

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:

- Describe 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.
- Describe the modal dynamics of three-bladed wind turbines, and to identify these structural modes in the aeroelastic response of operating wind turbines.
- Describe the mechanisms of the aeroelastic instability called stall-induced vibrations, and explain which turbine parameters that determine the stability limits with respect to stall-induced vibrations.
- Describe the mechanisms of the aeroelastic instability called classical flutter, and explain which turbine parameters that determine the flutter limits.
- Work with state-of-the-art topics within the area of 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 Department, 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 are presumed to 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 presumed.

Working Load

Approximately 40 hours in total, including work during the June 23-27, 2008 course period at DTU (lectures, discussions, and assignments) as well as preparatory required reading before course start.

Tentative program outline

Monday, June 23, 2008: Methodology

08.00-09.00	Delegate Registration
09.00-09.30	Welcome and Introduction
09.30-12.00	Methods for vibration analysis of three-bladed turbines
12.00-13.00	Lunch
13.00-17.00	Group work with methods for vibration analysis of three-bladed turbines

Tuesday, June 24, 2008: Modal Dynamics

09.00-12.00	Modal dynamics of two- and three-bladed turbines
12.00-13.00	Lunch
13.00-17.00	Group work with modal dynamics of three-bladed turbines

Wednesday, June 25, 2008: Stall-induced Vibrations

09.00-12.00	Stall-induced vibrations of isolated blades and three-bladed turbines
12.00-13.00	Lunch
13.00-17.00	Group work with stall-induced vibrations

Thursday, June 26, 2008: Classical Flutter

09.00-12.00	Classical flutter of isolated blades and three-bladed turbines
12.00-13.00	Lunch
13.00-17.00	Group work with classical flutter
19:00-	Workshop Dinner

Friday, June 27, 2008: State of the art & visit to Risø

09.00-09.30	Arrival to Risø and breakfast together with the Aeroelastic Design group
09.30-12.00	Presentation of current research in aeroelasticity of wind turbines
12.00-13.00	Lunch
13.00-14.00	Visit to the old Test Station for Small Turbines
14.00-15.00	Course evaluation and discussion of future work

Study Material

Papers and lecture notes covering the course will be distributed by e-mail to the participants at the time of registration.

Language

All lectures will be given in English.

Evaluation and Diplomas

To pass the course, 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 **May 23rd, 2008**. 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

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

Kgs. Lyngby, Denmark
June 23-27, 2008