



AALBORG UNIVERSITY  
DENMARK

**Ph.D. course**  
on  
**Fracture Mechanics  
for  
Laminated Composite Structures**

**13 – 17 November 2017**

at

Department of Mechanical and Manufacturing Engineering  
Aalborg University  
Fibigerstræde 16, DK-9220 Aalborg, Denmark

**Organized by**

The Department of Mechanical and Manufacturing Engineering, Aalborg University  
([www.m-tech.aau.dk](http://www.m-tech.aau.dk))

Aalborg University  
The Faculty of Engineering and Science  
The Doctoral School of Engineering and Science  
(<http://www.phd.teknat.aau.dk/>)

**In collaboration with**

DCAMM, Danish Center for Applied Mathematics and Mechanics  
([www.dcammm.dk](http://www.dcammm.dk))

DCCSM, Danish Centre for Composite Structures and Materials for Wind Turbines

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Fracture mechanics and cohesive zone modeling are methods that are increasing in importance within industries that are utilizing laminated composite materials. Striving for better and better performance is the driver both within academia and industry application of these methods. A PhD-course providing tools for applying and implementing these methods, as well as a platform for meeting peers with interest in the same area is an excellent opportunity for young researchers.

## Course Content

This Ph.D. course will concentrate on theory and practice related to fracture mechanical problems for laminated composite structures, such as wind turbine blades. The classical approach to fracture mechanics will be presented and extended to anisotropic and bi-material problems via analytical and numerical methods including the framework of cohesive zone modeling. Furthermore, practical aspects of laboratory testing in relation to determination of fracture mechanical properties will be covered and included in the exercises for the course as experiments. The course consists of four parts; lectures, exercises, laboratory testing, and an informal poster session. The net work load corresponds to 5 ECTS. The exercises will consist of analytical problems solved using math programs such as Maple, numerical problems solved using the Finite Element Program ANSYS, and laboratory exercises conducted in the Lab of AAU. For the poster session all participants are expected to upload a poster of their own work, project or similar, which include discussion of how fracture mechanics apply. This poster should be uploaded to the organizers a week before the start of the course.

Topics include:

- Classical fracture mechanics
- Bi-material fracture mechanics
- Anisotropic materials
- Numerical estimation of fracture mechanical parameters with the finite element method (FEM)
- R-curve effects
- Crack bridging
- Cohesive zone modeling
- Numerical implementation of cohesive zone models in FEM
- Experimental estimation of fracture mechanical properties
- Fatigue properties of laminated composites

The aim of the course is to provide the participants with a toolbox of theoretical knowledge, experimental insight, and competencies in numerical analyses that can be applied in the participants own projects.

## Lecturers

Associate Professor Esben Lindgaard ([elo@m-tech.aau.dk](mailto:elo@m-tech.aau.dk))

Associate Professor Jens Henrik Andreasen ([jha@m-tech.aau.dk](mailto:jha@m-tech.aau.dk))

Assistant Professor Brian Bak ([brianbak@m-tech.aau.dk](mailto:brianbak@m-tech.aau.dk))

Invited lecturers from national and international research institutions:

Professor Bent F. Sørensen ([bsqr@dtu.dk](mailto:bsqr@dtu.dk)), DTU Wind Energy, Technical University of Denmark.

Professor Henrik Myhre Jensen ([hmj@ase.au.dk](mailto:hmj@ase.au.dk)), Department of Engineering, Aarhus University.

Associate Professor Albert Turon Travesa ([albert.turon@udg.edu](mailto:albert.turon@udg.edu)), Department of Mechanical Engineering and Industrial Construction, University of Girona, Spain.

Invited lecturers from wind turbine industry:

Chief Engineer, PhD, Casper Kildegaard, LM Wind Power, [www.lmwindpower.com](http://www.lmwindpower.com)

## **Course Language**

The course will be given in English.

## **Teaching Material**

Extensive course notes will be handed out to the participants.

## **Course Format and Work Load**

The course will consist of a condensed session comprised of 5 full days of lectures, work on assignments, laboratory exercises, and discussions at AAU. After the course session the course participants (PhD students) are expected to solve and submit homework assignments. Diplomas will be issued on the basis of course participation and evaluation of homework assignments, and entitle Ph.D. students to 5 ECTS, corresponding to 125-150 hours of work load.

## **Prerequisites**

The participants are expected to have a basic knowledge in mechanics. The course is aimed specifically at Ph.D. students, but the course is also recommended for industrial engineers and engineering scientists. University staff and final year M.Sc. students are welcome as well. University staff, M.Sc. students and participants from industry may be exempted from the homework assignments and the course evaluation/examination.

## **Earlier Events**

This course was first held in October 2012 and then again in May 2015. Newsletter and pictures from previous event can be seen on: <http://www.m-tech.aau.dk/news-list/news/there-is-a-crack-in-everything...that-s-how-the-light-gets-in..cid198648>

## **Accommodation - Hotels**

Aalborg offers a variety of accommodations. An overview over the city and the accommodations can be found at <http://www.visitaalborg.com>. The organizers will recommend one hotel that is conveniently located and with low prices:

**Cabinn Hotel Aalborg** (<http://www.cabinn.com/english/aalborg/aalborg.html>)

Fjordgade 20, DK-9000 Aalborg

Hotel CABINN Aalborg is the newest hotel in the city and opened in October 2009. The hotel is located in the centre of Aalborg. Prices from DKK 495.

Even cheaper accomodation is possible at the Aalborg Hostel, see <http://uk.danhostelaalborg.dk/>

## **Research Internship**

After the course it will be possible to have a research internship at the Department of Mechanical and Manufacturing Engineering. The number of internships is limited, and will be initiated on the basis of a separate application procedure.

## **Registration**

Further information and registration:

<https://phd.moodle.aau.dk/course/index.php?categoryid=117>

If you are from outside Aalborg University and you wish to enroll in one of our PhD courses, you must create a profile. This is done by clicking on “log-in” and “create new account” and filling out the form.

## **Deadline for registration: 30 October 2017**

Course participation is free for national Ph.D. students and university staff. Participants from industry will be charged DKK 12,500 (DKK 2,500 pr. ECTS). International Ph.D. students and university staff get a discount of 50% and will be charged DKK 6,250.

The Doctoral School has over some time experienced problems with no-shows. Therefore, the Doctoral School has decided to introduce a no-show fee of DKK 5,000 for each course where the student does not show up. Cancellations are accepted no later than 2 weeks before start of the course. Registered illness is of course an acceptable reason for not showing up on those days.

For further information contact Associate Professor Esben Lindgaard, Phone (+45) 9940 7329, E-mail: [elo@m-tech.aau.dk](mailto:elo@m-tech.aau.dk) OR Associate Professor Jens Henrik Andreasen, Phone (+45) 9940 9316, E-mail: [jha@m-tech.aau.dk](mailto:jha@m-tech.aau.dk).