

Course Description

Background: Modal frequencies, damping, and shapes of the vibration modes of operating wind turbines can be computed with and without the influence of the aerodynamic forces from the surrounding flow. The vibration modes of the unforced turbine (excluding the aerodynamic forces) constitute a dynamic fingerprint that defines its modal dynamics; these structural modes form the basis of the aeroelastic response of wind turbines due to the aerodynamic forces. The vibration modes of the turbine including the aerodynamic forces determine its aeroelastic stability properties through the damping of these aeroelastic modes. Stall-induced vibrations and classical flutter are the two main mechanisms that may lead to aeroelastic instabilities of three-bladed turbines with negative damping of an aeroelastic mode.

Learning objectives: At the end of the course the participant should be able to:

- Explain the methods of computing the modal frequencies, damping, and shapes of the structural and aeroelastic modes of operating wind turbines, and apply these methods for turbine analysis.
- Analyze and optimize modal dynamics of three-bladed wind turbines, and to explain these structural modes in the aeroelastic response of operating wind turbines.
- Explain the mechanisms of the aeroelastic instabilities called stall-induced vibrations and classical flutter, and analyze the risk of these instabilities for a given wind turbine.
- Present and disseminate the important issues of wind turbine modal dynamics and aeroelastic stability to colleagues and fellow students.
- Perform further state-of-the-art research within dynamics and aeroelastic stability of wind turbines.

The teaching will consist of a combination of dialog-based lectures and group work with illustrative example assignments, where the introduced methods are applied.

Course homepage

<http://www.dcammm.dk>.

Organizer

Senior Scientist Morten Hartvig Hansen, Wind Energy Division, Risø National Laboratory for Sustainable Energy, Technical University of Denmark. This course is offered as part of the activities of the DCAMM International Graduate Research School, see www.dcammm.dk.

Participants

This course is aimed at graduate students interested in wind energy research and engineers in the wind turbine industry with purpose that they learn how to describe, analyze, and optimize the modal dynamics and aeroelastic stability of wind turbines based on the commercial three-bladed concept. The participants must have pre-knowledge of vibration analysis and linear dynamics of mechanical systems. No particular knowledge of wind turbines is needed; however, a general knowledge of structural dynamics and/or aerodynamics is required.

Working Load

Approximately 40 hours in total, including work during the August 24-28, 2009 course period at DTU (lectures, discussions, and assignments) as well as preparatory required reading before course start.

Tentative program outline

Monday, August 24, 2009: Introduction

08.00-09.00	Delegate Registration + Breakfast
09.00-09.30	Welcome and Introduction
09.30-12.00	Repetition of linear vibration analysis and introduction of turbine terminology
12.00-13.00	Lunch
13.00-17.00	Group work with modal dynamics of three-bladed turbines

Tuesday, August 25, 2009: Modal Dynamics

09.00-10.00	Student presentations of the results of yesterday's exercise
10.00-12.00	Methods for vibration analysis of wind turbines and their structural modal dynamics
12.00-13.00	Lunch
13.00-17.00	Group work with modal dynamics of wind turbines

Wednesday, August 26, 2009: Aeroelastic stability

09.00-10.00	Student presentations of the results of yesterday's exercise
10.00-12.00	Aeroelastic modeling and stability analysis of wind turbines
12.00-13.00	Lunch
13.00-17.00	Group work with aeroelastic stability analysis of wind turbines

Thursday, August 27, 2009: Aeroelastic stability

09.00-10.00	Student presentations of the results of yesterday's exercise
10.00-12.00	Aeroelastic instabilities for wind turbines: Stall-induced vibrations and classical flutter
12.00-13.00	Lunch
13.00-17.00	Group work with aeroelastic stability analysis of wind turbines
19:00-	Workshop Dinner (Pizza + drinks)

Friday, August 28, 2009: State of the art & visit to Risø

09.00-09.30	Arrival to Risø and breakfast together with the Aeroelastic Design group
09.30-10.30	Student presentations of the results of yesterday's exercise
10.30-12.00	Presentation of current research in aeroelasticity of wind turbines, course evaluation, and discussion of future work
12.00-13.00	Lunch
13.00-14.00	Written exam based on a case study.
14.00-15.00	Visit to the old Test Station for Small Turbines

Study Material

Lecture notes covering the course will be distributed by e-mail to the participants shortly after registration.

Language

All lectures will be given in English.

Evaluation and Diplomas

To pass the course, a sufficient score on the written exam and active participation and work with assignments are required. ETCS points: 2.5

Registration:

Ask for a registration form from the DCAMM-course secretariat, attn.: Kari Haugland, Department of Mathematics, Technical University of Denmark, Building 303S, DK-2800 Lyngby, Denmark. Tel.: (+45) 45253031, Fax: (+45) 45881399, E-mail: dcamm@mat.dtu.dk.

Registration fee:

There is no registration fee for students enrolled at universities and public research institutions. For researchers employed at universities and public research institutions the registration fee is 250 EURO. This covers hand-outs, coffee and social events. For all other participants the registration fee is 750 EURO.

Deadline:

Applicants should submit a request for registration to be at the hands of the course secretariat no later than **August 1st, 2009**. Information on enrollment will be posted within a week after this date.

Housing:

There are a limited amount of rooms available on the premises of the Technical University of Denmark (DTU). These will be offered free of charge to students and otherwise at a cost of EURO 25 Euro per night. Accommodation in hostels/hotels can also be arranged by the participants themselves, see e.g. the Wonderful Copenhagen website at www.woco.dk.

Scholarships:

For Ph.D.-students enrolled at non-Danish universities and research institutions outside the EU, we can offer a limited number of scholarships in order to facilitate participation, covering lodging (see above) and extra living costs with a per diem amount of 25 EURO. Travel expenses will not be covered. Your CV and a short letter of recommendation from your Ph.D.-supervisor should be sent in together with the application form.

Internet Resources

For facts on the Technical University of Denmark and visitor's information: see <http://www.dtu.dk>. For information about teaching and research at the DCAMM departments: see <http://www.dcammm.dk>. For information about the Wind Energy Department at Risø-DTU, see <http://www.risoe.dtu.dk/vea>

About DCAMM

The **Danish Center for Applied Mathematics and Mechanics, DCAMM** is an informal framework for internationally oriented scientific collaboration between staff members at a number of departments at the Technical University of Denmark (DTU) and Aalborg University (AAU). The departments cooperating within DCAMM are:

- Dept. of Informatics & Mathematical Modelling, DTU
- Dept. of Mathematics, DTU
- Dept. of Mechanical Engineering, DTU
- Dept. of Civil Engineering, AAU
- Dept. of Mechanical Engineering, AAU

DCAMM is an informal construction. The day to day activities are coordinated by the secretary of the Center, while the formal governing body of DCAMM is the Scientific Council.

The **DCAMM International Graduate Research School** functions within the standard framework of the Ph.D.-education at the Technical University of Denmark (DTU) and at Aalborg University (AAU). Ph.D.-students associated to the School are full members of DCAMM through their departments and are enrolled in relevant Ph.D. programmes at DTU and AAU.

The School's role is to provide for an interdisciplinary framework for education of young researchers in an international research environment, and the activities are supported by Danish Agency for Research, Technology and Innovation.



DANISH CENTER FOR APPLIED MATHEMATICS AND MECHANICS

Ph.D.-course / Advanced school



Wind Turbine Dynamics and Aeroelasticity

Wind Energy Division,
Risø National Laboratory for Sustainable Energy
Technical University of Denmark,

Held at DTU – Lyngby Campus,
August 24-28, 2009