EFS9AC ADVANCED FLUID MECHANICS

EFS9AC **Advanced Fluid Mechanics: Transition to Turbulence & Turbulence - Applications to Transfers, Aerodynamics & Wind Energy**	**ECTS Credits:** 2 **Duration:** 15 hours + 9 h Fondation	**Semester:** S9

Persons in charge:

Emmanuel Plaut, professor Uni. of Lorraine - http://emmanuelplaut.perso.univ-lorraine.fr

Joachim Peinke, professor Uni. of Oldenburg -

http://www.uni-oldenburg.de/en/physics/research/twist/staff-contact/joachim-peinke

Keywords: Nonlinear physics, instabilities, bifurcations, statistical and stochastic modeling, wind energy

Prerequisites: Fluid mechanics

Objective:

Introduction to the theory of bifurcations, in the context of the transition to spatio-temporal complexity or turbulence in fluid systems. Advanced turbulence modeling. Importance of small scale turbulence in the context of Wind Energy.

In the first part of this course (sessions 1-4), given by EP, the theory of bifurcations (or `catastrophe theory') is introduced. This theory is of general interest since it is relevant for many nonlinear systems, also, outside of the domain of Mechanics. Of course it is illustrated here with examples of fluid systems. The methodology of linear and weakly nonlinear stability analyses is presented and operated. In order to solve in an efficient manner the PDEs encountered, formal calculations and numerical computations with spectral methods are introduced and programmed with Mathematica. The examples studied are thermal convection, in a closed configuration, and aerodynamical waves over a plate or an obstacle in an open flow.

In the second part of this course (sessions 5-7), given by JP, statistical and stochastic modeling of turbulence is presented, focusing on the universal structure of small scale turbulence as well as on applications to Wind Energy. The small scale statistics of turbulent flows is reviewed: cascade, power spectra, intermittency corrections, extreme events... For Wind Energy, the characterization of wind conditions is presented: the IEC 61400 norm is described, and `wind gusts' are discussed. Experimental methods to investigate the impact of turbulence on the wind energy conversion, like sensors and wind tunnel with (active) grids, are presented. Finally, methods are developed, to handle the turbulent dynamical aspects of the energy conversion of a wind turbine. Topics are power output for a single turbine and a farm, as well as monitoring fatigue.

The last session corresponds to a test with programming, EP will help and validate some precise steps.

Web page of the module: http://emmanuelplaut.perso.univ-lorraine.fr/afm .

A funding of the **Fondation Mines Nancy** permits the involvement of JP, who has been until recently the president of the European Academy of Wind Energy.

Abilities:

Levels	Description and operational vocabulary
Know	Bifurcation phenomena and concepts: symmetry breaking, stability concepts, etc... Consequences on the heat and mass transfers. Turbulence phenomenology.
Understand	Bifurcation phenomena and concepts: symmetry breaking, stability concepts, etc... Consequences on the heat and mass transfers. Turbulence phenomenology and its multi-point correlations.
Apply	Linear and weakly nonlinear stability analyses, either based on formal calculus or spectral numerical methods. Statistical characterization and stochastic modeling of turbulence-related phenomena.
Analyze	Bifurcation phenomena, especially, in various forms of thermal convection, to model heat transfers. Fully developed small scale turbulence by stochastic processes, Wind Energy conversion processes and Wind Energy systems, their loads and power output.
Summarise	To see how bifurcation theory is important for fluid flow modeling. To see how fundamental aspects of turbulence are needed for an advanced understanding of applications like Wind Energy.
Asses	

Evaluation:

☑ Written test	☐ Continous Control	☐ Oral report	☐ Project	☐ Written report