REM master basic syllabus

Title:
AFDMFM Advanced fluid dynamics modeling for marine engineering applications

Credit value:
4.5 ECTS

Mandatory/Optional:
Optional

Semester:
2

Lecturer/s:
Jesús María Blanco, Gustavo Esteban, Alberto Peña, Unai Fernández

University:
University of the Basque Country UPV/EHU

Department:
Nuclear Engineering and Fluid Mechanics Department

Rationale:
The module concerns the applications of the fundamental equations governing the Fluid Mechanics of Newtonian fluids (Continuity, Navier Stokes and Energy Equations) to key issues of aerodynamics specific of marine engineering applications, such as the characterization of the boundary layer or the generation of lift and drag. It will be shown how these equations may be adapted and simplified to describe laminar flows, turbulence, and compressible flows. Appropriate solutions and techniques for each type of flow will be presented. The aim here is presenting correct simulation procedures of different types of flow for reliable CFD simulations in marine applications including "flow control devices" designed to maximize the efficiency of wind turbines.

Objectives:
The course is intended to provide students with the following benefits:

(1) Understanding the concept of fluid and the models of fluids
(2) Understanding and application of the basic physical flow equations
(3) Understanding the wind turbine rotor aerodynamics
(4) Ability to simulate the flow over different geometries with internal/external flows, including both laminar and turbulent regimes significant to marine engineering applications
(5) Ability to cooperate with the team members

Skills: *(according to the list of skills provided)*

Subject skills	REM Master Skills						
	L2.1	L2.2	L2.3	L2.4	L2.5	L2.6	L2.7
L3.1. Ability to understand the fundamentals of fluid mechanics and its application to solve engineering problems.	X			X			
L3.2. Ability to handle computer programs for solving the equations of fluid dynamics.	X	X		X			X
L3.3. Ability to organize information and produce effective reports individually and in a team				X		X	X
L3.4. Ability to communicate in various formats: group discussion, and oral presentations					X	X	

Teaching and learning methods:
The teaching and learning strategy will be based on lecture and demonstration work, with tutorial work to help develop an understanding of Fluid Flow and Computational fluid dynamics. Use will be made of models and diagrams. Real problem scenarios will be drawn on to provide the critical flow analysis on the components being investigated. The practical application of analysis will be emphasized by achieving computational simulations, and how it relates to marine engineering industry.

Allocation of student time:

	Attendance (classroom, lab,…)	**Non attendance (lecture preparation, self study…)**
Lectures	10 hours	25 hours
Computer lab	31 hours	40,5 hours
Seminars	4 hours	8 hours
Assignments		2 hours

-

Assessment:

Basic description of the assessment methodology

1. Class attendance and active participation: 50 %
2. Team assignment: 25 %
3. Individual assignments (written exam): 25 %

Class attendance

Attendance of students in class includes performance, discussion, in-class exercises and presentation. Class participation will be determined on the basis of their comments in each class session, and the completion of the exercise sheets handed in at the end of the lectures.

Some of the criteria that we will used to judge effective class participation include:

1. Is the participant a good listener?
2. Is the participant concise and articulate?
3. Are the points made relevant to the current discussion? Are they linked to the comments of others?
4. Do the comments show clear evidence of appropriate and insightful analysis of the case?

Team assignments

The team assignments are intended to be carried out by teams of students. The students use the knowledge from the Advanced Fluid Dynamics course, and complete the assignments through team work cooperation. Through accomplishing the team assignments, each student of the teams can have a good understanding of the principles and solution procedures of CFD. Each team is required to give a presentation of the team assignment work, and the quality of the team work will be graded. The team assignments must be completed on or before the scheduled due date in order to maintain the project schedule.

Individual assignments

Individual assignments help the students enhance their understanding of the Fluid Dynamics concepts and procedures. The students are required to complete their individual assignments independently, which reflects their personal understanding of the computational fluid dynamics course.

Assessment Matrix:

Subject skills	**Assessment method**					
	Exam	**Presentation**	**Homework**	**Report**	**…**	**…**
L3.1.	50 %	25 %	25%			
L3.2.	25 %	50 %	25 %			
L3.3.				100 %		
L3.4.		100 %				

Programme:

Lesson 1	***Boundary layer theory*** *a) Introduction, thickness of the BL, equations.* *b) Laminar Boundary Layer (Blasius and Karman approaches)* *c) Instability and transition to turbulent flow* *d) Turbulent Boundary Layer (Prandtl theory, pressure gradient, detachment)* *<u>Lecturer</u>: Jesús María Blanco* *<u>Distribution</u>: (3 h theory + 8 h computer + 4 h seminar (*))*
Lesson 2	***Lift and drag analysis*** *a) Introduction: Forces on solid bodies. Dimensional analysis: drag and lift coefficients (C_D and C_L).* *b) Drag: fiction and pressure drag, effect of shape, Reynolds number and roughness, the drag crisis. Von Karman vortex street.* *c) Lift: lift generation mechanism, Kutta – Joukowski theorem and Magnus effect, influence of the angle of attack, use of flaps, the stall, effects of compressibility.* *<u>Lecturer</u>: Gustavo Esteban* *<u>Distribution</u>: (2 h theory +8 h computer)*
Lesson 3	***BETZ limit + BEM-Blade element momentum theory + Rotor aerodynamics*** *a) General Introduction to Wind Turbines* *b) 1-D Momentum Theory for an Ideal Wind Turbine (Betz)* *c) The Classical Blade Element Momentum Method* *d) Beam Theory for the Wind Turbine Blade* *<u>Lecturer</u>: Alberto Peña* *<u>Distribution</u>: (3 h theory +7 h computer)*
Lesson 4	***Flow control devices for HAWT (Horizontal Axis Wind Turbines)*** *An overview about available knowledge, references and investigations on the active and passive flow control devices, initially developed for aeronautic industry that are currently being investigated and introduced on wind turbines.* *<u>Lecturer</u>: Unai Fernández* *<u>Distribution</u>: (2 h theory + 1 h practical classroom + 7 h computer)*

Resources:

Classrooms, Blackboard, laptop, projector, audio, computer room, laboratory, security issues,…

Bibliography:

Basic textbooks

[1] Çengel, Y. A. Y Cimbala, J. M. Fluid Mechanics, Fundamentals and Applications, 2nd Ed., McGraw-Hill, 2009.

[2] White, F.M. Fluid Mechanics, 7th Ed., Ed. McGraw-Hill, 2010

[3] The European Wind Energy Association (EWEA). Wind in Power: European Statistics. February 2015. http://www.ewea.org/fileadmin/files/library/publications/statistics/EWEA-Annual-Statistics-2014.pdf

[4] Poore, R., Lettenmaier, T. (2002) *Alternative Design Study Report: WindPACT Advanced Wind Turbine Drive Train Designs Study*. National Renewable Energy Laboratory. NREL/SR-500-33196. DOI: 10.2172/15004456

[5] Wood, R.M. *A Discussion of Aerodynamic Control Effectors (ACEs) for Unmanned Air Vehicles (UAVs)*, In AIAA's 1st Technical Conference and Workshop on Unmanned Aerospace Vehicle, Systems, Technologies, and Operations, Portsmouth, Virginia, number AIAA 2002-3494, May 2002. DOI: 10.2514/6.2002-3494

[6] Wind Energy Journal. Online ISSN: 1099-1824. http://onlinelibrary.wiley.com/journal/10.1002/%28ISSN%291099-1824

[7] Mohamed Gad-el-Hak. Flow Control: Passive, Active and Reactive Flow Management. Cambridge University Press 2000. ISBN-10 0-521-77006-8

[8] Schlichting, H. and Gersten, K. , Boundary Layer Theory, 8th ed., Springer, 2000

[9] Panton, R. L., Incompressible Flow, 3rd Edition, J. Wiley

[10] Wind Energy Explained: Theory, Design and Application, 2nd Edition James F. Manwell, Jon G. McGowan, Anthony L. Rogers ISBN: 978-0-470-01500-1 December 2009

[11] Wind Turbines Fundamentals, Technologies, Application, Economics Hau, Erich Ed. Sprimger 2013

Deepening bibliography

[12] Kundu, P. K. y Cohen, I. M. Fluid Mechanics, 5h Ed., Academic Press, 2011

[13] Shames, I. H. Mechanics of Fluids, 4th Ed., McGraw - Hill, 2002

Internet addresses of interest

IIHR- Hydroscience & Engineering, College of Engineering, The University of Iowa
http://www.iihr.uiowa.edu/

ANSYS: http://www.ansys.com/
STAR-CD: http://www.cd-adapco.com/

Specific journals

- Experimental Thermal and Fluid Science
- Experiments in Fluids
- Flow Measurement and Instrumentation
- Fluid Dynamics Research
- International Journal of Heat and Fluid Flow
- International Journal of Heat and Mass Transfer
- Journal of Fluid Mechanics
- Journal of Fluids Engineering
- Physics of fluids

Further comments:

(*) 2 seminars of 2h each one will be lectured:

1. Iñaki Zabala (SENER):
   "Towards a more realistic assessment of offshore renewable energy plants"

2. João Henriques: (IST Lisbon):
   "Design, optimization and control of air turbines for oscillating water columns"