PROGRAMME, LIST OF PARTICIPANTS and

ABSTRACTS

DCAMM

15th Internal Symposium

Monday, March 16 to
Wednesday, March 18, 2015

HOTEL OPUS
HORSENS

TECHNICAL UNIVERSITY OF DENMARK -
AALBORG UNIVERSITY - AARHUS UNIVERSITY –
UNIVERSITY OF SOUTHERN DENMARK

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Organizing Committee:
Gerda Helene Fogt, Mathias Stolpe, Niels Leergaard Pedersen and Erik Lund

Organization:
DCAMM

General Information:

The language of presentation is English.

PhD students early in their projects present in the poster session. The session is divided in two parts; a presentation part (2 minutes, 2 slides maximum), a display of the posters. The posters should be in vertical A0 format. Please include a picture of yourself in the poster.

Second and third year Ph.D. students are given 10 minutes for their presentation and 5 minutes for discussion.

All presenters are requested to send the electronic presentations to Mathias Stolpe (matst@dtu.dk) no later than 12.00 on Tuesday 10 March 2015, also the slides for poster session must be submitted. This is to avoid delays and technical problems between the presentations. All presentations will be available on a provided computer in the conference room. Acceptable formats are Microsoft PowerPoint files (.ppt), Adobe Portable Document files (.pdf) and multimedia files which can be viewed by Windows Media or QuickTime player.

Programme for Monday afternoon, March 16th, 2015

11:30 Arrival

12:00 - 13:00 Lunch

13:00 - 13:05 Welcome and practical information, NIELS LEERGAARD PEDERSEN (DTU Mechanical Engineering, 5 minutes)

1 – DYNAMICS I
(Chairman: Jan Høgsberg, DTU Mechanical Engineering)

13:05 – 14:45 VIKAS ARORA (ITI, SDU, 20 minutes)
Application of finite element model updating methods for damping identification and dynamic design

VLADISLAV SOROKIN (DTU, Mechanical Engineering, 20 minutes)
Effective dynamic properties of (non-) linear spatially periodic structures

PER HYLDAHL (Department of Engineering, Aarhus, 15 minutes)
An eight noded shear deformable shell element based on the absolute nodal coordinate formulation

JONAS LAURIDSEN (DTU Mechanical Engineering, 15 minutes)
Multiphysics modelling of high speed turbo-expander supported by active magnetic bearings

BO BJERREGAARD NIELSEN (DTU Mechanical Engineering, 15 minutes)
Finite Element Modelling and Experimental Validation of a Layered Double-Curved Shell with Piezoelectric MFC Patch

FABIAN G.P. VASQUEZ (DTU Mechanical Engineering, 15 minutes)
Model based control design for a flexible rotor supported by a controllable gas bearing

14:45 - 15:15 Coffee break

2 – DYNAMICS II
(Chairman: Jon Juel Thomsen, DTU Mechanical Engineering)

15:15 – 16:35 SHAOPING BAI (M-TECH, AAU, 20 minutes)
Determining linkage parameters from the coupler curve equation - a solution to the inverse kinematic problem

ESBEN ORLOWITZ (ITI, SDU, 15 minutes)
Damping estimation in Operational Modal Analysis

JORGE GONZÁLEZ SALAZAR (DTU Mechanical Engineering, 15 minutes)
On the Controllability and Observability of Tilting-Pad Journal Bearings with Active Lubrication

NIELS M. M. FRANDSEN (DTU Mechanical Engineering, 15 minutes)
Band-gap design in mechanical engineering

STEFAN NEUMEYER (DTU Mechanical Engineering, 15 minutes)
Macromechanical parametric amplification

16:45 – 17:20 POSTER PRESENTATIONS
(Chairman: Mathias Stolpe, DTU Wind Energy)

17:20 – 19:00 POSTER SESSION
Posters (started PhD after 1 April 2014)

DTU Mechanical Engineering (5)

(1) LASSE TIDEMANN
Cyclic Yielding of Tubular Structure

(2) SEBASTIAN NØRGAARD
Topology optimization of unsteady flow problems using the lattice Boltzmann method

(3) MATHIAS KLIEM
Composite Power Pylons for High-Voltage Transmission Lines

(4) ALI MOHAMMADI
Modelling for Dynamic Length Metrology in Accurate Manufacture

(5) PARIZAD SHOJAEEILIPPE COUTURIER
Modelling Climatic Reliability of Electronic Devices

DTU COMPUTE (1)

(6) ELENA BOSSOLINI
From non-smooth to smooth friction models, using regularization and slow-fast theory

DTU WIND ENERGY (6)

(7) KASPER SANDAL
Design optimization of bottom-fixed support structures for mass production

(8) MORTEN FOGTMANN KRISTIANSEN
Fatigue testing methods for unidirectional composites used in wind turbine blades

(9) JEPPE BJØRN JØRGENSEN
Adhesive Joints in Wind Turbine Blades

(10) OSCAR GERADO CASTRO ARDILA
Fatigue Strength of Composite Wind Turbine Structures

(11) GUSTAVO-ADOLFO RUIZ-MUÑOZ
Fracture mechanics approach to probabilistic inspection planning of offshore foundation structures for wind turbines

(12) EMRE BARLAS
Development of advanced propagation models for noise optimization in wind farms

AAU M-TECH (2)

(13) JACOB OEST
Optimal Design for Fatigue

(14) JENS JAKOB BENDER
Design, Testing and Simulation of a Cruciform GFRP Test Specimen in Biaxial Fatigue

SDU IMADA (1)

(15) CHRISTIAN VALDEMAR HANSEN
Computational Modeling of Fluorescence Loss in Photo bleaching

SDU ITI (1)

(16) MICHAEL STYRK ANDERSEN
The non-flutter design principle

19:00 - Dinner

Programme for Tuesday morning, March 17th, 2015

07:00 - 09:00 Breakfast

3 – OPTIMAZATION - I
(Chairman: Jakob S. Jensen, DTU Electrical Engineering)

09.00 – 10:30 SØREN RANDRUP HENRICHSEN (M-TECH, AAU, 15 minutes)
Discrete Material Buckling Optimization of Laminated Composite Structures Considering "Worst" Shape Imperfections

ANDERS CLAUSEN (DTU Mechanical Engineering, 15 minutes)
Topology optimization for coated structures and material interface problems

SUGUANG DOU (DTU Mechanical Engineering, 15 minutes)
Optimization problems and gradient-based methods in nonlinear structural dynamics

JOE ALEXANDERSEN (DTU Mechanical Engineering, 15 minutes)
Tailoring macroscale response of mechanical and heat transfer systems by topology optimisation of microstructural details using a spectral coarse basis preconditioner

RASMUS E. CHRISTIANSEN (DTU Mechanical Engineering, 15 minutes)
Acoustic Cavity Optimization; from idea to experimental validation

SUSANA ROJAS LABANDA (DTU Wind Energy, 15 minutes)
The use of second-order information in topology optimization

10:30 – 11:00 Coffee break

4 – INVITED PRESENTAION & OPTIMIZATION II
(Chairman: Niels Leergaard Pedersen, DTU Mechanical Engineering)

11:00 – 12:05 OLE SIGMUND (DTU Mechanical Engineering, 45 minutes)
Recent developments in Topology Optimization

RENÉ SØRENSEN (M-TECH, AAU, 20 minutes)
Thickness filters for simultaneous material and thickness optimization of laminated composite structures

12:05 – 13:05 Lunch

Programme for Tuesday afternoon, March 17th, 2015

5 – FLUID & CFD
(Chairman: Christian F. Niordson, DTU Mechanical Engineering)

13:05 - 14:25 JENS NØRKÆR SØRENSEN (DTU Wind Energy, 20 minutes)
The General Momentum Theory for Horizonal Axis Wind Turbines

CHRISTIAN K. CHRISTIANSEN (DTU Mechanical Engineering, 15 minutes)
Improvement in journal bearing design with application of computational fluid dynamics

KENNET OLESEN (Department of Engineering, Aarhus, 15 minutes)
High order structure preserving formulation of a stokes flow

ADNAN BALCI (DTU Compute, 15 minutes)
The streamline pattern for an axisymmetric flow on a free surface and close to the center axis

KAYA ONUR DAG (DTU Wind Energy, 15 minutes)
Development of large eddy simulation tools for simulation of atmospheric boundary layers in wind farms

14:45 - 18:00 Social Event

19:00 - Banquet

Programme for Wednesday morning, March 18th, 2015

07:00 - 09:00 Breakfast

6 – FATIGUE & CRACK
(Chairman: Henrik Myhre Jensen, Department of Engineering, Aarhus)

09:00 - 10:20 TROELS V. LUKASSEN (DTU Mechanical Engineering, 15 minutes)
FE model of Unbonded Flexible Pipes for Fatigue Life Prediction of Tensile Armour

BRIAN BAK (M-TECH, AAU, 20 minutes)
A Simulation Method for High-Cycle Fatigue-Driven Delamination using a Cohesive Zone Model

ALEX MØBERG (Department of Engineering, Aarhus, 15 minutes)
Analysis of Interface Crack Front in Layered Material using Fracture Mechanics

JENS GLUD (M-TECH, AAU, 15 minutes)
Top-down approach for multi-scale modeling of tension-tension fatigue damage in GFRP composites

SALIM EL-NAAMAN (DTU Mechanical Engineering, 15 minutes
Strain gradient crystal plasticity focusing on micro-structural evolution

10:20 - 10:50 Coffee break

7 – PROCESS MODELLING
(Chairman: Jesper H. Hattel, DTU Mechanical Engineering)

10:50 – 11:50 ZYGIMANTAS STALIULIONIS (DTU Mechanical Engineering, 15 minutes)
Moisture ingress to electronics enclosure

JIANJUN SHI (DTU Mechanical Engineering, 15 minutes)
Effects of Laser Dwell Interval Time and Substrate Size on a LENS-made Single-line Wall Part

ESBEN TOKE CHRISTENSEN (M-TECH, AAU, 15 minutes)
A fast and accurate surrogate for predicting the response of an adaptive mould system

SØREN BØGELUND MADSEN (CIVIL, AAU, 15 minutes)
Validation of the plastic strain pattern in the mechanical rolling process in tube-to-tube sheet joints using micrographs of grain structures and finite element calculation

11:50 – 13:00 Lunch

Programme for Wednesday afternoon, March 18th, 2015

8 – COMPOSITES
(Chairman: Erik Lund, M-TECH, AAU)

13:05 – 13:55 KIM BRANNER, DTU Wind Energy, 20 mintues)
Ultimate failure of wind turbine blades – computational methods compared with full-scale tests

KRISTINE MUNK JESPERSEN (DTU Wind Energy, 15 minutes)
Fatigue damage evolution in fiber composites for wind turbine blades

GILMAR FERREIRA PEREIRA (DTU Wind Energy, 15 minutes)
Structural Health Monitoring Method for Wind Turbine Trailing Edge: Crack Growth Detection Using Bragg Grating Sensor Embedded in Composite Materials

14:30 Departure from the hotel

List of Participants

DTU Mechanical Engineering-FAM:
Alexandersen, Joe*
Andreasen, Casper S.
Christiansen, Christian*
Christiansen, Rasmus E.*
Clausen, Anders*
Dou, Suguang*
El-Naaman, Salim A.*
Felter, Christian Lotz
Fogt, Gerda Helene
Frandsen, Niels*
Hansen, John M.
Høgsberg, Jan B.
Johansen, Villads Egede
Kliem, Mathias*
Lauridsen, Jonas*
Lian, Haojie
Lukassen, Troels*
Neumeyer, Stefan*
Nielsen, Bo Bjerregaard*
Nielsen, Kim Lau
Niordson, Christian
Nørgaard, Sebastian*
Pedersen, Niels L.
Pedersen, Pauli
Poulios, Konstantinos
Salazar, Jorge González*
Sigmund, Ole
Sorokin, Vladislav
Thomsen, Jon Juel
Tidemann, Lasse*
Tvergaard, Viggo
Vasquez, Fabian*
Wang, Fengwen

DTU Mechanical Engineering-FVM:
Pedersen, Preben Terndrup

DTU Mechanical Engineering-MPP:
Jabbari, Masoud
Hattel, Jesperc
Mohammadi, Ali*
Nasirabadi, Parizad S.*
Shi, Jianjun*
Thorborg, Jesper
Zygimantas, Staliulionis*

DTU Compute:
Balci, Adnan*
Bossolini, Elena*

DTU Electrical Engineering
Jensen, Jakob Søndergaard

DTU Wind Energy
Ardila, Oscar Gerardo C.*
Branner, Kim
Buhl, Thomas
Dag, Kaya Onur*
Emre, Barlas*
Hansen, Morten Hartvig
Jespersen, Kristine Munk*
Jørgensen, Jeppe Bjørn*
Kristiansen, Morten Fogtmann*
Labanda, Susana Rojas*
Mikkelsen, Lars Pilgaard
Muñoz, Gustavo A.R.*
Pereira, Gilmar Ferreira*
Sandal, Kasper*
Stolpe, Mathias
Sørensen, Jens Nørkær
Weldeyesus, Alemseged G.

M-TECH
Aalborg University
Bai, Shaoping
Bak, Brian
Bender, Jens Jakob*
Christensen, Esben Toke*
Glud, Jens*
Henrichsen, Søren Randrup*
Lindgaard, Esben
Lund, Erik
Oest, Jacob*
Olhoff, Niels
Overgaard, Lars Chr. T.
Sørensen, René
Sørensen, Søren Nørgaard

CIVIL
Aalborg University
Nielsen, Søren R.K.
Madsen, Søren Bøgelund*

Department of Engineering, Aarhus
Andresen, Gorm
Budzik, Michal Kazimierz
Hyldahl, Per*
Jensen, Henrik Myhre
Madsen, Søren Peder
Møberg, Alex*
Olesen, Kennet*
Wind, Jens Lycke

IMADA
University of Southern Denmark
Hansen, Christian Valdemar*

ITI
University of Southern Denmark
Andersen, Michael Styrk*
Arora, Vikas
Lund, Ivar
Orlowitz, Esben*
Wiggers, Sine L.

	Ph.d.	andre
FAM	16	17
FVM	0	1
MPP	4	3
DTU Compute	2	0
DTU Elec. Eng.		1
DTU Wind	10	7
M-Tech, AAU	5	8
CIVIL, AAU	1	1
ENG, Aarhus	3	5
IMADA, SDU	1	0
ITI, SDU	2	3
	44	46
I alt		90

* Ph.D.-student

Programme for Monday afternoon, March 16th, 2015

1 – DYNAMICS I
(Chairman: Jan B. Høgsberg, DTU Mechanical Engineering)

13:05 – 14:45 VIKAS ARORA (ITI, SDU, 20 minutes)
Application of finite element model updating methods for damping identification and dynamic design.
The finite element method (FEM) is widely used to accurately model dynamic systems. It is well known that finite element predictions are not accurate because of difficulties in accurate modeling of boundary conditions, incorrect modeling of joints, and difficulties in modeling of damping etc. This has led to the development of model updating techniques, which aim to reduce the inaccuracies present in the finite element model by using measured dynamic test data. Most of the model updating techniques neglect damping and so these updated models can't be used for predicting amplitudes of vibration at resonance and antiresonance frequencies. Dynamic design is the process that aims at obtaining desired dynamic characteristics of products, equipment and structures by specifying the right shape, size, configuration, materials and manufacturing of various elements. Desired dynamic characteristics may include reduced vibration and noise levels, shifting of natural frequencies or avoidance of resonances, higher dynamic stability and desired mode shapes. One of the applications of an updated model in dynamic design demands that it also predicts the effects of structural modifications with a reasonable accuracy. This presentation deals with application of finite element model updating methods for damping identification and subsequent use for predicting the effects of structural modifications.

VLADISLAV SOROKIN (DTU Mechanical Engineering, 15 minutes)
Effective dynamic properties of (non-)linear spatially periodic structures
Optimization of dynamic performance of periodic structures is a relevant technological challenge. To accomplish this task a detailed analytical study of these structures dynamics with the aim to provide essential insights into their behaviour is required. Up to now, such analysis has been performed mainly with linear models. Aim of the present work is to abandon this restriction and develop analytical techniques for studying nonlinear problems along with linear.

PER HYLDAHL (Department of Engineering, Aarhus, 15 minutes)
An eight noded shear deformable shell element based on the absolute nodal coordinate formulation
In the area of flexible multibody dynamics, the absolute nodal coordinate formulation (ANCF) has been subjected to much research during the later years. The ANCF is a finite element method but it is distinguished by using slope vectors to describe nodal orientations instead of rotational parameters. This has some benefits when using the method in conjunction with the multibody dynamics framework, such as a constant mass matrix and a non-incremental
formulation of the internal elastic forces. In overall, the method has shown promising results and applied for many interesting applications.

The literature contains numerous different ANCF beam elements with a wide span of complexity. These elements range from simple line elements based on Euler-Bernoulli beam theory to full continuum mechanics based elements. However, the same wide array of ANCF shell elements seems to be lacking.
This present study aims to introduce a new eight noded ANCF shell element. The kinematics of the element allows for both transverse shear and thickness deformation on top of the traditional membrane and bending deformation. This leads to a versatile element that can be applied for the modeling of both thin and moderately thick structures. Both a structural mechanics and a continuum mechanics description for the internal elastic forces will be applied, as well as appropriate remedies to overcome locking problems. Finally, several numerical studies will be presented in order to demonstrate the performance of the element.

JONAS LAURIDSEN (DTU Mechanical Engineering, 15 minutes)
Multiphysics modelling of high speed turbo-expander supported by active magnetic bearings
Rotors suspended by active magnetic bearings are essentially unstable systems whose properties cause several challenges to the design of active control systems due to: gyroscopic effects, mass unbalance vibrations, rotor elasticity among others. This PhD project deals with multiphysics modelling of a turbo-expander with active magnetic bearings for cryogenic air separation units. The turbo-expander consists of a flexible rotating shaft in connection with active magnetic bearings and high pressure seals. The purpose of the PhD project is to investigate the interaction between the fluid dynamics of the seals, the flexible rotating shaft, the electromagnetism of the bearings and the feedback controller implemented on a real time target. Several control architectures will be designed based on non-linear and adaptive control theories to; robustly handle rotor mass imbalances, control the shaft bending modes and compensate for instabilities generated by the seals due to fluid-structure interaction. Adaptive control schemes will be important in order to achieve robustness against changes in pressure and speed-dependent model parameters, and hence enlarge the operational range of the system. The turbo-expander will be constructed and experimental studies will be carried out.

BO BJERREGAARD NIELSEN (DTU Mechanical Engineering, 15 minutes)
Finite Element Modelling and Experimental Validation of a Layered Double-Curved Shell with Piezoelectric MFC Patch
The past few decades have seen the intense development and integration of smart materials into a variety of flexible structures, with the goal of sensing, monitoring and controlling the static and dynamic behavior of such flexible structures. In this framework this paper gives a theoretical and experimental contribution to the problem of smart materials connected to double curved flexible shells.
In the theoretical part the finite element modeling of a double curved flexible shell with a piezoelectric macro fiber composite (MFC) patch is presented. The finite element developed is based on an 8-node orthotropic isoperimetric element for a double curved shell, utilizing first order shear deformation theory.
The properties of the different shell layers are individually accounted for by integration over each layer thickness with respect to a common reference and linked together by summation to obtain the shell properties, i.e. mass and stiffness matrices. The electric-mechanical coupling of piezoelectric material is added to all elements, but can be excluded by setting the piezoelectric

material properties to zero. The piezoelectric MFC patch is polarized in one of the in-plane directions, i.e. perpendicular to the shell thickness. The electric field is applied or measured in the same in-plane direction, which corresponds to an in-plane expansion of the piezoelectric material. This makes use of the d33 piezoelectric constant, which is higher than the more traditionally used d31. The effect of in-plane electric field, as oppose to the out of plane for d31, is taken into account in the finite element formulation.

The validation of the numerical results is carried out using two different flexible shells, i.e. a flat and single curved. The experimental measurements are conducted with piezoelectric MFC patches of different sizes mounted on the outer curvature of the shells. The static and dynamic behaviors are investigated in open as well as closed circuit forms. Frequency response functions (FRF) are obtained via hammer test and white noise excitation via the piezoelectric MCF patch.

Good agreement between theory and experiments are obtained in the frequency range of interest. Discrepancies and insights into hysteresis, creep and nonlinear behavior are discussed.

FABIAN G.P. VASQUEZ (DTU Mechanical Engineering, 15 minutes)

Model based control design for a flexible rotor supported by a controllable gas bearing

Gas journal bearings are a convenient option to use in precise and high speed machinery applications because they can operate at higher speed than most bearing designs, almost without noise or heat generation. However, these bearings have a low load carrying capacity and are prone to instability, which limit their applications. In this framework active lubrication might represent an option to improve these limitations. The operational principle of the active gas bearing presented in this work, is to generate active forces by regulating the radial injection of a compressible lubricant (air) by means of piezoelectric actuators mounted on the back of the bearing sleeve.

A mathematical model for the rotor-active gas bearing system is presented and a controller is designed based on this multiphysics model. The active gas bearing model is based on the modified Reynold equation enhanced with a computational fluid dynamics model. The active gas bearing model is coupled with a finite element model of the rotor. A simple proportional controller is designed based on the theoretical multiphysics model and it is experimentally validated. Results show the considerable performance advantages of such a type of controllable bearing, for example increasing the damping by a factor ten for the investigated conditions. Small discrepancies between theoretical and experimental results come fundamentally from the complex behavior of the fluid film flow interacting with the injection flow and the simplifying assumptions used.

14:45 - 15:15 Coffee break

2 – DYNAMICS II
(Chairman: Jon Juel Thomsen, DTU Mechanical Engineering)

15:15 – 16:35 SHAOPING BAI (M-TECH, AAU, 20 minutes)

Determining linkage parameters from the coupler curve equation - a solution to the inverse kinematic problem

A fundamental problem in mechanism design is the synthesis of linkages from its coupler curve. According to the Roberts-Chebyshev theorem, three cognate linkages can generate the same coupler curve. In the past, the generation of cognate linkages is done by means of graphic approach. The analytical determination of linkage parameters from a known coupler curve was not solved yet. In this presentation, some progresses in the coupler-curve synthesis will be reported. This includes a new formulation of the synthesis problem, whereby the linkage parameters are determined accurately. A method of linkage synthesis from a known coupler-curve equation will also be described, demonstrated with examples.

ESBEN ORLOWITZ (ITI, SDU, 15 minutes)

Damping estimation in Operational Modal Analysis

The presented work is divided into two parts. Part I is about a full-scale measurement of a ship and Part II is about the areas studied in the research related to uncertainties for damping estimation in Operational Modal Analysis (OMA). The objective of the on-going research is to establish guidelines for execution of measurements for OMA. In Part the use of OMA for dynamic characterization of a ship structure based on experimental data, from a full-scale measurement of a 210-m long Ro-Lo ship during sea trial, is presented. The measurements contain three different data sets obtained under different operating conditions of the ship: 10 knots cruising speed, 18 knots cruising speed, and at anchor. The three different operating conditions showed a speed dependency of the natural frequencies and damping ratios. The natural frequencies were found to be lower for the 18-knots condition compared with the two other conditions, most significantly for the vertical bending modes. Also, for the vertical bending modes, the damping ratios increased by 28%–288% when the speed increased from 10 to 18 knots. In Part II the consequences of using a roving (or multi-setup) measurement strategy in OMA is compared to using a simultaneously measurement strategy. The main concern with the roving strategy is that it will often limit the measurement time. The measurement time has a large influence on the random errors in the following OMA of the measured data. In this work only time-domain methods are included which uses the correlation functions between the measured responses. The current work of the present research is on the estimation of these correlation functions and the errors that can arise from limited measurement time and measurement noise. Preliminary results on this are presented and it is shown how measurement noise can often be removed from OMA measurements and how the errors relate to the measurement time. This is believed to be the key for establishment of guidelines for reliable OMA measurements, for which the full-scale measurement of Part I will be used as validation data.

JORGE G. SALAZAR (DTU Mechanical Engineering, 15 minutes)

On the Controllability and Observability of Tilting-Pad Journal Bearings with Active Lubrication

The fundamental properties of a tilting-pad journal bearing (TPJB) featuring active lubrication from a control viewpoint are investigated, i.e., the stability, controllability and observability. This type of mechatronic technology, which involves the addition of a radial oil injection system, may present different configurations based on the positioning of the injection nozzles responsible for injecting the high pressurized oil into the rotor-pad gap. Likewise, the behavior of this sort of bearing is greatly influenced by the control law driving the injected oil flow. Also important for the analysis is the pivot compliance, since it has been shown to highly affect the TPJBs dynamics. For the objective of the work, a 3 DOF system consisting on a rigid rotor supported by a single rocker-pivoted rigid pad is studied taking into account as degree of freedoms; i) the vertical rotor movement, ii) the pad tilt and iii) the pivot deflection. Two configurations of the radial oil injection system with a single nozzle, which enables the active lubrication, are studied in order to determine which one presents better control characteristics. These characteristics can be accounted for during the design stage of this controllable bearing. The influence of the pivot compliance on the bearing dynamics is assessed, from a control point of view, by benchmarking cases with different pivot flexibility { soft and hard pivots { against the rigid pivot case. According to results, the offset difference between the pivot line and the injection nozzle line plays an important role in improving the controllability degree of such a mechatronic bearing. On the other hand, the pivot softening has shown to introduce new dynamics and to alter the system controllability degree within the standard frequency range of the system with rigid pivot.
Additionally, the benefit of measuring the pad's tilt and translation as a mean of improving the state observability of the system is highlighted. This, aimed at designing decreased order state observers, but at expenses of obtaining a single-input multiple-output system instead of a single-input simple-output system.

NIELS M. M. FRANDSEN (DTU Mechanical Engineering, 15 minutes)

Band-gap design in mechanical engineering

Band gaps are frequency ranges where no waves can propagate freely, allowing only for decaying waves. The design of materials or structures to have band gaps in specific frequency ranges could be used for e.g. vibration isolation of a piece of machinery operating at a specific frequency. The term “material” is used here for an infinite structure, whereby the material could consist of two phases such as steel and rubber, while a periodically supported beam or plate could also be considered a “material” in order to identify possible band-gaps in the finite structure.
One typical approach for creating band gaps is to utilize *Bragg scattering*, where destructive interference of reflected waves essentially cancels out the propagating waves wavelengths comparable to the periodicity. This could be done for a two-phase material such as the steel-rubber example, or by placing the supports periodically to obtain a band gap at desired frequency. Another approach is to periodically attach resonators to the material, whereby waves are attenuated by a local resonance effect not unlike the effect from a classical tuned mass damper.
A third, and newer approach, is to use inertial amplification devices, which are mechanisms applied to the structure that increases the effective inertia of

the system. These mechanisms work by an antiresonance principle, and early results indicate the possibility of low-frequency wide band-gaps when compared to the two aforementioned approaches, while still keeping the total mass relatively low. Additionally the gaps are deeper than traditional gaps, which essentially
means larger attenuation of the waves. Assuming that an actual design can perform as well as the generic model used in the initial study, the inertial amplification device seems to be a promising avenue of wave attenuation, and thus vibration suppression in engineering structures.

STEFAN NEUMEYER (DTU Mechanical Engineering, 15 minutes)
Macromechanical parametric amplification
The aim of this PhD project is to investigate theoretically and experimentally the phenomenon of parametric amplification in a macromechanical context. Parametric amplification is achieved by adding parametric excitation to externally driven near-resonant harmonic oscillations. It may provide an alternative to classical approaches of vibration control such as changing the forcing signal in a given system. It may also increase the signal-to-noise ratio, be exploited in sensoring and within energy harvesting.
We investigate effects of: sub- and superthreshold pumping; excitation parameters; nonlinear inertia, curvature and midplane stretching; modal interaction; frequency detuning; nonlinear and parametric damping; Rayleigh and van der Pol oscillators; mixed nonlinearities (second, third and fifth order); essentially nonlinear parametric amplifiers; and energy relations. The qualitative analysis involve derivation of steady-state vibration amplitudes using either the Multiple scales or Varying Amplitudes method, and is compared with numerical direct integration and in some cases experiments.

16:45 – 17:20 POSTER PRESENTATIONS
(Chairman: Mathias Stolpe, DTU Wind Energy)

17:20 – 19:00 POSTER SESSION

LASSE TIDEMANN

Cyclic Yielding of Tubular Structure

Many offshore structures are made of tubular steel beams and the structures act as elasto-plastic frame structures, when subjected to large loads. Previously, the largest loads were considered to be monotonic and the occurrence of an extreme wave was one of the primary design scenarios.

Design considerations have changed slightly; it is desired that the design is based more on the actual behaviour of the structure. Extreme waves impose cyclic rather than monotonic loads and are suspected to cause cyclic yielding in the structures. Therefore a simple cyclic elasto-plastic material model is being developed, which is based on a kinematic hardening yield surface and a plastic flow potential, which includes an additive term in terms of internal hardening parameters. The additive term is constructed to eventually dominate the first term of the plastic flow potential, ultimately bounding the stresses within an ultimate stress level.

A common characteristic of steels is the gradual degradation of the yield stress, the stiffness and the ultimate stress level. The degradation is to be modelled by the use of damage mechanics. It is desirable to have a simple, yet accurate model of the deterioration effects as well, so the combination of the cyclic model and the damage model is simple and represented by physically observable parameters. Ultimately, the cyclic plasticity model with damage is going to be the basis of a constitutive model of a beam element with concentrated yield hinges. By using an equilibrium format for the beam element it is possible to have a compact and intuitive format of the stiffness matrix, such that the beam element is represented by parameters closely linked to experimental results.

The final goal is a simple, yet accurate, model for cyclically yielding materials and structural members with easily identifiable parameters, so the design of a structure is based more closely on the actual behaviour of the structure than current currently used models.

SEBASTIAN NØRGAARD

Topology optimization of unsteady flow problems using the lattice Boltzmann method

The application of the topology optimization methodology for flow domain optimization has been the subject of increasing research interest in recent years. The complicated nature of fluid flows means that the method is very attractive as a systematic way of designing efficient fluid devices, with numerous potential applications such as control valves, microfluidic mixers, heat sinks, and heat regenerators.
One major challenge of this research is the high computational cost associated with the fluid simulations, often requiring massively parallel computing power even for moderately sized problems. Because of this, the lattice Boltzmann method is a very attractive alternative to traditional Navier-Stokes solvers. The method is very well suited for parallel implementation, and can handle complex geometries with relative ease.
In this work, the lattice Boltzmann method is implemented as the fluid solver

for topology optimization in an unsteady flow setting. The departure from more well-studied steady state conditions allows the investigation of more complex flow features such as time varying boundary conditions, and periodic phenomena such as vortex shedding. A specific problem which has been investigated aims to control the temporal and spatial profile of a flow past an obstacle, by altering the topology of the obstacle. Though the results are
highly sensitive to initial design conditions and the formulation of the objective function, the optimization process can successfully reproduce complex flow patterns.

MATHIAS KLIEM

Composite Power Pylons for High-Voltage Transmission Lines

The purpose of the PhD project is to design a damper device for vibration mitigation of overhead transmission lines. It is based on the interaction with noval composite pylons. Therefore, rotations of the transmission line should be damped at the cross-arm connection of the composite structure. Previous numerical and analytical solutions of equations are used to determine vibration modes, natural frequencies and modal interactions due to aerodynamic effects and closely spaced modes. A hybrid-test of the composite cross-arm and the preferred damper system is performed to validate the full numerical FEM analysis of the system.

ALI MOHAMMADI

Modelling for Dynamic Length Metrology in Accurate Manufacture

This PhD work is part of the project "ACCURATE MANUFACTURE – Dimensional measurements with sub-micrometer accuracy in a production environment and accurate measurements on parts made from dimensionally relatively less stable materials such as polymers" which is co-funded by the Danish National Advanced Technology Foundation, Metrologic Aps, LEGO Systems A/S and DTU Mechanical Engineering.

The LEGO bricks are going to be measured right directly after production. They will then be held in a room with controlled temperature for couple of weeks. Shrinkage, creep and moisture will affect the dimensions of the LEGO bricks during this time. The aim of this project is to estimate the final shape of the LEGO bricks by numerical calculations. This enables to predict if the dimensions are within tolerances or not by just one measurement. The combination of the highly anisotropic characteristics of the polymers and sub-micrometer accuracy as well as thermos-mechanical modelling, development of the prediction algorithms, and uncertainty estimations associated with these models are challenging parts of the project.

PARIZAD SHOJAEEILIPPE COUTURIER

Modelling Climatic Reliability of Electronic Devices

Nowadays, electronic control systems are used in all sorts of modern technological devices outside or indoors. Local climate inside the enclosures is an important contributor to the reliability of these systems and can cause several humidity-related failures on the sensitive Printed Circuit Board Assemblies (PCBAs) and their electronic components. Therefore, the humidity control inside enclosures becomes very important. This work will focus on applying suitable numerical models for coupled heat and mass transfer for the prediction of the microclimate in the electronic enclosures provided by industrial partners.

The study is based on partial differential equations such as Fick's 2nd law and

Navier-Stokes equations. The models will be applied to real electronic enclosures from the industrial partners in the IN-SPE Innovation Consortium and subsequent optimization will be carried out; all done with the aim of increasing the reliability of the PCBAs. The models will be based on in-house developed codes as well as commercial software in combination with proper optimization tools.

ELENA BOSSOLINI

From non-smooth to smooth friction models, using regularization and slow-fast theory

Many different phenomena in nature are modelled using non-smooth vector fields, i.e. differential equations with a discontinuous right hand side.

In mechanics, rigid body dynamics with impacts, switching or friction are all examples of non-smooth systems. Other examples may be found in seismology or control theory.

The poster will focus on dry friction and in particular on stick-slip phenomena. The understanding of the behaviour of dry friction is of key importance in several industrial sectors, for instance in brake manufacturing.

Several different friction models are present in literature and all of them are non-smooth. We are interested to see whether regularisation together with the use of slow-fast theory may be of use towards the unification of all the models. We also believe that we may get more insight on the brake squealing phenomenon by studying the regularised friction model.

When considering the friction interaction at a micro-scale level, we obtain in general smooth models. Thus we are interested to understand whether the non-smoothness of the models is eventually an idealisation of a smooth phenomenon.

We show that the widely used single degree of freedom oscillator describing the brake-pad interaction is not robust respect to regularisation. Indeed a canard solution may appear under certain conditions. The canard is a solution of singularly perturbed systems with a rather surprising behaviour. Indeed, it follows an attracting slow manifold, passes close to a bifurcation point of the critical manifold and then follows a repelling slow manifold for a considerable amount of time.

We also consider rate and state models, mainly used to describe fault dynamics in earthquakes. In these models, the state variable describes the aging process of the surface interaction due to friction. An analysis of the model is performed, when rewritten in a slow-fast formulation.

KASPER SANDAL

Design optimization of bottom-fixed support structures for mass production

The aim of the project is to reduce the cost of offshore wind energy by reducing the cost of the support structures. A significant part of a wind farms capital expense comes from the design, manufacturing and installation of support structures, and as wind farms are advancing beyond shallow waters, this expense continues to rise. By developing tools for design optimization that includes mass production, the aim is to automate the design process in a way that minimize material, manufacturing and installation costs. Ongoing work includes a three-level design process that contains topology optimization, finite element verification and an advanced cost model. Further work consists of introducing modules and mass production to the optimization and the cost model respectively, and establish communication between the optimization levels.

MORTEN FOGTMANN KRISTIANSEN

Fatigue testing methods for unidirectional composites used in wind turbine blades

During operation, wind turbine blades are subjected to highly fluctuating loads caused by e.g. turbulence, wind shear and gravitational forces. Loads which will contribute to fatigue damage of the load carrying unidirectional fibre composite elements in the blades. Reliably test results for material fatigue properties are therefore of great importance when designing composite wind turbine blades. Currently used testing methods to determine fatigue properties of unidirectional fibre composite materials are however not considered reliable as test specimens tend to fail outside the gauge section due to undesirable failure modes. Failure modes not relevant for the final applications, such as failure inside the clamping grips, splitting of the specimens or debonding of tabs. These unwanted failure modes leads to incorrect test results and an apparent short fatigue life time of the tested material.

The purpose of the present project is to improve fatigue testing methods so test results represent real material fatigue performance under tension-tension, compression-compression and tension-compression cyclic loading conditions. New design of test specimens and test methods will be suggested based on comprehensive numerically finite element simulations of the specimens and load introduction mechanisms, combined with experimental observations of the failure modes following current testing strategies. The proposed new specimens and test strategies will be tested experimentally using thermography, digital image correlation and acoustic emission. The project will enhance the understanding of the governing material properties controlling tensile and compressive fatigue failure of unidirectional composite materials.

JEPPE BJØRN JØRGENSEN

Adhesive Joints in Wind Turbine Blades

This project will develop and improve analysis tools for adhesive joints in wind turbine blades. Thus, the main scientific aim of the PhD project can be stated as:

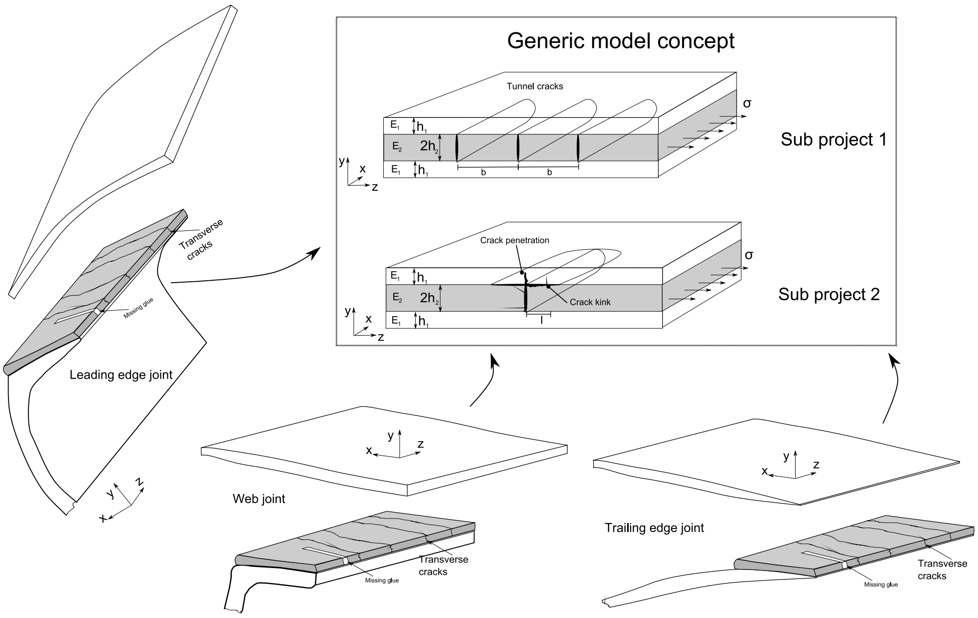
Develop novel design rules and generic models of adhesive bonded joints in wind turbine blades.

The leading edge-, trailing edge- and web joints, shown on the figure below, are referred to as a family of joints since they contain similar failure modes. Although the structural details are different, from a fracture mechanics point of view, the damage sequence is the same. This is exemplified by transverse cracks shown in the figure below. The main research objective is, based on fracture mechanics, to develop a generic model concept which can predict crack initiation and propagation of transverse cracks. The possibility for a crack to propagate/kink from the bond lines and into the laminates is also a failure mode to be assessed and included in the generic model concept. These two overall problems define the contents for the two major sub projects:

1) Tunneling cracks: The transverse cracks in the bond lines can be modeled as a confined tunneling crack in the adhesive constrained by the laminates.

2) Crack kinking: The possibility for a crack to kink from the bond lines and into the laminates can be modeled by methods for crack kinking.

Parameter studies are used to evaluate the effect of substrate/adhesive thickness, elastic mismatch, material orthotropy, and residual stresses on the energy release rate. Some of the configurations are to be tested experimentally.



OSCAR GERADO CASTRO ARDILA

Fatigue Strength of Composite Wind Turbine Structures

Wind turbines blades are made of composite materials and are important for determining the performance and lifetime of the turbine. For this reason, more accurate and reliable fatigue lifetime prediction methods for composite blades are needed for making the wind turbines more cost effective and thereby more competitive than other energy supply technologies.

Minimum structural design requirements are specified by the IEC 61400-1 international standard and by classification rules and guidelines such as the Germanischer-Lloyd (GL) and Det Norske Veritas (DNV) regulations. However, commonly used lifetime prediction methods suggested by these guidelines, are to some extend based on experience from metals. This can lead to inaccurate results for the lifetime prediction of composite blades under the strongly varying loads to which they are subjected.

The present PhD study deals with a new tool to analyze the fatigue behavior of composite wind turbine rotor blades not only following lifetime prediction methods described by current guidelines but also using nonlinear fatigue life models. The tool will be an extension to the aeroelastic HAWC2 code and the beam cross section BECAS software developed by DTU, which already to some extend are capable of predicting the fatigue lifetime of a number of different material systems under different loading conditions.

Initial results obtained from a fatigue analysis of the DTU 10 MW Reference Wind Turbine rotor blade using this tool are presented in this work.

GUSTAVO-ADOLFO Ruiz-Muñoz

Fracture mechanics approach to probabilistic inspection planning of offshore foundation structures for wind turbines

The overall project consists of analysing support structures in offshore wind turbines.

The study is focused on developing knowledge of fracture mechanics on butt welds for monopiles and of node welds for jackets foundations. As a wind farm consists of approximately 100 similar structures, the fracture mechanics calculations are used in connection with probabilistic inspection planning. Furthermore, a range of material and geometrical data related to steel plates and tubular elements are given by sub-suppliers, such as Charpy test results and crack tip opening displacement values (CTOD). During the investigation, it will be understood how this data can be taken into account and how it would have an impact in future designs.

The project structure contains 4 phases.

The first one is the structural analysis, which is developed in a stepwise order, from welds in the Transition Piece(TP) to brackets and jacket welds. During this phase, studies on crack growth(direction and rate) depending on welds characteristics will be done, achieving final S-N curves.

The second phase is the reliability and sensibility study of structure and parameters. In this case, it is studied which information (eg. material properties, geometry, flaws, corrosion) has relevant impact and how it should be retrieved for future designs.

The third phase, it is the inspection planning for offshore foundations. This section includes POD(Probability of Detection) curves and possible data retrieved. It will define frequency and places for crack inspections.

The final phase concerns the analysis of consequences when an structural component fails, such as collapse of structure or reallocation of stresses.

Results from each phase can possibly influence in the other three, and thus some iterative procedures will be taken into account. These iterative results may lead to a new background and methods for enhancing lifetime assessment. The improvements can help to approach to more cost-effective designs and lower the levelized cost of electricity(LCOE).

EMRE BARLAS

Development of advanced propagation models for noise optimization in wind farms

Within the last decades a large number of wind turbines have been installed in Europe, bringing wind energy into public awareness. However, its further development is restricted mainly by visual impact and noise. The noise regulations of various countries urge; the turbine manufacturers to reduce the noise emission of the wind turbines and the developers to have better noise map estimations for the surroundings of the wind farms.

This PhD project addresses the latter issue and the purpose Is to develop advanced noise propagation models based on Parabolic Equation in a moving, inhomogeneous, refracting, turbulent atmosphere on complex terrain for optimization of low noise wind farm with high annual energy output.

The latest status of the project is that; a 2D solver based on Generalized Terrain Parabolic Equation [1,2] which can handle all the aforementioned issues is ready to use and has to be further developed for realistic source representation as well as more sophisticated terrain and atmospheric characteristics such as added wake turbulence, barriers and obstacles. Moreover, validation of the newly developed codes must be carried out via comparisons against engineering models as well as existing measurements[3].

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[2] Sack, R.A., & West, M. (1995). A parabolic equation for sound propagation in two dimensions over any smooth terrain profile: the generalized terrain parabolic equation (GT-PE). Applied acoustics, 45(2), 113-129.
[3] Søndergaard, et al. Noise and energy optimization of wind farms. Validation of the Nord2000 propagation model for use on wind turbine noise. DELTA 2009

JACOB OEST

Optimal Design for Fatigue

Metal fatigue in engineering has been widely investigated in many years. However, fatigue constrained optimization is not generally used, even though it can prove less conservative than the more frequently used stress constrained optimization. As a result, this PhD project consists of the development and implementation of gradient based fatigue life optimization for preliminary design of offshore wind turbine jacket support structures. The fatigue constraints will be capable of capturing multiaxial and nonproportional effects of high-cycle fatigue with very many loads. To efficiently deal with large load timeseries an efficient cycle counting algorithm conserving the sequential effects will be applied. Together with an adjoint sensitivity formulation with aggregation functions and an active set strategy, computational efficiency will be ensured. In short, a gradient based fatigue life optimization method for 3D structural optimization of jacket structures will be presented. Moreover, the method will be capable of application to other high-cycle fatigue driven structural design problems subjected to both multiaxial and nonproportional loading.

JENS JAKOB BENDER

Design, Testing and Simulation of a Cruciform GFRP Test Specimen in Biaxial Fatigue

The following is based on a master thesis, as an exploration task for the PhD project. The first part concerns design of a cruciform test specimen for biaxial fatigue loading. The design process was governed by the desire to ensure a constant biaxial stress field within the gauge zone and hereby produce the required failure type based on a given load ratio in a given laminate. The new design entailed a reduction in damage initiation at the corners and in the ply-drops. The second part concerns biaxial fatigue testing of the specimen. It is shown that there is no delamination in the plydrops in the gauge zone and that failure occurs in the gauge zone without influence from damage progression at the corners. This is achieved by using internal ply-drops. The third part concerns simulation of the fatigue test using the linear progressive strength degradation model FADAS (Fatigue Damage Simulator). It is found through experimental testing and numerical simulations that the applied fatigue damage model is quite conservative.

CHRISTIAN VALDEMAR HANSEN

Computational Modeling of Fluorescence Loss in Photo bleaching

Fluorescence Loss in Photobleaching (FLIP) is a modern microscopy method for visualization of transport processes in living cells. Although FLIP is widespread, an automated reliable analysis of image data is still lacking. The paper "Computational Modeling of Fluorescence Loss in Photobleaching" by Chr. V. Hansen, H. J. Schroll and D. Wüstner, that poster presentation will be based on, presents a well–posed computational model based on spatially resolved diffusion and transport rates. The model is a reaction–diffusion system, discretized by continuous finite elements. The cell geometry is segmented from FLIP images using an active contours algorithm and the PDE model is subsequently solved in real, two–dimensional geometry. Based on this model, FLIP images are simulated and thus molecular transport in living cells is reliably quantified.

MICHAEL STYRK ANDERSEN

The non-flutter design principle

Increasing span of suspension bridges tends to decrease the torsional natural frequencies of the bridge deck.

Consequently the bridge deck is more prone to wind induced instabilities. Classical flutter and torsional divergence are dynamic and static instabilities respectively. Both of them will cause the bridge deck to collapse.

Therefore innovative solutions are needed to ensure stability for long and super long span bridges.

At torsional-to-vertical frequency ratios(□□) below 1, classical flutter is avoided. However, aerostatic instability in terms of torsional divergence is troublesome when the torsional stiffness is low (e.g. at □< 1), but may be avoided by reducing the aerodynamic moment coefficient derivative C_M' of the bridge deck.

The aim of the present project is to identify and evaluate bridge deck cross sections with frequency ratios □< 1 which are aero-dynamically and -statically stable.

19:00 - Dinner

Programme for Tuesday morning, March 17th, 2015

3 – OPTIMAZATION - I
(Chairman: Jakob S. Jensen, DTU Electrical Engineering)

09.00 – 10:30 SØREN RANDRUP HENRICHSEN (M-TECH, AAU, 15 minutes)

Discrete Material Buckling Optimization of Laminated Composite Structures Considering "Worst" Shape Imperfections

Composite materials are often used when manufacturing lightweight thin-walled structures. If compressive forces are present, thin-walled structures are prone to fail due to buckling, making it desirable to maximize the buckling load. However, as a structure always contains imperfections these must be included into the optimization. Robust buckling optimal designs of laminated composite are obtained by including imperfections into the design optimization. The Discrete Material Optimization approach is applied to obtain optimal laminate designs. The optimal geometric imperfection is represented by the "worst" shape imperfection. The two optimization problems are combined through the recurrence optimization approach. This approach enables the possibility to study the imperfection sensitivity of structures. The recurrence optimization is demonstrated through two examples, where the imperfection sensitivity of the optimized structures is shown to decrease.

ANDERS CLAUSEN (DTU Mechanical Engineering, 15 minutes)

Topology optimization for coated structures and material interface problems

Coating is commonly used to enhance functional properties or to reduce component cost. A cheap polymer which is easily processed into complex shapes can be used as a substrate to create a base structure. Coating such a structure with a superior material combines the processing and cost advantages of the substrate with the performance benefits of the coating material. A novel method [1] is presented for including coated structures and prescribed material interface properties into the minimum compliance topology optimization problem. The original study [1] was limited to 2D applications. Extensions to 3D are under development.

Several elements of the method are applicable to a broader range of interface problems. The approach extends the standard SIMP method by including the normalized norm of the spatial gradient of the design field into the material interpolation function, enforcing coating material at interfaces by attributing particular properties. The length scales of the base structure and the coating are separated by introducing a two-step filtering/projection approach.

An alternative interpretation of the model is to perform single-material design for additive manufacturing. Optimized components will have a solid outer shell. Infill is assumed to be constituted of an isotropic porous microstructure satisfying the Hashin-Shtrikman bounds and is modeled using the homogenized material properties.

[1] A. Clausen, N. Aage, O. Sigmund, Topology optimization of coated structures and material interface problems, in review.

SUGUANG DOU (DTU Mechanical Engineering, 15 minutes)

Optimization problems and gradient-based methods in nonlinear structural dynamics

The heavy computation and rich dynamics (e.g., multiple solutions and jumping phenomenon) in nonlinear structural dynamics make it extremely challenging to perform gradient-based structural optimization. By combing insights in nonlinear vibrations and advanced techniques in computational mechanics and structural optimization, we can efficiently perform gradient-based optimization for tailoring hardening/softening behavior, nonlinear resonance peak, super-harmonic resonance and essentially intermodal coupling effects. The core concepts that play a significant role in these methods are norm form and nonlinear normal mode. The proposed methods have promising applications in design optimization of micro-electro-mechanical systems, e.g. mechanical oscillators for generating clock signal with lower phase noise, and ultra-sensitive sensors for mass and force based on frequency shift. These methods may also find applications in vibration energy harvesting devices and nonlinear vibration dampers.

References

[1] S. Dou and J.S. Jensen, Optimization of nonlinear structural resonance using the incremental harmonic balance method, *Journal of Sound and Vibration*, vol. 334, pp. 239 – 254, 2015.

[2] S. Dou, B.S. Strachan, S.W. Shaw and J.S. Jensen, Structural optimization for nonlinear dynamic response, submitted, 2014.

[3] S. Dou and J.S. Jensen, Optimization of hardening and softening behavior of plane frame structures using nonlinear normal modes, in preparation, 2015.

JOE ALEXANDERSEN (DTU Mechanical Engineering, 15 minutes)

Tailoring macroscale response of mechanical and heat transfer systems by topology optimisation of microstructural details using a spectral coarse basis preconditioner

A methodology for tailoring macroscale response by designing microstructural details is presented. Topology optimisation is applied to the design of structures with periodic and layered microstructural details without length scale separation, i.e. considering the complete macroscopic structure and its response, while resolving all microstructural details, as compared to the often used homogenisation approach. The approach takes boundary conditions into account and ensures connected and macroscopically optimised microstructures regardless of the difference in micro- and macroscopic length scales. This results in microstructures tailored for specific applications rather than specific properties.

Manufacturability is further ensured by the use of robust topology optimisation.

Dealing with the complete macroscopic structure and its response is computationally challenging as very fine discretisations are needed in order to resolve all microstructural details. Therefore, the benefits of applying a contrast-independent spectral preconditioner based on the multiscale finite element method (MsFEM) to large structures with fully-resolved microstructural details is shown.

It is shown that a single preconditioner can be reused for many design iterations and used for several design realisations, in turn leading to massive savings in computational cost. The presented approach is shown to allow for the topology optimisation of very large problems in Matlab, speci_cally a problem with 26 million displacement degrees of freedom in 26 hours using a single computational thread. It is further demonstrated that it is important to account for the boundary effects to ensure prescribed behavior of the macrostructure.

RASMUS E. CHRISTIANSEN (DTU Mechanical Engineering, 15 minutes)

Acoustic Cavity Optimization; from idea to experimental validation

We consider a 2D-model of an acoustic cavity and seek to introduce a design which minimizes sound pressure locally using optimization. The model problem is illustrated in figure 1a. Here Ω_{OP} denotes the area of local pressure minimization and Ω_{d} the area where a design is introduced. We consider a pure acoustics model modeled using the Helmholtz equation with zero Neumann boundary conditions, along $\delta\Omega$, which represents hard walls. The pressure is generated by a non-zero Neumann boundary condition at $\mathbf{P}$, corresponding to a sound source mounted in the wall. Topology optimization is used as the design tool following the formulation presented in [1]. The design is optimized for high performance under a range of geometric variations using a robust formulation [2]. The Method of Moving Asymptotes (MMA) [3], is used as the optimization tool. Based on the approach described above we obtain an optimized design.

A 3D model is created by extruding the optimized design. A multi-physics simulation including acoustics and linear elasticity is performed to confirm that the full 3D model behaves as the simple 2D model. The 3D model is 3D printed in ABS plastic, see figure 1b. An experimental setup is created which allows the pressure field in the cavity to be mapped. Figure 1c shows the measured pressure. Good agreement is shown between the simulated and measured pressure fields.

(a) 2D-model schematics. (b) 3D-printed acoustic cavity. (c) Contourplot of pressure field.

Figure 1: Illustration of (a) 2D-model problem, (b) 3D-printed design, (c) Measured pressure field.

References

[1] Dühring, M. B.; Jensen, J. S. & Sigmund, O. *Acoustic design by topology optimization.* Journal of Sound and Vibration 317, Pages 557-575, 2008.

[2] Wang, F.; Lazarov, B. S. & Sigmund, O. *On Projection Methods, Convergence and Robust Formulations in Topology Optimization.* Structural Multidisciplinary Optimization 43, Pages 767-784, 2011.

[3] Svanberg Krister, *The Method of Moving Asymptotes - A New Method for Structural Optimization.* International Journal for Numerical Methods in Engineering 24, Pages 359-373, 1987.

SUSANA ROJAS LABANDA (DTU Wind Energy, 15 minutes)

The use of second-order information in topology optimization

Structural topology optimization determines the optimal distribution of material in a prescribed design domain. The resulting optimization problems are generally solved using first-order sequential convex separable approximation methods, such as the Method of Moving Asymptotes (MMA). However, since they are described as nonlinear constrained optimization problem, they can be solved using other general optimization methods.

The purpose of this work is to show that the use of second-order information produces more accurate designs improves robustness of the solvers. The problem under consideration is one of the most common in topology optimization. It consists of maximizing the stiffness (minimizing the compliance) under a restriction on the total volume.

First of all, we present an extensive study comparing different general nonlinear second-order solvers with special-purpose optimization methods.

Performance profiles from a large test set of more than 225 different minimum compliance problems provide clear, fair and representative results. They confirm that the exact Hessian is essential to improve the efficiency of the solvers.

Based on the results, a sequential quadratic programming method for structural topology optimization is developed. The exact Hessian of the minimum compliance problem is computationally very expensive since the inverse of the stiffness matrix is involved. In addition, topology optimization problems are generally nonconvex. In order to overcome these difficulties, an approximate positive definite Hessian is defined and then, the sub-problem is reformulated to improve the efficiency of the solver. The final results reinforce the importance of second-order information.

10:30 – 11:00 Coffee break

4 – INVITED PRESENTAION & OPTIMIZATION II
(Chairman: Niels Leergaard Pedersen, DTU Mechanical Engineering)

11:00 – 12:05 OLE SIGMUND (DTU Mechanical Engineering, 45 minutes)

Recent developments in Topology Optimization

Topology optimization is a numerical tool for finding optimal material distributions for mechanical and civil engineering structures, fluids, antennas, nano-optics and many other engineering disciplines. The method consists in repeated Finite Element simulations, adjoint sensitivity analyses and gradient-based design updates. Using element-based design variables, the approach has huge design freedom and is by now extensively being used in industry to save weight and/or improve dynamical response. Structures optimized using topology optimization are often visually appealing and hence, apart from structural superiority, offer architectural advantages and potential.

Topology optimized design may sometimes exhibit complex geometries difficult to manufacture using traditional manufacturing techniques. This problem is partly circumvented using 3d printing techniques which, on the other hand, offer both challenges as well as new design freedom to the topology optimization process.

The talk will present the State-of-the-Art of density-based topology optimization methods and present recent developments in large scale and multiphysics applications. Extremely efficient codes have been developed for handheld devices (see the TopOpt and TopOpt 3D Apps) for educational and demonstration purposes, whereas research codes developed by the TopOpt-group now handle problems with +100M design variables and +250M degrees of freedom. Apart from structural problems, application examples will include extremal nonlinear materials and thermofluidic problems.

RENÉ SØRENSEN (M-TECH, AAU, 20 minutes)

Thickness filters for simultaneous material and thickness optimization of laminated composite structures

Laminated composite structures are made by stacking and bounding a series of plies on top of each other until the desired thickness is achieved. These plies may consist of Fiber Reinforced Polymers (FRP) with different fiber orientations or core materials such as balsa wood or foam in the case of sandwich structures. This versatility makes it possible for engineers to tailor the material properties for the specified application, typically resulting in
a high stiffness to weight ratio. However, because of the complex relationship between the structural response and the applied sequence of materials, determining a suitable layup can be an iterative and thus time consuming process. This has lead to an increasing interest in numerical optimization methods which can aid engineers during the design process.

Recently, Sørensen and Lund (2013) and Sørensen et al. (2014) proposed the Discrete Material and Thickness Optimization (DMTO) method which enables engineers to determine an optimum material and thickness variation throughout the laminated composite structure. The thickness variation was enabled by the application of a topology or density variable which governs the presence of material in each layer. In order to avoid designs with intermediate void through the thickness of the laminate, the authors applied a series of explicit constraints. In this work, these constraints are replaced by the application of so-called casting constraints, or thickness filters in this context, to control the thickness variation throughout the laminate. The filters replace the layerwise density variables with a single continuous through the thickness design variable. Consequently, the filters eliminate the need for having xplicit constraints for preventing intermediate void through the thickness of the laminate. Therefore, the filters reduce both the number of constraints and design variables in the optimization problem. Combined with an in-plane density filter, the method enables manufacturers to control the length scale of the geometry while obtaining near discrete designs.

References

Sørensen, S. N. and Lund, E. Topology and thickness optimization of laminated composites
including manufacturing constraints. *Structural and Multidisciplinary Optimization*, 48(2): 249–265, 2013.

Sørensen, S. N., Sørensen, R., and Lund, E. DMTO - a method for discrete material and thickness optimization of laminated composite structures. *Structural and Multidisciplinary Optimization*, 50(1):25–47, 2014.

12:05 – 13:05 Lunch

Programme for Tuesday afternoon, March 17th, 2015

5 – FLUID & CFD
(Chairman: Christian F. Niordson, DTU Mechanical Engineering)

13:05 - 14:25 JENS NØRKÆR SØRENSEN (DTU Wind Energy, 20 minutes)

The General Momentum Theory for Horizonal Axis Wind Turbines

The blade-element/momentum (BEM) theory has for more than a century been the main tool for analyzing and designing wind turbines. The technique was more or less concluded with the very comprehensive text book of Glauert (1935), in which it was shown that the theory in combination with the Prandtl tip correction, yaw corrections, and the so-called Glauert correction was able to cope with most operating cases. Later developments of the model have focused on unsteady effects and the coupling to structural models for the blades and driving system. However, looking more closely into the basics of the equations, it is clear the model relies on some unjustified assumptions.
In the presentation, I will evaluate the approaches taken and discuss possibilities for refining the basics of the model. Furthermore, I will give a brief historical introduction to the most pertinent rotor models that still today are the subject of discussion.

Some reading:

1. Van Kuik, G.A.M., Sørensen, J.N. and Okulov, V.L. (2015) The Rotor Theories by Professor Joukowsky: Momentum Theories. ***Progress in Aerospace Sciences***, vol. 73, pp. 1–18.
   Link: http://authors.elsevier.com/a/1QUSM1LW8We2Wx
2. Okulov, V.L., Sørensen, J.N. and Wood, D. (2015) The Rotor Theories by Professor Joukowsky: Vortex Theories. ***Progress in Aerospace Sciences***, vol. 73, pp. 19–46.
   Link: http://authors.elsevier.com/a/1QUSM1LW8We2X7
3. Sørensen, J.N. (2011) ‘Aerodynamic aspects of wind energy conversion’. ***Annual Review of Fluid Mechanics***, vol. 43, pp. 427-448.

CHRISTIAN K. CHRISTIANSEN (DTU Mech. Engineering, 15 minutes)

Improvement in journal bearing design with application of computational fluid dynamics

Journal bearings are extensively used in combustion engines due to superior load carrying capacity. They belong to the class of hydrodynamic bearings, which means their capability to carry a load on a pressurised oil film is velocity driven. During the last decades emission legislations at sea have been tightened and coupled with increasing fuel costs, ship owners want to improve engine efficiency by an increase of the combustion pressure as well as lowering the engine speed as those large ships do not feature a gearbox. With those increased demands a need for improved lubrication have risen to avoid fatal bearing failures.
A three dimensional, commercial computational fluid dynamics code is used to investigate the flow phenomena in the inlet. This problem relates to the lubricant entering a wide groove and being distributed into a thin domain (main bearing geometry). The filling is interesting for a statically loaded bearing, but gets more vital to predict for a dynamically loaded bearing like those in an engine. With the ability to predict the flow in the bearing, under dynamic loading, a new bearing design can be optimised to the above conditions and thus minimise friction but still ensure that fatal contact between journal and housing is avoided.

For simpler (and hence faster) investigations of a possible design, a two dimensional finite element code can be used to predict the orbit of the journal within its housing. This model relies on a rough application of pressure boundary conditions at inlet areas.
Comparisons between the two methods, including their respective advantages and drawbacks, will be presented. Finally, an experimental setup intended for verification will be shown.

KENNET OLESEN (Department of Engineering, Aarhus, 15 minutes)
High order structure preserving formulation of a stokes flow
Physical models can be decomposed into conservation laws and constitutive models. In the case of fluid flows the conservation laws are given by conservation of mass and conservation of momentum. These conservation laws are topological and should have the same representation for high order methods and low order methods, and for coarse grids and fine grids.
Constitutive equations have varying complexity depending on the type of uid, but in general they describe metric-dependent relations between the stress tensor and the rate of deformation tensor.
Structure-preserving schemes form an emerging field of scientific computing, in which basic structures of the physical models are fully represented in a discrete setting, [1, 2, 3]. These principles are applied to a steady Lid driven cavity Stokes flow of a Newtonian fluid.
In this talk a structure-preserving spectral element method is presented. Through a numerical example on one spectral element it is shown that mass and linear momentum are preserved to machine precision independent the polynomial expansion order.

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ADNAN BALCI (DTU Compute, 15 minutes)
The streamline pattern for an axisymmetric flow on a free surface and close to the center axis
In incompressible and axisymmetric three-dimensional flows, one can obtain the streamline patterns using a Taylor expansion of the stream function Ψ which can be written in cylindrical coordinate as

$$\Psi = r^2 \sum_{n,m=0}^{\infty} a_{2m+2,n} r^{2m} z^n,$$

due to the symmetry Ψ(r,z)= Ψ(-r,z) and Ψ(r,z)=0 on the center axis. Applying the boundary conditions which are kinematic, tangential-stress and normal-stress boundary condition, we reduce the number of parameters from the stream function. Using the Navier-Stokes equation we obtain the correlation between the coefficients for pressure and azimuthal velocity since we need them for tangential and normal stress boundary conditions. As a next step, we obtained the simplified stream function. Linearized system matrix for this stream function is written as

$$\begin{pmatrix}\dot{x}\\ \dot{y}\end{pmatrix} = \begin{pmatrix}a_{2,1} & 0\\ 0 & -a_{2,1}\end{pmatrix}\begin{pmatrix}x\\ y\end{pmatrix}.$$

When $a_{2,1} = 0$ degeneracy occurs and higher order terms must be investigated in order to determine the flow topology. In our study, we investigate the topology of the streamline up to the co-dimension 4, which means the stream function has maximum three different parameters. We have the following cases:

1. $a_{2,1} = 0, a_{2,3} \neq 0, a_{4,1} \neq 0,$
2. $a_{2,1} = 0, a_{2,3} = 0, a_{4,1} \neq 0,$
3. $a_{2,1} = 0, a_{2,3} \neq 0, a_{4,1} = 0,$
4. $a_{2,1} = 0, a_{2,3} = 0, a_{4,1} = 0,$

which are the parameters of the stream function. Using the near-identity transformation to simplify the stream function, we obtain the degenerate cases and their unfolding. In conclusion, we investigate to the streamline patterns that can occur when the parameters are close to their degenerate values using the bifurcation theory.

KAYA ONUR DAG (DTU Wind Energy, 15 minutes)

Development of large eddy simulation tools for simulation of atmospheric boundary layers in wind farms

In the past, different tools based on the solution of the Navier-Stokes equations have been developed to simulate the interaction between the ambient atmospheric boundary layer and the wind field inside a wind farm. The present project deals with the further development of a Large Eddy Simulation CFD code tailor-mode to perform efficient, accurate and fast simulations of flows in wind farms subject to an atmospheric boundary layer.
The general scope of the project is to develop a high-order accurate Navier-Stokes/ Actuator Line technique [1,2] for Large Eddy Simulations [3,4] of turbulent boundary layers around and inside wind farms. The numerical approach is anticipated to combine high-order finite-difference schemes with a Fourier-decomposed spectral method [5,6] where horizontal axes will be represented by Fourier modes and the vertical will be treated with a high-order finite-difference approach. To include the stability of the atmospheric boundary layer, also the energy equation will be taken into account. Various sub-grid scale turbulence models will be considered and tested, and the code will be validated against in-house EllipSys code and full-scale experimental data. Additionally, the code will be parallelized and optimized for CPU/GPU heterogeneous computing.
The aim of the project is to simulate the wind turbine – atmospheric flow interactions in an efficient and accurate way.

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14:45 - 18:00 Social Event

19:00 - Banquet

Programme for Wednesday morning, March 18th, 2015

07:00 - 09:00 Breakfast

6 – FATIGUE & CRACK
(Chairman: Henrik Myhre Jensen, Department of Engineering, Aarhus)

09:00 - 10:20 TROELS V. LUKASSEN (DTU Mechanical Engineering, 15 minutes)

FE model of Unbonded Flexible Pipes for Fatigue Life Prediction of Tensile Armour

Unbonded flexible pipes are a key component in the field of offshore hydrocarbon exploration. Due to depletion of shallow water oil fields and increased demands, oil exploration is carried out at fields in ever greater water depths. Unbonded flexible pipes consist of several layers, from the inner layer to the outer one: a stainless steel core, or carcass, an extruded polymer sheath, pressure armour, tensile armour and external sheath. One of the most critical failure modes is fatigue failure in the tensile armour.

A 3D implicit parametric finite element model of the unbonded flexible pipe is developed in the commercial finite element program Abaqus. The purpose of the model is to analyze the stress condition of each tensile armour wire, find the global response of the flexible riser when subjected to different loadings and finally study the friction effects. Nonlinear frictional interaction is included between the parts in the FE model which result in hysteresis response during bending.

The FEA predicted stress condition of the tensile armour wires and the global response of the unbonded flexible pipe is validated by comparing against experimental results from an in-plane bending test of an 8” test riser.

BRIAN BAK (M-TECH, AAU, 20 minutes)

A Simulation Method for High-Cycle Fatigue-Driven Delamination using a Cohesive Zone Model

A novel computational method for simulating fatigue-driven mixed mode delamination cracks in laminated structures under cyclic loading is presented. The method is based on a cohesive zone model for quasi-static crack growth and a Paris’ law like model described as a function of the energy release rate for the crack growth rate during cyclic loading. The J-integral has been applied to determine the energy release rate. Unlike other cohesive fatigue methods the proposed methods does not rely on parameter fitting of any kind. The method has been implemented as a zero thickness 8-noded interface element for Abaqus and as a spring element for a simple finite element model in Matlab. The method has been validated in simulations of mode I, mode II and mixed mode crack loading for both self-similar and non-self-similar crack propagation. The method produces highly accurate results compared to currently available methods and is capable of simulating general mixed mode non-self-similar crack growth problems.

ALEX MØBERG (Department of Engineering, Aarhus, 15 minutes)

Analysis of Interface Crack Front in Layered Material using Fracture Mechanics

Delamination in layered materials is studied using a numerical model of a cantilever beam and analysed using linear elastic fracture mechanics. A special purpose linear finite element model of the cantilever beam has been developed using Mindlin?s plate elements. The cantilever beam is used to model an adhesive bond to a rigid body. An end load is applied to the beam and the crack propagation is monitored. Using fracture mechanics and simple optimisation, the crack front shape is found in a case of a planer interface crack. The bonding can be altered to be both homogeneous and heterogeneous.

The homogeneous interface is mainly used for studying edge e_ects, while the heterogeneous interface is used to analyse the loading in the transition zone between adhesions with different fracture toughnesses. In order to verify the model, results have been compared to experiments with some agreement.

Parameter studies have been conducted to analyse the influence of different model parameters on the edge effects. Here, the influence of Poisson's ratio and the slenderness of the beam have been studied. It has also been shown that the crack front is influenced by combinations of all three components of the moment tensor along the crack front.

JENS GLUD (M-TECH, AAU, 15 minutes)

Top-down approach for multi-scale modeling of tension-tension fatigue damage in GFRP composites

Glass fibre reinforced polymer (GFRP) laminates are extensively used in wind turbine blades. Wind turbine blades are weight critical structures and are subjected to ultra-high cycle fatigue due to their long and extreme service life. The fatigue loading experienced by the GFRP laminates is multiaxial and causes strength and stiffness degradation, which leads to a finite lifetime of the blades. The objective of the present research is to conduct an experimental tension-tension fatigue characterization of a GFRP material made from the same material and produced by a similar process and using similar constituents as used by the wind turbine manufacturers. The damage mechanisms of primary interest for the multi-scale fatigue model are initiation and propagation of off-axis matrix cracks and their influence on the macroscopic engineering properties, namely Young's modulus and Poisson's ratio.

SALIM EL-NAAMAN (DTU Mechanical Engineering, 15 minutes)

Strain gradient crystal plasticity focusing on micro-structural evolution

Published experimental studies show that distinct dislocation patterns form in ductile crystalline materials when subject to plastic deformation. These patterns are often characterized as dislocation wall and cell structures, where highly non-uniform distributions of dislocations are present, producing discontinuities in the lattice rotations. However, existing continuum models of the micro-structural evolution tend to show a much more smoothened dislocation field. When the overall structural dimensions span multiple length scales and deformation gradients become large, so called higher order strain gradient plasticity theories are needed to obtain accurate results.

In the present study a non-work conjugate type theory is adopted, which is a higher order extension of conventional crystal plasticity theory. One obvious issue with modeling these experimentally observed physical phenomena, in terms of continuous field quantities, is that the evolution of dislocation structures is inherently a discrete and discontinuous process and the bridge between the length scales has not been fully resolved. This challenge, in particular, motivates the present study, in which the aim is to improve the accuracy of predicting micro-structural evolution using strain gradient crystal plasticity in a continuum mechanics framework. One approach to modeling the GND density distributions observed experimentally is through a back stress formulation, which is related to gradients of GND densities in the adopted theory.

The work presents an investigation of a constitutive equation for the back stress based on a generalized form of the gradient energy as well a back stress formulation originating from a purely phenomenological starting point. It is shown that both approaches can lead to an improvement in predicting the micro-structural evolution and plastic material response, of ductile crystalline materials, at the sub-micron level. The influence of various model parameters is demonstrated through a parametric study.

10:20 - 10:50 Coffee break

7 – PROCESS MODELLING
(Chairman: Jesper H. Hattel, DTU Mechanical Engineering)

10:50 – 11:50 ZYGIMANTAS STALIULIONIS (DTU Mechanical Engineering, 15 minutes)

Moisture ingress to electronics enclosure

The number of outdoor electronics is growing and exposed to harsh environment which causes moisture-related problems and affects their reliability. Hence, moisture prediction models in respect of ambient environment become very important which can also be combined with thermal design of electronics. Moisture ingress to non-hermetic electronics enclosures is investigated under isothermal and non-isothermal conditions. Moisture ingress was studied theoretically using enclosure with one hole and compared with experiments where diameter of hole was different. A simple quasi-steady state (QSS) approach was developed and applied where time constants can easily be calculated for moisture ingress to the enclosure through hole or walls. Time constants were derived for moisture ingress to enclosure under diffusion and advection transport mechanisms. QSS model was applied for ambient moisture and temperature cycling as well. The response of moisture was simulated by the use of an equivalent circuit consisting of multiple resistors and capacitors (RC hygro circuit) where concentration was represented as the voltage. The temperature response was also simulated using the same RC circuit approach and it can be coupled with RC hygro circuit through the temperature. Such coupled RC hygro-thermal circuit allows to predict the climate inside enclosure. LTspice was used to implement this RC approach and the example demonstrates how the theoretical models predict the humidity and temperature inside enclosure in respect of ambient conditions.

JIANJUN SHI (DTU Mechanical Engineering, 15 minutes)

Effects of Laser Dwell Interval Time and Substrate Size on a LENS-made Single-line Wall Part

Laser Engineered Net Shaping (LENS) is one of the most advanced technologies to directly fabricate a 3D part from compute aided design (CAD) to a physical solid. In this process, there are many parameters who can affect the LENS-made part in terms of final geometry, surface characteristics as well as interior material properties. A numerical model of manufacturing a single-line wall part is created and discussed in this article. Based on the optimized process parameters of laser power, scanning speed and powder feed rate from experiments, the model focuses on the laser dwell interval time at the two ends of every scanning layer during the build-up of the wall, and the dimensional size of the substrate to see how these parameters affect the temperature distribution during the process. Meanwhile, a specially designed hollow laser heat source, which has an even saddle-hacked irradiation energy distribution, is applied into the numerical model. The numerical model indicates a transient from the substrate being the main heat sink in the beginning to the already deposited layers being the heat sink later on. Different dwell times of the laser and substrate sizes are adjusted to shorten this period of time.

ESBEN TOKE CHRISTENSEN (M-TECH, AAU, 15 minutes)
A fast and accurate surrogate for predicting the response of an adaptive mould system
This work centers around the AdaptiveMould, an adaptive mould system by Adapa A/S. The AdaptiveMould follows the same basic approach as many other reconfigurable mould systems. The system consists of a bed of actuators arranged in a grid that are used to provide the overall shape together with an interpolating membrane draped over these to provide the mould surface. The AdaptiveMould differs by using a complex interpolating membrane that gives better interpolation, which reduces the number of actuators needed for a given mould size.
Given a CAD geometry, the actuators of the system are adjusted using optimization techniques in order to have the mould surface approximate this geometry as well as possible. Since each mould has no measurement system, this optimization relies on having an accurate and fast predictor of the mould response. Due to the complexity of the AdaptiveMould the use of an FE model for this purpose is infeasible as the solution time will be too high. Therefore fast surrogates based on response surface methods will be considered instead.
In this work, modeling approaches for this problem are presented. The approaches use non-stationary Kriging methods for providing a corrective layer for an underlying fast but inaccurate model of the system.

SØREN BØGELUND MADSEN (CIVIL, AAU, 15 minutes)
Validation of the plastic strain pattern in the mechanical rolling process in tube-to-tube sheet joints using micrographs of grain structures and finite element calculation
The focus of my work is the expansion joint used in heat exchanger manufacturing. The joint is between the heat exchanger tube and the tube sheet. It is a mechanical rolling process where a series of rollers roll across the inner surface of the tube. While the rollers rotate the rolling diameter is increased, which plastically deforms the tube. This expansion creates a residual force between the tube and the tubesheet, which renders the joint leak proof and strong if done correctly. The main focus is to use numerical models to predict jo joint quality. However the challenge is to validate how accurate these models have to be to accurately predict the joint quality. In the project three different numerical models is used. In order to validate the models two different techniques is used. First a geometric comparison between the models and experiments is performed. After that microscopy is used to compare the plastic strain pattern in the models and in the experiments. The material used is austenitic stainless steel, which is a metastable metal that transforms under plastic deformation. The amount of transformation from austenite to martensite is related to the plastic deformation. When the correct model to simulate the rolling process is known, a more advanced material model can be implemented to further increase the accuracy of the predicted joint. This is the next step after determining which numerical model best simulates the rolling process.

11:50 – 13:00 Lunch

Programme for Wednesday afternoon, March 18th, 2015

8 – COMPOSITES
(Chairman: Erik Lund, M-TECH, AAU)

13:05 – 13:55 KIM BRANNER, DTU Wind Energy, 20 mintues)
Ultimate failure of wind turbine blades – computational methods compared with full-scale tests
Today, wind turbine blade certification tests are based on flapwise and edgewise loading only. However, some results have indicated that loads in other directions than pure flap- or edgewise directions may have major importance. A thorough analysis of the behavior of wind turbine blades in different loading direction validated by testing is needed in order to improve their structural design and move the design limits.
These issues are studied in a Danish national funded project “Experimental Blade Research – phase 2”. This talk will present recent results from that project with main focus on Finite Element Analysis (FEA) and comparison with full-scale tests for ultimate failure.

KRISTINE MUNK JESPERSEN (DTU Wind Energy, 15 minutes)
Fatigue damage evolution in fiber composites for wind turbine blades
For wind turbines to become a more competitive energy resource, it is necessary to push the designs to the limit. As the power output of a wind turbine is proportional to the blade length squared, increasing the blade length generally decreases the cost of energy. A wind turbine is subjected to a high number of load cycles during its lifetime, and for this reason fatigue damage evolution is one of the main limiting factors for designing longer blades. Therefore it is important to understand the fatigue damage mechanisms, in order to improve the current designs.
The fatigue damage evolution in a uni-directional (UD) glass fibre composite is studied both through experiments and modelling. Using 3D x-ray computed tomography (XCT) the fatigue damage evolution can be studied indestructively. This opens up for the possibility of visualizing the damage evolution inside the material over time during a fatigue test. Additionally the idea is to analyse the micro-structure of a specific composite in terms of fibre misalignment, fibre radius, local fibre volume fraction, etc. The micro-structural parameters will then be used as input parameters in models for parametric studies considering the effect on fatigue life.
At this time the scanned 3D micro-structure can be meshed with SimpleWare and imported into the finite element program ABAQUS to be used for further analysis. This is, however, not without problems as nabouring fibres tend to blend together as a consequence of the image resolution. For this reason studies are performed, in collaboration with DTU Compute, on algorithms to extract key parameters describing the micro-structure. Additionally seeing broken fibres within the full size fatigue test specimen is a challenge, as the 3D XCT resolution decreases with increasing sample size. This can possibly be solved by applying tension to the sample during scanning in order to open cracks making them more visible.

GILMAR FERREIRA PEREIRA (DTU Wind Energy, 15 minutes)

Structural Health Monitoring Method for Wind Turbine Trailing Edge: Crack Growth Detection Using Bragg Grating Sensor Embedded in Composite Materials

This research presents a novel method to asses a crack growing/damage event in composite material, in polymer, or in structural adhesive using Fibre Bragg Grating (FBG) sensors embedded in the host material, and its application in to a composite material structure: Wind Turbine Trailing Edge. A *Structure-Material-Sensor* Finite Element Method (FEM) model was developed to simulate the Fibre Bragg Grating sensor output response, when embedded in a host material (Composite material or adhesive), during a crack growing/damage event. This *Structure-Material-Sensor* model provides a tool to analyse the application of this monitoring technique in other locations/structures, by predicting the sensor output and deciding, based on this, the optimal sensor distribution/configuration.

Experimental tests were conducted in order to fully characterize this concept and validate the model. Double Cantilever Beams (DCB were instrumented with one array of FBG sensors embedded in the host material. Digital image correlation technique was used to determine the presence of the specific phenomena caused by the crack, and to correlate with the FBG sensor.

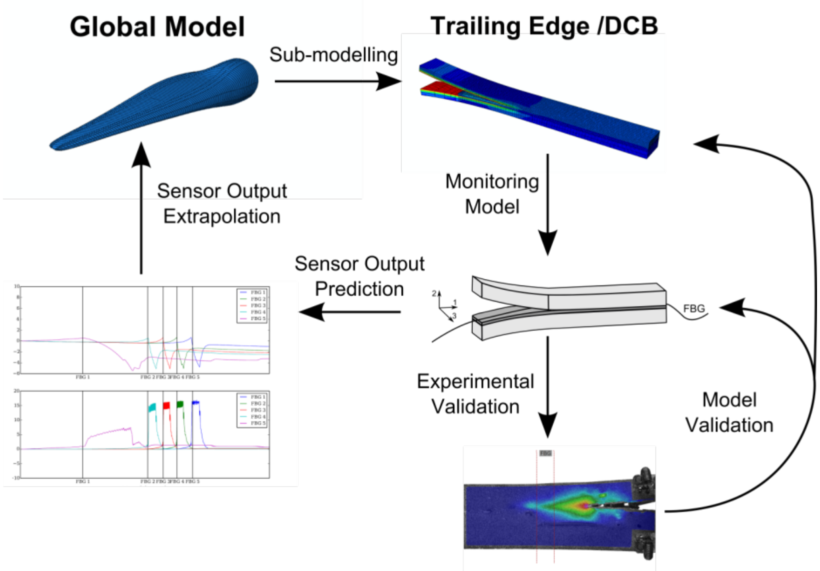

Figure 1: Model scheme of crack/delamination detection by embedded fibre Bragg gratings.

14:30 Departure from the hotel