; mass, momentum and energy conservation, Introduction of turbulence; macroscopic effects of turbulence; characteristic scales of turbulence and the energy cascade; theoretical approach for turbulent flow: the kolmogorov's theory, Modelling approaches for turbulent flows: DNS, LES, RANS;Effects of turbulence on the mean flow; Reynolds decomposition; time average or mean of flow property; properties of the average; Reynolds-averaged Navier Stokes Equation, RANS: eddy viscosity models; The Boussinesq Hypothesis; Reynold analogy; The mixing lenght model; Turbulent flow near solid regions; One equation model (Prandtl Model); Two equation models: k-e standard, K-e RNG, k_w standard, k-w SST; RANS: direct models; RSM Model.
STH codes general overview; Differences between TH-SYS codes and CFD codes; RELAP5 TH-SYS code and its documentation; RELAP5 treatment of noncondensable gases; RELAP5 treatment of Boron transport; State relationship and constitutive models: flow regime maps and heat transfer models, RELAP5 staggered spatial mesh; Time discretization; Numerical solution scheme: Semi-implicit and nearly-implicit;Implicit Vs Explicit time differencing; properties of numerical scheme; hydrodinamic components; volume orientation; RELAP5 input structure: cards and words; variable trip; Hydrodynamic components; Time dependent volume cards description, RELAP5 execution; General errors and errors detections; Heat structures; mesh points; heat structure examples with heat structure thermal properties and general table data,
Part 1 – Thermal-Hydraulic teaching units (Practical aspects):
DesingModeler: sketches and planes concept; Operation with sketches: modify, Dimension, Constraints; 3D feature creations (extrude, revolve, pattern); Boolean operations; slice operation; active and frozen bodies; 2-D feature creations; Single and multy-body parts
Ansys meshing: meshing methods for 3D geometry; mappable faces; Meshing method for 2-D geometries; Selective mesh
Ansys Fluent: mesh independence analysis; Post Processing tools; Fluent User Defined Functions: UDF structure, interpreting or compiling an UDF; UDF examples: Inlet parabolic velocity profile, Inlet unsteady velocity profile, Heat flux profile at wall; Coupling Matlab & Fluent: procedure instruction and example;
RELAP5: thermal-hydraulic components and heat structure components.
Part 2: Neutronic teaching units (Theoretical aspects):
Neutron transport numerical codes: deterministic versus stochastic codes. Advantages and disadvantages of both deterministic and stochastic codes. The input files of the OpenMC stochastic code: generation of the geometry.xml, materials.xml, settings.xml, and plots.xml files for a sample problem making use of the python API and the Jupyter notebook. Plotting the geometry as a check of the input files.
Part 2: Neutronic teaching units (Practical aspects):
Implementation of a model problem with the OpenMC code. Simulation and analysis of the results.
Part 3: Finite Elements units (Theoretical aspects):
FEM Theory lessons will cover the following topics: Study of discrete systems, starting from the structural matrix calculation to the definition and implementation of matrix of stiffness, constraints, applied loads, and boundary conditions.
The Finite Element Method: Introduction and Mathematical formulation of the finite element method. Discretization of continuum, elements, shape function with reference to the main types of elements for 1D, 2D, 3D problems: rods, beams, plate/flat and shell, axisymmetric elements, and solid elements.
How to implement Linear and nonlinear analysis: pre-processing (model definition, definition of the elements for the discretization, materials behavior (equation of state), methods and issues related to the discretization, boundary conditions: loads, constraints and user subroutine), analysis and post- processing phases (visualization, interpretation and analysis of the main results)

Part 3: Finite Elements units (Practical aspects)
Computer Lab lessons will address the implementation of the finite element method. In particular:
- data structure and algorithm for a planar region
- discretization, interpolation and numerical integration algorithm for 2D (axisymmetric, simply planar, and shell) and 3D model
- static and dynamic analysis of a complex shape tank: steady state, modal and transient analysis (with material behaviour elastic and/or elastic-plastic).

Bibliografia e materiale didattico

Teaching materials provided by the teacher
Recommended readings for further details:

1. Versteeg, W. Malalasekra, An Introduction to Computational Fluid Dynamics

Ansys software manuals
RELAP5 Manuals
OpenMC Manual
MSC.MARC user guide

1. C. Zienkiewicz et al., The Finite Element Method: Its Basis and Fundamentals

Indicazioni per non frequentanti
Contact the teachers for any direction.

Modalità d'esame
Oral examination.
The oral test consists of an interview between the candidate the lecturers. The duration of the oral interview depends on the quality of it.
To pass the test the candidate has to show the ability to express him/herself in a clear manner using the correct terminology to answer the posed questions. If the candidate will show a complete lack of knowledge of one of the different topics discussed during the course, the test will fail.

Note
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