PROGRAMME, LIST OF PARTICIPANTS and

ABSTRACTS

DCAMM

14th Internal Symposium

Wednesday, March 13 to
Friday, March 15, 2013

BEST WESTERN
NYBORG STRAND

TECHNICAL UNIVERSITY OF DENMARK
AALBORG UNIVERSITY & AARHUS UNIVERSITY

LIST OF CONTENTS

Organizing Committee:
Gerda Helene Fogt, Erik Lund, Christian Niordson and Mathias Stolpe

Organization:
DCAMM

General Information:

The language of presentation is English.

Ph.D. students early in their projects present in the poster session. 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 Erik Lund (el@m-tech.aau.dk) no later than 12.00 on Friday 8 March 2013. 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 Wednesday afternoon, March 13th, 2013

11:30	Arrival
12:00 - 13:00	Lunch
13:00 - 13:05	Welcome and practical information, CHRISTIAN NIORDSON (DTU Mechanical Engineering, 5 minutes)
	1 – COMPOSITES (Chairman: Kim Branner, DTU Wind Energy)
13:05 – 14:55	RYSZARD PYRZ (M-TECH, AAU, 20 minutes) Continuum mechanics at atomic scale
	STEFFEN LAUSTSEN (M-TECH, AAU, 15 minutes) Design of Sandwich Structures with Grid Scored Core Materials for Wind Turbine Blades
	GEORGIOS MARTAKOS (M-TECH, AAU, 15 minutes) Enhanced performance of sandwich structures by improved damage tolerance
	JENS LYCKE WIND (Department of Engineering, Aarhus, 15 minutes) Composite materials in compression
	DANIAL VAJARI (DTU Mechanical Engineering, 15 minutes) Micro Mechanical Damage Evolution in Unidirectional Composites
	SØREN GIVERSEN (DTU Civil Engineering, 15 minutes) Blast impact on composite plates
	RASMUS NORMANN WILKEN ERIKSEN (DTU Civil Engineering, 15 minutes) High Strain Rate Test of Fibre reinforced Polymers
14:55 - 15:15	Coffee break
	INVITED PRESENTATION (Chairman: Christian Niordson, DTU Mechanical Engineering)
15:15 – 16:00	MORTEN BRØNS (DTU Compute, 45 minutes) On Vorticity and Vortices
	2 - FLUIDS (Chairman: Knud Erik Meyer, DTU Mechanical Engineering)
16:15 – 17:00	TORBEN B. CHRISTIANSEN (DTU Mechanical Engineering, 15 minutes) Efficient Hybrid-spectral model for fully nonlinear numerical wave tank
	RAPHAËL COMMINAL (DTU Mechanical Engineering, 15 minutes) Numerical simulation of viscoelastic flows with free surfaces

ØISTEIN WIND-WILLASSEN (DTU Compute, 15 minutes)
Bouncing drops on a vibrating fluid bath

17:00 – 19:00 POSTER SESSION

(1) MORTEN BAKKEDAL (DTU Mechanical Engineering)
Phase stability and phase diagrams of steels computed from first-principles

(2) ADNAN BALCI (DTU Compute)
Unfolding of non-simple degenerate streamline patterns near a no-slip wall

(3) CHRISTIAN CHRISTIANSEN (DTU Mechanical Engineering)
Diesel engine tribology

(4) ANDERS CLAUSEN (DTU Mechanical Engineering)
Topology optimization for additive manufacturing

(5) PHILIPPE COUTURIER (DTU Mechanical Engineering)
Modelling and Analysis of Coupled Wind Turbine Blades

(6) SUGUANG DOU (DTU Mechanical Engineering)
Optimization in nonlinear structural dynamics with reduced order models

(7) SALIM A. El-NAAMAN (DTU Mechanical Engineering)
Measuring and Modeling Geometrically Necessary Dislocation Densities

(8) NIELS FRANDSEN (DTU Mechanical Engineering)
Damping of Beams by Viscoelastic Layers

(9) PATRICK GUERRIER (DTU Mechanical Engineering)
Numerical modeling of magnetic induction, heating and flow in injection molding tools

(10) PHILIPP HASELBACH (DTU Wind Energy)
Ultimate strength of wind turbine blade structures under multi axial loading

(11) IVA HRGOVAN (DTU Wind Energy)
Aerodynamic and structural design of wind turbine blades

(12) SØREN RANDRUP HENRICHSEN (M-TECH, AAU)
Optimum Design of Laminated Composite Structures for Robot-Based Manufacturing

(13) SHRAVAN JANAKIRAMAN (DTU Mechanical Engineering)
Elasto Hydrodynamic Lubrication in Bearing Contact

(14) SUSANA ROJAS LABANDA (DTU Wind Energy)
Mathematical programming method for large-scale topology optimization problems

(15) SHIZHAO LI (DTU Mechanical Engineering)
A CFD-model for prediction of unintended porosities in metal matrix composites

(16) CHRISTOFFER LYTHCKE-JØRGENSEN (DTU Mechanical Engineering)
Design and Optimization of Novel Polygeneration Systems

(17) SANKHYA MOHANTY (DTU Mechanical Engineering)
Evolution of optimal grid-based scanning strategy for selective laser melting

(18) CHRISTOPHER NELLEMANN (DTU Mechanical Engineering)
Incorporating Size Effects into Conventional Plasticity Model

(19) STEFAN NEUMEYER (DTU Mechanical Engineering)
Macromechanical parametric amplification

(20) JACOB PAAMAND WALDBJØRN (DTU Civil Engineering)
Hybrid testing of composite structures with single-axis control

(21) ZILI ZHANG (CIVIL, AAU)
Dynamic Stall and Aeorelastic Stability of Wind Turbines.

19:00 - Dinner

Programme for Thursday morning, March 14th, 2013

07:00 - 09:00 Breakfast

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

09.00 – 10:20 SØREN R.K. NIELSEN (CIVIL, AAU, 20 minutes)
Stochastic Nonlinear Control of Wave Energy Point Absorbers

MARTIN BJERRE NIELSEN (DTU Mechanical Engineering, 15 minutes)
Conservative Integration of Constrained Rigid Body Rotation

PER HYLDAHL (Department of Engineering, Aarhus, 15 minutes)
A thin plate finite element based on the Arbitrary Lagrange-Euler and Absolute Nodal Coordinate Fomulations

NIELS FUGLEDE (DTU Mechanical Engineering, 15 minutes)
Roller chain drive dynamics: Theoretical modeling and analysis

MARTIN FELIX JØRGENSEN (DTU Mechanical Engineering, 15 minutes)
500 kW wind turbine multibody drivetrain model

10:20 – 10:50 Coffee break

4 – DYNAMICS II
(Chariman: Jon Juel Thomsen, DTU Mechanical Engineering)

10:50 – 11:50 JUAN GALLEGO-CALDERON (DTU Wind Energy, 15 minutes)
Electromechanical Drivetrain Simulation

JONAS MORSBØL (M-TECH, AAU, 15 minutes)
Modelling of Elastic Wave Guide Properties of Flexible Pipes

RASMUS BRUUS NIELSEN (M-TECH, AAU, 15 minutes)
Propagation of elastic waves in spatially curved and inhomogenous rods

MARK LAIER-BRODERSEN (DTU Mechanical Engineering, 15 minutes)
Damping of Tower Vibrations by Viscous Damper Systems.

12:00 - 13:00 Lunch

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5 – MULTI-PHYSICS MODELLING
(Chairman: Ole Sigmund, DTU Mechanical Engineering)

13:00 - 14:30	ISMET BARAN (DTU Mechanical Engineering, 15 minutes) 3D Thermo-Mechanical Analysis of the Pultrusion Process
	MADS ROSTGAARD SONNE (DTU Mechanical Engineering, 15 minutes) Modelling the deformation process of flexible stamps for nanimpint lithography
	PETER CHRISTIANSEN (DTU Mechanical Engineering, 15 minutes) Numerical modelling of defects distribution and residual stresses in forged components
	KONSTANTINOS POULIOS (DTU Mechanical Engineering, 15 minutes) Finite Element modelling of contact using GetFem++
	FREJA NYGAARD JESPERSEN (DTU Mechanical Engineering, 15 minutes) Interaction of stresses and concentration during thermochemical surface engineering
	KRISTOFFER HOFFMANN (DTU Compute, 15 minutes) Stability of a linearised hybrid inverse problem
14:45 - 18:00	Social Event
19:00 -	Banquet

Programme for Friday morning, March 15th, 2013

07:00 - 09:00	Breakfast
	6 – OPTIMIZATION (Chairman: Niels Leergaard Pedersen, DTU Mechanical Engineering)
09:00 - 10:35	JAKOB SØNDERGAARD JENSEN (DTU Mechanical Eng., 20 minutes) Topology optimization of advanced materials
	KONSTANTINOS MARMARAS (DTU Wind Energy, 15 minutes) Optimal Design of Composite Structures by Advanced Mixed Integer Nonlinear Optimization
	SØREN NØRGAARD SØRENSEN (M-TECH, AAU, 15 minutes) An MINLP Formulation for Global Topology and Thickness Optimization of Monolithic Laminates
	RENÉ SØRENSEN (M-TECH, AAU, 15 minutes) A Methodology for Material and Thickness Optimization of Laminated Composite Structures.
	ALEMSEGED G. WELDEYESUS (DTU Wind Energy, 15 minutes) Multidisciplinary Free Material Optimization of Two Dimensional and Laminate Structures
	VILLADS EGEDE JOHANSEN (DTU Mechanical Engineering, 15 minutes) Structural Color Design
10:35 - 11:00	Coffee break
	7 – FATIGUE AND FRACTURE (Chairman: Henrik Myhre Jensen, Department of Engineering, Aarhus)
11:00 – 12:20	KIM LAU NIELSEN (DTU Mechanical Engineering, 20 minutes) *It will take* Joint Efforts to Bridge the Gaps in Ductile Fracture Mechanics
	NIELS HØRBYE CHRISTIANSEN (DTU Mechanical Eng., 15 minutes) Hybrid Method Simulation of Slender Marine Structures
	ÓLAFUR MAGNÚS ÓLAFSSON (DTU Civil Engineering, 15 minutes) Improved design bases for welded joints in seawater
	MICHELE CERULLO (DTU Mechanical Engineering, 15 minutes) Application of Dang Van Criterion to Very High Cycle Fatigue in Wind Turbine Roller Bearings
	MADS KRABBE (Department of Engineering, Aarhus, 15 minutes Crack Mechanisms and Crack Interaction in Thin Films
12:20 – 13:20	Lunch

Programme for Friday afternoon, March 15th, 2013

	8 – EXPERIMENTS (Chairman: Erik Lund, M-TECH, AAU)
13:20 – 14:40	CHRISTIAN BERGGREEN (DTU Civil Engineering, 20 minutes) Testing of Composite Structures and Components in DTU Structural Lab
	EMIL BUREAU (DTU Mechanical Engineering, 15 minutes) Experimental bifurcation analysis using control based continuation
	PENG WANG (M-TECH, AAU, 15 minutes) Optimized experimental characterization of PVC foam using DIC test and the virtual fields method.
	JACOB H. HØGH (DTU Civil Engineering, 15 minutes) High precision strain and displacement control by FBS and DIC
	SANITA ZIKE (DTU Wind Energy, 15 minutes) Micro-Scale Experiments and Models for Composite Materials: Application of Strain Gauges in Soft Material Testing
15:00	Departure from the hotel

List of Participants

DTU Mechanical Engineering-FAM:
Andreasen, Casper S.
Bureau, Emil*
Cerullo, Michele*
Christiansen, Christian*
Christiansen, Niels Hørbye*
Clausen, Anders*
Couturier, Philippe*
Dou, Suguang*
El-Naaman, Salim A.*
Fogt, Gerda Helene
Frandsen, Niels*
Fuglede, Niels*
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Høgsberg, Jan B.
Janakiraman, Shravan*
Jensen, Jakob Søndergaard
Johansen, Villads Egede*
Jørgensen, Martin Felix*
Laier-Brodersen, Mark*
Nellemann, Christopher*
Neumeyer, Stefan*
Nielsen, Kim Lau
Nielsen, Martin Bjerre*
Niordson, Christian
Pedersen, Niels L.
Pedersen, Pauli
Poulios, Konstantinos*
Richelsen, Ann Bettina
Sigmund, Ole
Thomsen, Jon Juel
Vajari, Danial*
Wang, Fengwen
Aage, Niels

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Meyer, Knud Erik

DTU Mechanical Engineering-TES:
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Jespersen, Freja Nygaard*

DTU Mechanical Engineering-MPP:
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Christiansen, Peter*
Comminal, Raphaël*
Guerrier, Patrick*
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Mohanty, Sankhya*
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Hjorth, Poul
Hoffmann, Kristoffer*
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Hrgovan, Iva*
Labanda, Susana Rojas*
Marmaras, Konstantinos*
Mikkelsen, Lars Pilgaard
Stolpe, Mathias
Zike, Sanita*
Weldeyesus, Alemseged G.*

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Lund, Erik
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Nielsen, Rasmus Brus*
Olhoff, Niels
Pyrz, Ryszard
Sorokin, Sergey
Sørensen, René*
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Zadeh, Maziyar N.

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Zhang, Zili*

Department of Engineering, Aarhus
Balling, Ole
Hyldahl, Per*
Jensen, Henrik Myhre
Krabbe, Mads*
Wind, Jens Lycke*

§8-member:
Wiggers, Sine Leergaard

	Ph.d.	andre
FAM	19	14
FVM	1	1
TES	1	0
MTU	2	0
MPP	7	0
DTU Compute	3	3
DTU Civil	5	2
DTU Wind	7	5
M-Tech, AAU	8	7
CIVIL, AAU	1	2
ENG, Aarhus	3	2
§8	0	1
	57	37
alt		94

* Ph.D.-student

Programme for Wednesday afternoon, March 13th, 2013

1 – COMPOSITES
(Chairman: Kim Branner, DTU Wind Energy)

13:05 – 14:55 RYSZARD PYRZ (M-TECH, AAU, 20 minutes)

Continuum mechanic at atomic scale

Nanoscale systems are intrinsically of a discrete nature and the applicability of macroscopic continuum theories at that scale is in many cases restricted. Quite often the macroscopic continuum theory is chosen based on phenomenological observations without consideration of the microscopical (atomic or molecular) deformation behavior. This may however lead to predictions not observable at atomic scale. Recent advances in experimental techniques and atomistic modelling allow accessing quantities which are related to their continuum counterparts and/or quantities which can be used to build augmented continuum theories. These issues will be illustrated with some examples including nanoscopic systems with deformation tunable functional properties and polymer based nanocomposites.

STEFFEN LAUSTSEN (M-TECH, AAU, 15 minutes)

Design of Sandwich Structures with Grid Scored Core Materials for Wind Turbine Blades

The project concerns the development of validated predictive modeling tools, that enable the prediction of both load-response and failure behaviour of curved composite sandwich structures with grid scored polymer foam core material under quasi-static and cyclic loading in wind turbine blades.

The requirements for composite sandwich structures often dictate that they should have a single or double curved geometry, which implies that the sandwich structure needs to be draped in order to follow the geometry. This is usually not a problem for the face sheets, since these are made of thin layers of fabrics of different constitution. The foam core materials, which are used for a large variety of modern sandwich structures, are however much thicker and for such materials thermoforming is often not feasible. Thus, the core materials, which are usually delivered as plates, are cut in small blocks (typically perpendicular) and attached to a thin carrier fabric, which then can be draped. This type of core is known as “grid scored”.

When the manufacturing process is based on vacuum infusion, resin material passes through these cuts (or scores), thus creating a resin grid within the lightweight foam core. Since the resin material is much stiffer (with a factor of 10-100) than the foam material, the presence of the grid will affect the local stiffness and load transfer of the core material significantly. This in turn will change the stress distribution locally, and induce local stress concentrations in the interfaces between the core and face sheets in the vicinity of the intersections (or junctions) between the grid score and the polymer foam core. These local stress redistributions, which are also known as local effects, may seriously jeopardize the structural integrity of a composite sandwich structure.

Thus, the outcome of the project is a set of guidelines, which ensure a safe and at the same time not overly conservative (i.e. weight ineffective) design of sandwich structures with the grid scored foam configuration.

GEORGIOS MARTAKOS (M-TECH, AAU, 15 minutes)

Enhanced performance of sandwich structures by improved damage tolerance

Sandwich structures exhibit high stiffness and strength to weight ratios, and they are used extensively for multiple applications for this reason. However they are very sensitive to localized stress concentrations occurring at load introductions and discontinuities between the face sheet and core, which may lead to the development of interface debonds and cracks. A new concept for a crack stopping device is proposed as a means to induce a damage tolerant design approach to sandwich structures. The new concept is based on a Polyurethane crack stopper, reinforced with Glass fibres. The new crack stopper approach is tested in static and fatigue loading conditions in order to prove it capable of achieving crack deflection away from the face-core interface, crack arrest and also preventing the crack from kinking back into the face-core interface and continue propagating. Numerical modeling and fracture mechanics are used to simulate and predict interface crack propagation and kinking as a result of the crack stopper in a sandwich structures. A feedback link between the experimental and the numerical work is to be established to complement progress on both sides. Results from the numerical modeling are to provide insight for the experimental investigation, while experimental results should afterwards provide feedback for the most advanced numerical tools to be used for full crack propagation analyses. The outcome of the study will be an extensive methodology for applying damage tolerance in sandwich structures by including crack stoppers.

JENS LYCKE WIND (Department of Engineering, 15 minutes)

Composite materials in compression

The present work is aimed upon studying the interaction of overall structural buckling and local material instabilities by kink band formation in plate and shell structures of composite materials. The method chosen is a detailed quasi static finite element simulation of composite structures based on individual discretization of fibers and matrix material in order to track the load/displacement response of the material. The results will be compared with a finite element formulation based on constitutive relations for effective properties of fiber composites, Jensen (1998). The discretization of fibers and matrix material makes it possible to add notches and holes in the structure to simulate a more direct application towards the use of this research in the industry. The possible outcome could be a method that could increase the critical buckling load for lightweight structures and thereby the possibility of making stronger and lighter composite structures.

The finite element analysis is performed as a nonlinear analysis with material- and geometric non-linearity included. The numerical solution technique used is the arc-length method that has the availability of handling limit points and snapping problems. Besides this the code can include multipoint constraints by the use of Lagrange multipliers. The code has been verified against standard examples to check that the material- and geometric non-linearity works as intentioned.

DANIAL VAJARI (DTU Mechanical Engineering, 15 minutes)

Micro Mechanical Damage Evolution in Unidirectional Composites

Under transverse compression and out-of-plane shear loads, the behavior of unidirectional composites is controlled by the shear yielding of the matrix and decohesion of the fiber-matrix interfaces. While under transverse tension loads the brittle decohesion of the interfaces triggers the final failure of the material, leading to a brittle behavior of the composite. In this study, the micromechanical failure in unidirectional fiber-reinforced composites is studied by means of the finite element analysis of a representative volume element (RVE) of the lamina. To model the fracture of the fiber-matrix interfaces, the trapezoidal cohesive zone model is used. The modified Drucker-Prager yield criterion is employed for the elasto-plastic behavior of the matrix by taking into account the pressure dependency of the epoxy. The aim is to assess the macroscopic stress-strain response as well as predicting the failure locus in fiber reinforced composites by taking into account the micromechanical failure mechanisms associated with matrix damage and micro-cracks growing at the fiber/matrix interfaces. In addition, the effect of micro voids on the initiation and propagation of micro cracks in the matrix and subsequently on the macroscopic response of composites has been studied. The results show that the interface parameters have a significant influence on the macroscopic response of lamina. Furthermore, the existence of voids in the matrix may lead to change the crack path. However, since the volume fraction of voids is very small (around 2%) they slightly affect on the overall stress-strain response and the failure locus of the RVE.

SØREN GIVERSEN (DTU Civil Engineering, 15 minutes)

Blast impact on composite plates

During the recent years there has been an increasing focus on the utilization of light weight composite and sandwich structure for blast protection in e.g. military vehicles when exposed to a blast impact. This has been motivated by the need to find alternative and lighter armour materials, as the use of traditional armour steel to meet the increasing demands on vehicle protection, entail that the vehicles becomes too heavy which reduces manoeuvrability and load capacity of the vehicle.

To explore the use of fibre reinforced polymers as blast protection there is a need to perform physical blast tests to evaluate the performance of selected panel constructions and to have numerical tools that can be used for parametric studies in the design process. This includes the impact of fibre matrix combinations, ply layup and loading conditions. The objective of this PhD project has been to establish these experimental and numerical facilities. A test setup has been designed that allows for measuring blast pressure and monitoring the response of tested panels through the use of high speed imaging and Digital Image Correlation which allows for full field dynamic analysis of the structural deformation, and the possibility of monitoring the initial failure mechanisms in case of fracture. Numerical modelling is performed in the commercial explicit FEM software LS-DYNA which is suitable for simulation of transient events. Models of the experimental setup is being established and verified by the use of the DIC analysis, measuring of blast pressure and material parameters obtained at dynamic loading.

RASMUS NORMANN W. ERIKSEN (DTU Civil Engineering, 15 minutes)

High Strain Rate Test of Fibre reinforced Polymers

Affordable fibre reinforced lightweight polymer materials are potential candidates to substitute rolled homogenous armour steel in add-on panels for military vehicles to reduce their total footprint during deployment. Among other threats, the panels protect against improvised explosive devices (IED), which produce explosions that causes high strain rate deformation in both in-plane and out-of-plane directions of the plate. Numerical simulation of blast events on composite panels requires calibration of material models that can reproduce the impact behaviour of the material including strain rate effects.

The Spilt Hopkinson Pressure Bar is a widely used test setup to determine the flow stress of metallic materials at higher strain rates, but the method can also be used for test of fibre reinforced composites which are elastic up to fracture. The test method sandwiches the test specimen between two long slender bars and loads the specimen to failure with a single mechanical wave through the bars. To obtain valid data for calibration of the material models, the specimen must attain an equilibrium state and a constant strain rate before the specimen starts to fail. There exist 1D wave models in literature which can approximate if these conditions are met for a given test setup by utilizing an analysis of wave motion in the specimen. However these models are restricted to setups where the two bars are equal in material, length and cross sectional area, but this may not be the best setup for test of fibre reinforced materials. This work present an expanded wave model derived in the time domain which removes all restrictions on type of bars and dimension. The model is used to approximate test conditions at high strain rates for a fibre reinforced polymers and the approximated conditions are compared to the obtained conditions.

14:55 – 15:15 Coffee break

INVITED PRESENTATION
(Chairman: Christian Niordsen, DTU Mechanical Engineering)

15:15 – 16:00 MORTEN BRØNS (RISØ DTU, 45 minutes)

On Vorticity and Vortices

Vorticity, the curl of the velocity, is an important quantitiy in fluid mechanics as it measures the local rotation of fluid particles. It is a simple consequence of the divergence theorem that there cannot be any sources of vorticity in the interior of a fluid. Hence vorticity must be created at boundaries and interfaces, but the precise mechanisms are not always well understood. I will show that vorticity is, surprisingly, in most cases a conserved quantity, even if momentum and angular momentum are not.

Vorticity typically organizes itself into vortices, regions of concentrated vorticity. I will review recent research on the genesis and dynamics of vortices, mostly in bluff-body wakes, in terms of concepts from dynamical systems theory.

16:15 – 17:00 2 – FLUIDS
(Chairman: Knud Erik Meyer, DTU Mechanical Engineering)

TORBEN B. CHRISTIANSEN (DTU Mechanical Engineering, 15 minutes)

Efficient Hybrid-spectral model for fully nonlinear numerical wave tank

This contribution presents our recent progress on developing an efficient fully nonlinear numerical wave tank (NWT) based on the 'OceanWave3D' solution strategy established in Bingham & Zhang (2007) [J. Eng. Math. 58], and in Engsig-Karup et al. (2009) [J. Comp. Phys. 228]. Here, the fully nonlinear free-surface boundary conditions are time-stepped using the classical fourth-order Runge-Kutta scheme. The vertical free-surface velocity, which is required to close the free surface problem, is obtained by directly solving the three-dimensional potential flow problem using high-order finite differences in transformed coordinates, which results in a time-constant spatial computational domain. The present work introduces the use of hybrid-spectral methods for the spatial discretization of the free surface and the fluid domain. We combine a Fourier (cosine) collocation method horisontally (similar to the HOS-type NWT models detailed in Bonnefoy et al. (2006) [Applied Ocean Research 28] and in Ducrozet et al. (2012) [Eur. J. Mech. B Fluids 34]) with a Chebyshev Tau method vertically acting as the Dirichlet-to-Neumann operator. The resultant linear system of equations is solved by a defect correction iterative method, preconditioned by the corresponding constant coefficient problem which, when cast in Fourier space only requires solving a tri-diagonal system while still being spectrally accurate. The computational effort of the method shows optimal scaling with increasing problem size.

In the hybrid-spectral NWT a fully nonlinear wavemaker can further be modelled through a combination of coordinate transforms and the introduction of an additional potential, as first suggested by Agnon & Bingham (1999) [Eur. J. Mech. B Fluids 18] which, in contrast to the HOS-type NWTs, can be obtained essentially for free. The concept of additional potentials can also be employed to model submerged moving structures in the fluid domain. This hybrid-spectral NWT model thus combines the best properties of both the HOS model (the spectrally accurate solution, efficiently evaluated through the application of FFTs) and the OceanWave3D model (the abbility to handle varying bottom bathymetries and the introduction of a fully nonlinear wavemaker model at no cost), while also improving the inferior efficiency of the OceanWave3D model compared to the HOS model which was discussed in Ducrozet et al. (2011) [Int. J. Num. Methods in Fluids (published online)].

RAPHAËL COMMINAL (DTU Mechanical Engineering, 15 minutes)

Numerical simulation of viscoelastic flows with free surfaces

A 2D solver for incompressible, isothermal, viscoelastic flows with free surfaces is presented. The flow is governed by the continuity and the momentum equations. However, the conservation of mass is imposed by a pressure equation. The equations are discretised, in space and time, by the finite-volume method, and the three-step backward differential formula, respectively. The constitutive relation used in this work is the Oldroyd-B model, in which the total stress is composed of two components, a purely Newtonian stress and a linear viscoelastic stress. When the viscoelastic stress component is dominant, the Oldroyd-B constitutive model is well known to cause numerical difficulties, referred to in the literature as the high Weissenberg number problem. Those numerical difficulties are addressed by a different treatment of the viscoelastic stress, which is implicit or explicit, depending on whether it acts as a source or as a sink of momentum. This procedure aims at improving the stability and the robustness of the numerical simulation. The free-surface of the fluid is tracked by the volume-of-fluid (VOF) method. This method can also be used to solve a two-phase flow with different material properties. The developed methodology is used for the numerical simulation of extrusion of polymer melts.

ØISTEIN WIND-WILLASSEN (DTU Compute, 15 minutes)

Bouncing drops on a vibrating fluid bath

Bouncing drops on a vibrating fluid bath has been the subject of growing interest recently. These drops have very rich dynamics with behaviour ranging from simple to complex, and they are the first example of a macroscopic pilot-wave system. The system can self-organize into archimedian lattices, exhibit wavelike statistics even though the motion is seemingly random, and show tunnelling through barriers. Typical drop sizes are $r_0 \approx$ 1 mm, and bath and drop are of the same fluid (typical silicone oil). Their coalescence is inhibited due to the slow thinning of the intervening air layer. The vibration frequency of the bath is fixed for a given experiment, but the amplitude of the oscillations can be varied. At sufficiently high forcing (γ_w) the drops start moving along the surface of the bath. The upper limit on the acceleration of the bath is the onset of the Faraday instability, where standing waves spontaneously form on the bath surface due to the parametric forcing. This dynamical system is very interesting for many reasons: Mathematically it is very rich, and shows for instance bifurcations occurring when the drops start walking at (γ_w), period doubling and period doubling cascades leading to chaotic behaviour, and continuous transitions between different phase locking modes. Physically and philosophically the system has features reminiscent of quantum mechanics, and offers a particle-wave duality not macroscopically seen before. I will show some beautiful videos and explain the experiments and briefly describe the model developed in the theoretical work.

17:00 – 19:00 POSTER SESSION

MORTEN BAKKEDAL (DTU Mechanical Engineering)

Phase stability and phase diagrams of steels computed from first-principles

Predicting properties of materials only using first-principles, i.e. the laws of quantum physics, is a very challenging exercise; even more so if temperature dependent properties are to be computed instead of just computing at a frozen configuration at zero temperature. This is nonetheless the goal of this project for a range of steel alloys. A technique known as density functional theory allows reducing the many-variable ground state wave function to an electronic density function, leaving only a three-variable differential equation to be solved as well as an unknown residual functional to be estimated. Thermal energy as vibrations of ion cores can be estimated to second order, resembling a harmonic oscillator, by performing a small finite displacement of each ion in each possible direction. Combining this with a more easily estimated electronic thermal energy, we may write down an expression for the thermodynamic free energy of the system. This is used in the search for stable crystal configurations. As atomic site occupancy preferences are unknown, this is itself a potentially huge combinatorial problem to solve and is attacked using a method known as cluster expansion.

ADNAN BALCI (DTU Compute)

Unfolding of non-simple degenerate streamline patterns near a no-slip wall

In incompressible two-dimensional flows one can find the streamline patterns using a Taylor expansion of the stream function Ψ. The stream function close to a no-slip wall can be expanded as

$$\psi = y^2 \sum_{n,m=0}^{\infty} a_{n,m+2^{x^n y^m}}$$

where the wall is located at y=0. The topology of streamlines of this stream function has been considered by many authors. The bifurcations occuring when the Jacobian is the zero matrix (i.e. $a_{0,2} = a_{1,2} = a_{0,3} = 0$) under non-degeneracy conditions

$$a_{2,2} \neq 0, \quad \tilde{a}_{0,4} = \frac{a_{0,4}}{a_{2,2}} - \frac{a_{1,3^2}}{4\, a_{2,2}{}^2} \neq 0$$

is studied by Hartnack. The case where the first degeneracy condition is broken is treated by other authors. We study the case where the other condition is broken i.e.

$$a_{0,2} = a_{1,2} = a_{0,3} = \tilde{a}_{0,4} = 0, a_{2,2} \neq 0$$

We use normal form transformations to simplify the streamfunction and use bifurcation theory to study to streamline patterns that can occur when the parameters are close to their degenerate values.

CHRISTIAN CHRISTIANSEN (DTU Mechanical Engineering)

Diesel engine tribology

The HERCULES-C project is the framework of the PhD project “Diesel engine tribology”. HERCULES is a long-term R&D programme of the European Commission regarding large marine engines and the PhD project being a corporation between DTU Mechanical Engineering and MAN Diesel & Turbo. Aiming at minimising the friction of engine bearings the filling of lubricant into the bearing are to be investigated. Hereby especially the effects from cavitation. Environmental legislation and fuel costs rises are factors worsening the load conditions of the engine bearing why it is of increasing importance to be able to model the bearing behaviour. A journal bearing has an inherent likelihood of experiencing cavitation in the diverging part of the bearing. For the static load case the occurrence is well understood, but due to the time-dependent combustion forces the problem becomes highly dynamic. A direct link between the gas content and dynamic properties of the lubricant, i.e. damping and stiffness coefficients exists, why the filling ratio of the bearing is of interest.

The bearing-lubricant interaction is going to be investigated both numerically and by experimental set-ups. Numerical analysis will include Finite Element modelling of the bearing and lubricant but also by Computational Fluid Dynamics (CFD) with a commercial code enabling advanced cavitation modelling. The experimental analysis will cover the visual inspection of the formation of cavitation bubbles. From the CFD simulations the introductory studies shows promising results and good agreement with existing theory.

ANDERS CLAUSEN (DTU Mechanical Engineering)

Topology optimization for additive manufacturing

The overall objective is to improve the applicability of topology optimization for additive manufacturing purposes, thereby better utilizing the potential of both fields. The project will involve two main work streams: "Algorithm development", where topology optimization algorithms will be adapted to include relevant AM constraints (e.g. avoidance of cavities); and "Interface integration", where relevant opportunities and constraints of both topology optimization and AM will be integrated into relevant 3D design tools.

PHILIPPE COUTURIER (DTU Mechanical Engineering)

Modelling and Analysis of Coupled Wind Turbine Blades

A concept developed to reduce loads seen by a wind turbine is to promote blade twisting with the use of biased lay-ups in the blade skin to decreases the angle of attack when it is subject to a wind gust. This concept has however remained at the academic level because of the lack of insight regarding the fundamental principles at play. The goal of this project is to develop a methodology to facilitate the design of wind turbine blades that make use of anisotropic materials to generate desired displacement characteristics, including bend-twist response and change of shape generated by uneven transverse contraction of the cell walls. Three specific tasks will enable to reach the overall objective. The first step will be to develop a cross-section analysis program by considering a slice of the beam as a fully 3D elasticity problem with fully anisotropic materials. Second, the beam formulation currently used will be improved by implementing a non-linear finite beam element developed in terms of equilibrium states supplemented by a geometric stiffness matrix generated from generalized quadratic strains. At the end, the developed methodology will be used in conjunction with an aeroelastic program to systematically consider bend-twist coupling in the design and dynamic analysis of a rotor.

SUGUANG DOU (DTU Mechanical Engineering)

Optimization in nonlinear structural dynamics with reduced order models

The goal of this PhD project is to develop a gradient-based optimization method with consistent consideration to nonlinear structural dynamics. The PhD project will focus on developing reduced-order models to facilitate efficient analysis and optimization by replacing the full time-dependent FE model with a lower-dimensional model. The first approach is to evaluate the steady-state vibration amplitude and eliminate the time dimension. The second approach is to apply an order reduction to the spatial dimension so that the full finite element model is replaced by a model with fewer degrees-of-freedom. At first, we will consider analysis and design of steady-state nonlinear dynamics with time-harmonic excitation by use of time-reduced model. Then, we will consider analysis and design of transient nonlinear dynamics with transient loads by use of space-reduced model. At the end, the two reduced-order models are integrated together in topology optimization procedures. The new methods will first be demonstrated on plane beam structures and then applied to more complex 2D and 3D problems.

SALIM A. EL-NAAMAN (DTU Mechanical Engineering)

Measuring and Modeling Geometrically Necessary Dislocation Densities

Recent lattice rotation measurements performed on non-uniformly deformed single crystals of aluminum, nickel and tantalum have shown highly non-uniform distributions of dislocations, which are the main carriers of plastic deformation in metals. These experiments are based on High Resolution Electron Back Scatter Diffraction (HR-EBSD) measurements, through which detailed maps of crystal lattice incompatibility can be obtained. The lattice incompatibility can be linked to the existence of certain dislocation densities – so called Geometrically Necessary Dislocation (GND) densities.

While size-effects on the overall response have been adequately modeled using new higher order methods, the models do not predict realistic microstructural evolution. Theoretical and numerical modeling of mechanical behavior over these small length scales make use of advanced continuum mechanics theories of higher order nature. In the higher order crystal plasticity theory by Kuroda and Tvergaard, the GND densities appear directly as free variables and gradients of GND densities influence the viscous slip rate through the back stress. These properties are believed to form a good basis for the further development of a model for accurately predicting the microstructural behavior.

This study presents theory for obtaining the GND densities based on HR-EBSD mapping of the crystal lattice rotations and a numerical approach to modeling the microstructural evolutions in crystalline materials, in which dislocations carry the plastic deformation.

NIELS FRANDSEN (DTU Mechanical Engineering)

Damping of Beams by Viscoelastic Layers

The damping of beam vibrations by applying a viscoelastic layer to the beam is considered. The viscoelastic layer is applied to the full length of the beam,

along with a constraining layer on top of the viscoelastic layer. The effect of the constraining layer is to ensure that the viscoelastic layer deforms primarily in shear.
A model of the compound beam is developed by deriving the kinematic relations in the beam followed by equilibrium considerations. The proposed model produces a set of coupled differential equations governing the behavior of the beam, one for the transverse deflection and one for the shear deformation of the viscoelastic layer.
The equation for the transverse deflection is very similar to the classic differential equation for beam bending vibrations with contributions to stiffness and mass from the additional layers. Furthermore an extra inhomogeneous term coupling the transverse deflection to the shear stress in the viscoelastic layer is present.
The differential equation for the shear deformation of the viscoelastic layer is coupled to the transverse deflection of the beam and to the shear stress in the viscoelastic layer. The coupling to the shear stress in both differential equations is handled by the introduction of the complex shear modulus, which directly relates the shear stress to the shear strain in the frequency domain.
The use of a complex modulus to describe viscoelastic behavior is widely used, and it is demonstrated how the complex modulus can be derived for a number of material models commonly used in viscoelasticity.
The complex modulus is derived from a representation of the viscoelastic material behavior by standard rheological models, a representation that is valid in both the time and frequency domain.
Using the frequency dependent complex modulus, the governing equations are solved in the frequency domain for a simply supported beam. This leads to a frequency response function determining the modal frequency amplitudes. The equations are completely uncoupled by the simply supported assumption of the beam.
The frequency response function is used to define the complex valued natural frequencies of the simply supported beam system by an implicit frequency equation.
The equation is approximated by an explicit equation, and optimum calibration of the system parameters in terms of maximum attainable damping ratio is carried out.
A number of numerical experiments, comparing the frequency response determined by the analytical model to the frequency response obtained by a full Finite Element model in ABAQUS is carried out. The correlation between analytical and numerical results is good, as long as the assumptions made in deriving the governing equations are fulfilled. For low damping it is demonstrated that the real part of the complex valued natural frequency is a reasonable estimate for the peak frequency, however when large damping is introduced the peak frequency is seen to be lower than the real part of the complex valued natural frequency.

PATRICK GUERRIER (DTU Mechanical Engineering)

Numerical modeling of magnetic induction, heating and flow in injection molding tools

Plastic components made by means of injection molding are used in many products. Injection molding, however, can be difficult to handle - especially if very fine structures in the plastic are needed. At the same time the process consumes a lot of energy. It is the aim to develop a numerical modeling tool for injection molding of plastic, to help increase both the quality of the injection molding and lower the consumption of energy in the process. To accommodate this, magnetic induction heating is used in the mold, to heat up the mold surface where the melt is flowing. This will keep the polymer molten until the mold is filled. The idea with the use of induction heating is to rapidly heat up where it is needed, and hereby avoiding heating up the entire mold, as the molded part has to cool off after injection. The aim with the developed numerical tool is that it can help predict and optimize where the generated heat will arise from the magnetic induction by solving Maxwell's equations. The magnetic field will change in the mold depending on the different materials that are used and their geometrical position. The generated heat is coupled with the heat conduction equation, to calculate the temperature rise from the induction heating. The magnetic properties are temperature dependent, so it is coupled back again. A flow can in general be described by Navier-Stokes equations, which are to be solved for the filling of the mold. The mold filling is also coupled to the energy equation, as the viscosity of the melt is dependent on the temperatures at the mold surface, which are increased by the generated heat from the magnetic induction. The problem therefore becomes fully coupled.

PHILIPP HASELBALCH (DTU Wind Energy)

Ultimate strength of wind turbine blade structures under multi axial loading

Wind turbines must endure a variety of weather conditions including uncontrollable, extreme winds without developing damage and fracture during a lifetime of minimum 20 years. The variety of loading leads to multi axial loading resulting in complex states of stress. The prediction of the effects of the complex states of stress with existing failure criteria can be uncertain and damages and failures often occur earlier than expected. In order to increase reliably and robustly operating wind turbine systems it is of great importance to predict damage initiation and growth accurately. Therefore a profound understanding of the mechanical behaviour of composite materials and structures for wind turbine blades is necessary.

The purpose of this PhD project is to investigate how multi axial loading effects influence the ultimate strength of typical composite structures in wind turbine blades and to develop methods to perform reliable prediction of failure. The complex loading of wind turbine blade structures subjected to different realistic load case will be investigated in order to determine most critical multi axial loading spots in the structure. Damage detection, modelling and prediction of damage evolution under multi axial loading will be carried out based on accurate physics-based failure criteria that have been developed and are preferred to curve-fitting-based criteria. The main limitation associated with latter criteria is that their applicability is restricted to load combinations corresponding to those from which the fitted curves originate. The ability of different criteria to predict failure under multi axial loading conditions will be investigated and methods to account for imperfections will be developed.

IVA HRGOVAN (DTU Wind Energy)

Aerodynamic and structural design of wind turbine blades

The general scope of the PhD project is to demonstrate that an integrated coupled aerodynamic and detailed structural design optimization can lead to new and higher performing MW wind turbine rotors, where the aerodynamic design will based on the DTU-LN series airfoils together with new high performance/low noise wind turbine airfoils which will be designed in the related EUDP project.

The PhD project consists of 2 parts:

First, the aerodynamic airfoil design code developed at DTU will be further developed by linking it into a structural optimization, thus establishing an integrated link between the aerodynamic performance and the structural response at a blade cross-sectional scale. Finite element analysis will be used to analyze a turbine blade section and new cross-section design concepts taking further advantage of sandwich components in the primary load carrying regions of the blade will be proposed and analyzed. Additionally, comparisons with conventional blade designs will be carried out. Finally, the outcome of this part of the PhD project will be a new turbine blade cross-sectional designs which are both aerodynamic and structural optimum.

Due to the complexity of developing a structural design model for an entire blade, the second part of the PhD project focus only on the aerodynamic design of MW wind turbine blades using the airfoil designed in the first part, the DTU-LN airfoils and the new designed airfoils from the EUDP project. The new designed rotors will be verified or checked by using 3D CFD computations. Comparisons with existing rotors will also be carried out.

SØREN RANDRUP HENRICHSEN (M-TECH, AAU)

Optimum Design of Laminated Composite Structures for Robot-Based Manufacturing

The focus of the PhD is the analysis and design optimization of composite structures including the manufacturing constraints imposed by a robot manufacturing-unit. This ensures designs which are effectively manufactured by the robot-unit. The basis of the optimization algorithm is a rational optimization method with finite element based simulation models and advanced draping analysis. This provides the possibility of achieving minimum weight composite structures fulfilling a set of structural demands (e.g., strength and stiffness) together with manufacturing constraints. The outcome of the optimization is a set of fiber paths based on a special purpose developed path-planning algorithm according to the manufacturing process, thus preventing specifications of layups and structures which cannot be manufactured resulting in an optimized structure with respect to structural performance (high stiffness and/or strength to weight ratio).

SHRAVAN JANAKIRAMAN (DTU Mechanical Engineering)

Elasto Hydrodynamic Lubrication in Bearing Contact

Rolling element bearing are used in the planetary gear systems found in the gearbox of wind turbine drive-trains. High pressures can be generated in the lubricant film between the non-conformal contacts of the roller and the inner ring. At high pressures, the viscosity of the lubricant varies as a function of the pressure. These high pressures cause a deformation in the roller surfaces, thus significantly altering the values of lubricant film thicknesses. This regime of lubrication is referred to as Elastohydrodynamic Lubrication (EHL). A model has been developed to calculate the lubricant pressure profile and the film thickness. Pressure profiles and lubricant film thickness profiles are obtained for various values of loads and surface velocities. The EHL model was coded using FORTRAN. A test-rig has also been developed to conduct high pressure EHL tests for both conformal and non-conformal contacts. Interfacial shear forces have been measured for combinations of various input parameters, viz., slide-roll ratios, loads, surface roughness and materials.

SUSANA ROJAS LABANDA (DTU Wind Energy)

Mathematical programming method for large-scale topology optimization problems

Structural topology optimization problems are today solved using sequential convex approximation methods such as the Method of Moving Asymptotes (MMA). This method was especially designed for use within optimal design and is by now extensively used both in commercial optimal design software and in academic research codes. However, this rather old first order method show poor convergence rates and may require many function evaluations for large-scale problems.

One of the goals of this project is to perform extensive numerical tests and compare the commonly used first-order special purpose optimization algorithms in the field of structural topology optimization, with existing state-of-the-art general purpose optimization methods. The second part of the project will consist in developing, analyzing, implementing and benchmarking efficient second order optimization methods which can utilize the particular mathematical structure of large-scale-structural topology optimization problems. In particular, we will analyze and implement tailored versions of a sequential linearly constrained Lagrangian method and a primal-dual interior point method. In general, these methods are both robust and show excellent local convergence properties in practice.

The theoretical analyses will focus on establishing local and global convergence while the implementation of the methods will focus on efficiency in the linear algebra related to these methods when applied to the same classes of topology optimization problems. We expect to significantly reduce the number of iterations compared to the existing and popular first order methods. Furthermore, we expect the number of iterations to remain almost constant with increasing problem size.

SHIZHAO LI (DTU Mechanical Engineering)

A CFD-model for prediction of unintended porosities in metal matrix composites

Metal-matrix composites (MMCs) are materials with a great potential in applications related to lightweight structures and structural damping. However, several experimental investigations in literature show that the fabrication process of MMCs is a delicate matter, which often results in incomplete infiltration. Numerical modeling can be a theoretical tool to provide very useful information on the general behavior of the infiltration process and potentially reduce the experimental work related to obtaining optimized process parameters. Previous numerical studies have focused on capturing the global propagation of the fully and non-fully saturated regions by the usage of the porous media/Darcy flow approach. The drawback of this approach is the disability of capturing one of the key fabrication errors which is the unintended porosities at the end of the process. This paper reports a numerical approach that enables for the simulation of the flow through the porous corridors of the preform. The numerical approach consists of creating a geometrical representation of the preform with an algorithm developed in MATLAB and afterwards importing it into the commercial software FLOW-3D from where the computational fluid dynamics calculation is carried out. The results of the numerical model illustrate the methods capability of predicting unintended porosities in MMCs.

CHRISTOFFER LYTHCKE-JØRGENSEN (DTU Mechanical Engineering)
Design and Optimization of Novel Polygeneration Systems
Biorefineries play a key role in the production of fuels and chemicals from renewable biomass in a future sustainable society. Due to the energy intensive nature of most biomass processing technologies, biorefinery concepts are often assumed integrated with heat and power production in polygeneration systems to increase the energy efficiency and economy of the production.
This study treats the design and optimization of process integration in polygenerations systems operating in a fluctuating and constrained macro-economic environment. In the first part of the study, a numerical tool for optimizing the process integration in polygeneration systems is developed. The tool is able to design and dimension internal energy and mass flows with the aim of optimizing the production economy and efficiency of the system. The optimization is carried out with respect to a constrained macro-economic environment based on the Balmorel model. In the second part of the study, several numerical models of polygeneration systems are developed and optimized using the optimization tool, and general conclusions are drawn with respect to important system and process parameters. Various proposed polygeneration system layouts and biorefineries are also compared based on their expected production economy in the constrained macro-economic environment used by the optimization tool.

SANKHY MOHANTY (DTU Mechanical Engineering)
Evolution of optimal grid-based scanning strategy for selective laser melting
Selective laser melting is a rapid manufacturing technology used to construct functional prototypes or final products using fine metallic powder. Products from this process, however, tend to show an increased amount of defects such as distortions, residual stresses and cracks; primarily attributed to the high temperatures and temperature gradients occurring during the process.
A unit cell approach towards the building of a single layer has been investigated in the present work. A pseudo-analytical model has been developed and validated using thermal distributions obtained using existing scanning strategies. Several existing standard and non-standard scanning methods have been evaluated and compared using the empirical model as well as a 3D-thermal finite element model. Finally, a grid-based scan strategy was obtained for processing a single layer, one unit cell at a time, using genetic algorithms, with an objective of reducing thermal asymmetries.

CHRISTOPHER NELLEMANN (DTU Mechanical Engineering)
Incorporating Size Effects into Conventional Plasticity Model
A material model which relate size dependent plastic deformation to a macroscopic quantification of dislocation mechanisms associated with size dependent plastic behavior is presented. The material model is derived within the framework of rate independent anisotropic crystal plasticity and introduces the concept of higher order stresses in order to account for the size dependent plastic behavior. This rate independent framework introduces dissipation of energy through plastic deformation and recoverable energy through slip gradients. Hereby introducing two different field quantities, one associated with elastic deformation, and one associated with the rate of plastic slip. In this manner size dependent behavior is introduced through the

recoverable (free) energy, whereas gradient effects related to dissipation is neglected. A finite element implementation is presented which is readily extendable to three dimensions.

STEFAN NEUMEYER (DTU Mechanical Engineering)

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 excitations 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 increase the signal-to-noise ratio, and it may be exploited in sensoring and within energy harvesting.

Specifically, the effects of midplane stretching, modal interaction, point masses, high frequency excitation, dynamic buckling and snap-through alongside general energy-considerations are to be examined. The model objects are initially long slender beams with various boundary conditions, but plates, strings and membranes are also possible to study in the context of parametric amplification.

JACOB PAAMAND WALDBJØRN (DTU Civil Engineering)

Hybrid testing of composite structures with single-axis control

Hybrid testing is a sub-structural testing and analysis concept with the emulated structure partitioned into an experimental- and analytical substructure. When combining the response of the two substructures, the behavior of the emulated structure is obtained. The experimental substructure is a physical test which provides the capability to isolate and test a critical component which displays complicated structural behavior e.g. buckling, viscoelastic behavior, etc. The remainder of the structure is well understood and for that reason simulated in a numerical model. The coupling between the experimental and numerical substructure is achieved by maintaining the compatibility and equilibrium at the shared boundary.

The research within hybrid testing has been focusing on testing of e.g. fluid dampers for seismic protection of building structures [1], [2] and [3]. In these tests – referred to here as multi component hybrid testing - the shared boundary between the experimental- and numerical substructure is clearly defined by a discrete point with a few degrees of freedom. However with the aim of doing hybrid testing on a single component structure e.g. wind turbine blade, boat hull, etc. the shared boundary conditions between the two subcomponents becomes significantly more complicated. This is caused by the continuous boundary between the two models, resulting in an infinite amount of degrees-of-freedom.

The scope of this research is to introduce a sound base for a quasi-static hybrid testing of a single component structure with an emphasis on system stability and compliance of the test setup. This is done by a simple emulated structure separated in two sections: i) experimental substructure consisting of a 3-point bending test and ii) numerical substructure consisting of a simple cantilever beam. The shared boundary is described by a discrete point with a single degree of freedom. The hybrid testing application is operated by LabVIEW 8.6 and executed in a state-machine framework. This configuration is capable of operating a: i) deformation controlled actuator through a PID controller, ii) FE-model by ANSYS 11.0 and iii) data acquisition from several gauges on the specimen and actuator.

It was by this simple emulated structure verified that the hybrid testing platform was stable and capable of simulating the emulated structure within the linear elastic regime.

References:

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[3] M. Ahmadizadeh and G. Mosqueda "Online energy-based error indicator for the assessment of numerical and experimental errors in a hybrid simulation". Engineering Structures, Vol. 31, pp 1987-1996, 2009

ZILI ZHANG (CIVIL, AAU)

Dynamic Stall and Aeorelastic Stability of Wind Turbines

Wind turbine may render into dynamic stall either due to excessive gust or large flap-wise dynamic vibrations, resulting in the loss of aerodynamic damping and stability. Additional, wind turbines are time dependent systems due to the coupling between degrees of freedom defined in the fixed and moving frames of reference, which may trigger off internal resonances. Finally, the rotational speed is not constant due to the gusts, which induces an additional auto-parametric component in the parametric excitation. This research deals with the problems of almost sure non-linear aeroelastic stability of wind turbines, taking the indicated topics into consideration in addition due to external stochastic excitation from the turbulent wind. Two methods for sample curve stability are derived. The first concerns the first-passage time failure probability of the maximum Lyapunov exponent on condition of initial deterministic start at a given negative value of this process. In the second case the stability is determined assuming ergodicity of the response and excitation processes. The resulting stability criteria requires the evaluation of the expected value of a quantity related to the ergodic sampled maximum Lyapunov exponent. Further, control of stall induced vibration will be carried. One possible solution is to initiate so-called vortex spoilers which are small flaps of the magnitude of few centimeters. By initiating these small flaps, a more stable profile is achieved.

Programme for Thursday morning, March 14th, 2013

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

09:00 - 10:20 SØREN R.K. NIELSEN (CIVIL, AAU, 20 minutes)

Stochastic Nonlinear Control of Wave Energy Point Absorbers

A wave energy point converter may be defined as a dynamic system with one or more degrees of freedom with a size that is small compared to the dominating wave length, which is capable of absorbing mechanical energy from the waves and convert the absorbed energy in the waves into electric energy. The point absorber is connected to electric power generator via a hydraulic force system, and the reaction force from the latter influence the motion of the point absorber. Within certain ranges these reaction forces can be specified at prescribed values. In so-called reactive control these reactive forces are used to control the motion of the WEC in such a way that a maximum mechanical energy is absorbed from the waves. With a certain loss due to friction in the hydraulic force actuator the control forces are next transferred to the generator, where they are converted into electric energy. The dynamic system is non-linear due to strong non-linear buoyancy forces and non-linear wave-structure interaction. Since, the irregular wave force excitation needs to be described in stochastic terms, which renders the optimal control problem stochastic as well.

In the talk the optimal control law for a single point absorber ensuring optimal mean absorbed power in irregular sea-states is first derived in case of infinite control horizon on condition of no constraints on the displacement of the floater and the control force. The control law turns out to be of the closed loop type with feedback from measured displacement, velocity and acceleration of the floater. However, a non-causal integral control component depending on future velocities appears in the optimal control law, rendering it less useful for real time implementation. Instead, a causal close loop controller with the same feedback information is proposed, based on a slight modification of the optimal control law. The basic idea behind the control strategy is to force the stationary velocity response of the absorber into phase with the wave excitation force at any time. The controller is shown to be optimal under monochromatic wave excitation.

The mean generated electric power is different from the mean absorbed power due to the losses at positive and negative side loops of the instant power. Further, constraints on the displacement of the absorber and the control force needs to be considered, which induce further non-linearity in the problem. In order to calculate the mean electric power the full probability density function of the instantaneous electric power is needed, which has been determined by the so-called probability density evolution method.

MARTIN BJERRE NIELSEN (DTU Mechanical Engineering., 15 minutes)

Conservative Integration of Constrained Rigid Body Rotation

Rigid body rotations are of great interest for many mechanical applications. However, finite rotations do not combine by the simple rules of vector addition, and thus special parameterizations have to be used. In the present formulation the orientation of a rigid body is represented via a convected set of orthonormal base vectors in absolute coordinates, and thus the three translational components and the nine base vector components constitute a set of generalized displacements. Orthogonality and unit length of the base vectors are imposed by a set of holonomic constraint equations representing vanishing of the Green strain components. The equations of motions are derived from an augmented Hamiltonian where zero strain constraints as well as external constraints associated with the presence of joints are included via Lagrange multipliers. This leads to a set of first order evolution equations for the generalized displacements and their conjugate momentum variables, which can be descretized into a conservative form by a suitable combination of mean values and finite differences. A key feature of the present formulation is that the Lagrange multipliers associated with the zero-strain constraints can be eliminated by using a set of orthogonality relations between the displacement and the momentum vector. This leaves the original number of equations in a form where the incremental form of the constraints on the base vectors is embedded without recourse to additional variables. The conservative integration scheme then ensures exact conservation of the constraints. Furthermore, it is illustrated that the Lagrange multipliers in a discretized system serve the role as the reaction forces needed to prevent the constraints from changing over each time interval, and thus the multipliers are associated with the intervals rather than specific points in time. The accuracy and conservative properties of the algorithm are illustrated by simple examples.

PER HYLDAHL (Department of Engineering, Aarhus, 15 minutes)

A thin plate finite element based on the Arbitrary Lagrange-Euler and Absolute Nodal Coordinate Formulation

This presentation will give a short introduction to a newly developed technique suitable for modeling flexible bodies with e.g. mass flow, sliding joints or traveling forces. The technique is based on a combination of the Arbitrary Lagrange-Euler (ALE) and the Absolute Nodal Coordinate Formulation (ANCF). The ANCF method is a non-incremental finite element method capable of describing both large overall motion and large deformations. This is accomplished by using global position vectors to describe nodal positions and global gradient vectors to describe orientations. The use of global position and gradient vectors to describe the element kinematics leads to a constant mass matrix, which makes it suitable for multibody dynamics. When combining the ANCF method with the ALE description element nodes are no longer tied to any specific material point. This allows for the nodes to relocate in the mesh.

The presentation will give a short introduction to the kinematics of an ANCF based plate element, and show how extra degrees of freedom to track nodal positions inside the mesh are introduced. The equation of motion for the element is derived using the principle of virtual work, and at the end some numerical examples are given.

NIELS FUGLEDE (DTU Mechanical Engineering, 15 minutes)

Roller chain drive dynamics: Theoretical modeling and analysis

This study contributes to the areas of kinematics and chain span dynamics. Roller chain drives transfer power and timing efficiently and are easy to install. The desire to minimize vibration and ensuring safe operation motivates the ongoing research. In roller chain drives, the chain wraps around the sprockets, which form polygons, instead of circles as in belt drives. This introduce several characteristic effects: Impact occurs when a roller seats on a sprocket, span length varies discontinuously in time and the rotational speed of the driven sprocket generally varies, despite the rotational speed of the

driver sprocket being constant. Altogether this makes numerical modeling challenging, and simulation- and experimental work involved.
Kinematic analysis is performed to quantify the effects of polygonal action. By considering the four-bar mechanism equivalent to the chain drive, the influence of main design parameters such as shaft center distance are highlighted. The dynamic response of the chain span is examined by modeling the chain span as an axially moving, non-linear string forced by boundaries moving as prescribed by the kinematic analysis. Vibration of the chain span is thereby examined under the characteristic and inherent loading of chain spans: Periodic, parametric and external impulsive. Closed form approximate analytical results are obtained using perturbation methods, and resonance phenomena are identified. This makes it possible to understand the influence of main operating parameters such as pre-tension, and span velocity. Analytical predictions are compared with results of multibody simulation.

MARTIN FELIX JØRGENSEN (DTU Mechanical Engineering, 15 minutes)
500 kW wind turbine multibody drivetrain model
A dynamic rigid wind turbine multibody model, has been developed in Matlab. The aeroelastic and industry-accepted FLEX 5 code is used for producing the aeroelastic forces and torque, acting on the rotor. Experimental data using strain gauges has been used for verification and assessment. Of particular interest is how to obtain the wind turbine gear tooth stresses, which are normally hard to estimate because of the complexity of tooth profiles and loadings etc. The gear tooth reaction forces have been calculated by means of Lagrange multipliers and the Jacobian and the result is used together with realistic geometric gear tooth profile data in the FEM-package, Comsol Multiphysics. The described method is capable of estimating the gear tooth stresses as a function of turbulent mean wind speed. Furthermore, the multibody model allows insight into loadings on all main components, e.g. for instance for studying heavily loaded bearing reaction forces. A flexible multibody model of a planetary gearbox is also presented, to evaluate differences between the behavior of a rigid planetary gearbox model.
Experimental measurements ensures realistic data on both input and output variables, which together form a base for further studies of e.g. gearbox fatigue loads, the effect of wind turbulence on main mechanical components such as lowspeed/highspeed shaft and for calibration and verification of the gearbox model.

10:20 – 10:50 Coffee break

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

10:50 – 11:50 JUAN GALLEGO-CALDERON (DTU Wind Energy, 15 minutes)
Electromechanical Drivetrain Simulation
Wind turbines are complex structures that are subject to different dynamic loads from fluctuating wind resource and the dynamic behavior of the grid. A consequence of this is the exposure of the wind turbine to different structural loads resulting in wear and fatigue of its components. The purpose of this PhD project is to study the electromechanical interaction between the rotor and the generator, and the resulting drivetrain loads. The dynamic response of the different components in the drivetrain will be investigated, along with

experimental testing to develop new conceptual designs of the drivetrain with improved reliability.

The drivetrain model from the main bearing to the generator is modeled as a flexible multibody system with appropriate generator controls based on a MATLAB/SIMULINK interface. The developed drivetrain model is to be integrated with the DTU Wind Energy developed aeroelastic code HAWC2. This is done in an integrated dynamic analysis environment, developed at DTU Wind Energy. This approach allows taking into account the influence of the aerodynamic and mechanical loads from the rotor and the electrical loads from the grid.

Load cases with extreme drivetrain events such as grid loss, emergency stops, as well as turbulent wind fatigue loads are studied under typical field conditions for a multi-MW machine.

JONAS MORSBØL (M-TECH, AAU, 15 minutes)

Modelling of Elastic Wave Guide Properties of Flexible Pipes

Wave guide modelling of flexible pipes has a wide range of applications. Risers used in the oil and gas industry, suffering under internal and external flow induced vibrations, hydraulic hoses acting as structural wave guides in power transmission systems, and also diagnosis of cardiovascular diseases in the larger blood vessels are just some of the areas. In many of these applications the pipe is either containing fluid, submerged in a fluid, or both. In these cases the wave guide properties are a result of fluid-structure interaction. A full description must therefore contain a model of the structural part, a model of the fluid part and a relation of how these are coupling. Though for the time being the focus is only on the structural part in what follows. Thus depending on the stiffness properties of the pipe and the frequency range under considerations different modelling techniques can be applied. At sufficiently low frequency relative to the stiffness of the pipe a one-dimensional beam model may be sufficient. At higher frequencies the plane cross-section assumptions of e.g. a Timoshenko beam become too restrictive whereas a two-dimensional shell model of the pipe wall might still be valid. Then, at even higher frequencies, deformation modes across the thickness of the pipe wall also need to be taken into considerations and a full-blown three-dimensional elasticity model is then needed.

In this work an analytical shell model of the wave guide properties of a flexible pipe is carried out. The flexible pipe is modelled as a thin walled bend cylinder by means of Gol'denweizer-Novozhilov's thin shell theory. Then the dispersion relation between the frequency and wave number associated with the waves along the length of the pipe is determined by means of the Galerkin method. The benefits of an analytical are, as usual, insight into the mechanisms governing the system and faster evaluation of the solution. The dispersion relation of this model is compared to a corresponding Timoshenko beam model and wave finite element models consisting of, respectively, shell elements and solid elements.

RASMUS BRUUS NIELSEN (M-TECH, AAU, 15 minutes)

Propagation of elastic waves in spatially curved and inhomogenous rods

In this study the propagation of elastic waves is considered through rods with inhomogeneities. Inhomogeneities of rods could, amongst others, be features like: varying curvature, changing cross section, nonconstant foundation stiff-ness etc. This topic is of interest in the search of 'silent design' of vibrating machinery using inhomogeneous rods as vibration isolators (e.g. springs of regular or perturbed helical shape) or noise reduction through piping systems, as well as for nondestructive testing of hanging wires, rails, etc.

The study presented will mainly be on asymptotic analysis by the WKB approximation of wave propagation in beams with changing cross section modeled by the plane cross section hypothesis.

Ideas of this kind has as well been presented in [1] and [2]. The solutions are subjected to studies of eigenfrequencies and compared to numerical solutions by the Finite Element Method to assess the validity range of the asymptotic solutions. The concept of asymptotic analysis of wave propagation by the WKB approximation is carried on to problems of wave motion of rods with spatial curvature, where some preliminary results will be shown.

As a final comment it will be discussed how the ideas of asymptotic approximations of wave motion may be brought into a computational environment, more precisely by a combination of the Waveguide Finite Element Method and the WKB approximation.

Acknowledgement

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MARK LAIER-BRODERSEN (DTU Mechanical Engineering, 15 minutes)

Damping of Tower Vibrations by Viscous Damper Systems

Offshore wind turbines supported on monopiles are sensitive to waves acting at an angle relative to the wind direction because of the small aerodynamic damping in the side-to-side mode. A way to extend the feasibility of the monopile support to deeper waters and larger turbines is to reduce the dynamic response by means of external damping. The classic approach of placing a TMD or pendulum type damper where the absolute motion amplitude of the targeted vibration mode is largest has some disadvantages in terms of large damper motion and mass. Furthermore, a resonant damper requires several periods to get synchronized with the motion of the primary structure, thus making it less efficient with respect to instantaneous impulse loading from a large wave. Instead the present Ph.D. project considers the possibility of installing dampers inside the wind turbine tower using bracing systems, whereby the dampers is acting on the relative motion of the tower. Maximization of the attainable damping and the damper stroke is of primary concern for the effective implementation of the present damper systems inside the wind turbine tower. The relative motion of the tower is expected to be small, which means that an effective damper system requires some form of motion amplification devices, e.g. toggle braces, in order to amplify damper stroke. On the other hand attainable damping is associated with the dampers ability to lock the structure motion in a modified mode shape, which is slightly different due to the presence of the damper system itself. As demonstrated optimal damper design and installation requires a compromise between damper stroke and attainable damping.

12:00 – 13:00 Lunch

Programme for Thursday afternoon, March 14th, 2013

5 – MULTI-PHYSICS MODELLING
(Chairman: Ole Sigmund, DTU Mechanical Engineering

13:00 – 14:30 ISMET BARAN (DTU Mechanical Engineering, 15 minutes)

3D Thermo-Mechanical Analysis of the Pultrusion Process

Fibre-reinforced polymer (FRP) composites have been used widely in aerospace and marine applications for years and are now increasingly being used in construction industry due to their high strength-to-weight ratio, low maintenance cost and high corrosion resistance. Pultrusion is one of the cost efficient composite manufacturing processes in which constant cross sectional continuous FRP profiles are produced. Recently, pultruded structures are foreseen to have potential for the replacement of conventional materials used in the construction industry. More specifically, the application of pultruded composite rods is significantly increasing for reinforcements of concrete elements in the construction industry. The increasing usage of the pultruded profiles in the construction industry requires detailed understanding of the mechanical behavior as well as the failure mechanism of the profile.
The process induced residual stresses and distortions for the pultrusion of a unidirectional (UD) glass/epoxy flat beam profile in 3D, which has not been considered in the literature up to now, are predicted in the present study. The temperature and the cure degree distributions are first obtained in the thermo-chemical analysis of the pultrusion process. Afterwards, the calculated temperature and cure degree profiles are used in the mechanical analysis in which the process induced residual stresses and distortions are evaluated. More specifically, 3D transient Eulerian thermo-chemical analysis is coupled with the 3D quasi-static Lagrangian mechanical analysis of the pultrusion process. The cure hardening instantaneous linear elastic (CHILE) approach is used for cure-dependent and temperature-dependent resin modulus development. At the end of the process, tension stresses prevail for the inner region of the composite since the curing takes place later as compared to the outer regions where compression stresses are obtained. The proposed process model has a great potential for the future investigation of the process induced residual stresses and distortions of more complex pultrusion process models including the axial frictional force evolution.

MADS ROSTGAARD SONNE (DTU Mechanical Engineering, 15 minutes)

Modelling the deformation process of flexible stamps for nanimpint lithography

The work presented here, is a contribution to a larger project called NANOPLAST. The aim of this project is to produce injection moulding tool inserts with nano-patterned functional surfaces. Such surfaces can give functions like antireflective, super hydrophobic, tactile- and color-effects to the molded plastic parts. The nano-patterns are transferred to the steel tools by a technology called nanoimprint lithography (NIL). This technology was originally invented for use on planar wafers as an alternative to traditional UV lithography, but here, as the tool inserts are non-planar 3-D structures, the technology is a bit modified and uses so-called flexible stamps for the nanoimprinting process. In order to design the nano-patterns on the 2-D undeformed flexible stamp, prediction of the 3-D deformed shape is essential. Modelling the deformation of this flexible stamp is the aim of this PhD project. Finite element simulations are used as the tool for prediction, but the problem is in many ways non-linear: The flexible stamp is made of the polymer PTFE (polytetrafluoroethylene), which constitutive behavior is described by a 1-D rheological model consisting of both viscoelastic and viscoplastic components. Geometrically, even though the scale is in micro- or nanometer, the problem is also non-linear as large strains up to 50% and large deflections will occur during deformation, and an updated Lagrangian formulation is needed to take that non-linearity into account. Finally, contact between flexible stamp and steel tool inserts should also be addressed, and it is discovered that the frictional behavior changes drastically as the length scale is decreased.

PETER CHRISTIANSEN (DTU Mechanical Engineering, 15 minutes)

Numerical modeling of defects distribution and residual stresses in forged components

The main purpose of the open die forging operation, used when producing large metallic parts such as shafts for ships, power plants or wind turbines, is to ensure a sufficient minimization of internal defects originating from the casting process. Such defects may for instance be segregations, inclusions, coarse microstructure and porosities. It has long been known that a v-shaped lower die is beneficial for the internal defect closure. However little research has been performed in order to investigate which lower die angle is the best regarding defect minimization. In former times this was especially due to the large cost of full scale experiments. With modern finite element simulation it is now possible to perform a more detailed analysis of the open die forging process.

In the present work a combination of both numerical and physical modelling of the open die forging process is presented. It is found that the lower die angle has a marked influence on internal defect minimization and also on the size of the forging force.

KONSTANTINOS POULIOS (DTU Mechanical Engineering, 15 minutes)

Finite Element modeling of contact using GetFem++

As part of the development of a combined brake and sliding bearing unit for the yaw system of wind turbines, numerical simulation was applied for studying the contact and friction between solids. The fundamentals and application examples of two relevant finite element models that were based on the software library GetFem++ are presented.

As an introduction, an overview of the capabilities of GetFem++ is given and its application to solving structural problems including contact is discussed. The possibility of running GetFem++ based models on multiple cores in parallel is also commented.

The first model to be presented, refers to the micro-scale and aims the calculation of the real area of contact between nominally flat rough surfaces. The model includes representative rectangular samples of the solids in contact and can take arbitrary roughness topographies for the contacting surfaces into account. Plastic deformation of the bulk materials can also be taken into account. The presented example calculations are based on roughness data measured on real specimens and realistic material parameters and loading conditions.

The second model represents phenomena that occur in the macro-scale and aims the calculation of the load distribution among the several segments that constitute the newly developed yaw system.

The input parameters, the automate meshing of a simplified geometry as well as the boundary and load conditions are discussed and results from a calculation example are presented.

FREJA NYGAARD JESPERSEN (DTU Mechanical Engineering, 15 minutes)
Interaction of stresses and concentration during thermochemical surface engineering
Thermochemical surface engineering, which includes processes like nitriding and carburizing, is the deliberate modification of the composition of an alloy in the surface region through the reaction of components from the workpiece with components from an external source at enhanced temperature. It is among the most widely applied surface treatments of, in particular, ferrous materials, to improve materials performance with respect to wear, corrosion and/or fatigue.
As a consequence of thermochemical surface engineering, residual stresses are introduced in the treated zone, arising from the volume changes that accompany the phase transformations that occur in the solid state.
The intriguing phenomenon during thermochemical surface engineering is that the residual stresses evoked by phase transformations in the solid state, affect the actual occurrence of phase transformations, for example the diffusion of the nitrogen/carbon. Solid mechanics is thus now combined with thermodynamics to build a model which takes into account the interaction between the stress and the concentration.

KRISTOFFER HOFFMANN (DTU Compute, 15 minutes)
Stability of a linearised hybrid inverse problem
Hybrid inverse problems describe novel imaging methods that make use of coupled physical phenomena to provide images with high contrast and high resolution. We consider such a problem where the mathematical formulation is given by a system of generalised Laplace equations augmented with additional data given by internal power densities. This is the mathematical description of a hybrid imaging method known as Ultrasound Modulated Electrical Impedance Tomography (UMEIT). The simplest way of treating such an inverse problem is to analyse the corresponding linearisation. A theoretical analysis shows whether or not the linearised problem is elliptic and thereby provide information about when to expect a wellposed reconstruction with optimal stability. A numerical implementation of the linearized problem has been made in order to analyse and verify these theoretical results.

14:45 – 18:00 Social Event

19:00 - Banquet

Programme for Friday morning, March 15th, 2013

6 – OPTIMIZATION
(Chairman: Niels Leergaard Pedersen, DTU Mechanical Engineering)

09:00 – 10:35 JAKOB SØNDERGAARD JENSEN (DTU Mech.Eng., 20 minutes)
Topology optimization of advanced materials
New developments in the use of topology optimization as a design tool for creating materials with advanced static and dynamic properties are demonstrated. Examples of porous metal materials with high vibration damping capabilities and/or a high stiffness to weight ratios will be given and perspectives for tailoring the nonlinear response of materials are discussed.

KONSTANTINOS MARMARAS (DTU Wind Energy, 15 minutes)
Optimal Design of Composite Structures by Advanced Mixed Integer Nonlinear Optimization
The use of composite materials offer tremendous potential weight savings and increased performance capabilities compared to metals. Yet, designing composite parts is a highly complex and expensive task. In this presentation we consider optimal lay-up design of laminated composite structures. Our aim is to develop modern special purpose global optimization methods and heuristics capable of solving minimum compliance (i.e. maximum stiffness) problems with a mass constraint and minimum weight problems with compliance constraints to global optimality.
The numerical experience with our methods and heuristics are reported on a set of discrete material optimization benchmark problems. Minimum compliance and minimum weight designs for laminated composite plates are obtained for both in-plane and out of plane loadings. The ability of our framework to perform multi-material optimization is examined and we are considering both single and multiple load cases. The obtained results are in good agreement with previous studies performed on the same examples. Our implementation outperforms existing methods for optimal design of laminated composite structures. Several of the problem instances were solved to proven global optimality.
The obtained results indicate the importance of including manufacturing and stress constraints in the optimal design problem. For the purpose of this presentation we have not taken such constraints into consideration. The inclusion of such constraints poses several theoretical and computational challenges that have to be overcome before they can be included in practical lay-up design problems of laminated composite structures with many design variables. The presentation will include ideas on how manufacturing constraints can be included as linear constraints in the problem formulations and the methods. Some promising preliminary results will be demonstrated.

SØREN NØRGAARD SØRENSEN (M-TECH, AAU, 15 minutes)
An MINLP Formulation for Global Topology and Thickness Optimization of Monolithic Laminates
A non-convex, gradient based topology optimization method for large-scale discrete orientation and thickness optimization of monolithic, laminated composite structures, considering a variety of manufacturing constraints to attain industrial relevance, has previously been developed by the author. The methodology was based on the so-called Discrete Material Optimization

method. This work concerns a reformulation of the originally bi-linear, and hence non-convex problem formulation, into a convex mixed integer non-linear problem solved by outer approximation. Mixed integer formulations are not commonly applied for structural topology optimization, primarily due to limited problem size capabilities. This issue may however change over time as both hardware and state-of-the-art optimizers keep getting increasingly efficient. Despite the limitation to small-scale problems, global optimum formulations remain invaluable for providing benchmark examples with guaranteed optimality, applicable for quality assessment of promising, but non-convex, competing formulations such as e.g., the authors' previous methodology. Both methodologies are demonstrated on several numerical examples.

RENÉ SØRENSEN (M-TECH, AAU, 15 minutes)

A Methodology for Material and Thickness Optimization of Laminated Composite Structures

The presented work concerns a gradient based topology optimization methodology for minimizing the
mass of large-scale laminated composite structures through the determination of an optimum thickness and material distribution. This is accomplished while also considering constraints on the structural performance, e.g., minimum buckling load factors, eigenfrequencies, and limited displacements. Furthermore, a series of manufacturing constraints are considered in order to reduce the required amount of manual post-processing of the optimized structure. The contradictory criteria functions result in a challenging problem. However, a set of robust and efficient parameters have been determined. Finally, numerical result of a generic main spar from a wind turbine blade will be presented at the symposium.

ALEMSEGED G. WELDEYESUS (DTU Wind Energy, 15 minutes)

Multidisciplinary Free Material Optimization of Two Dimensional and Laminate Structures

Free Material Optimization (FMO) is a branch of structural optimization in which the design variable is the full material tensor which can vary freely at each point of the design domain. Certain necessary conditions on the physically attainability are the only requirements on the material tensor. The solution yields optimal distribution of the material with local material properties. Therefore the optimal structure found by FMO can be considered as an ultimately best structure. Depending on the problem formulation additional constraints on local stresses and displacements are considered on the structure. The resulting optimization problem is a nonlinear semidefinite program, a non-standard problem with many matrix inequalities for which special optimization methods must be developed. Existing robust and efficient primal-dual interior point methods for nonlinear programming are extended to FMO. The robustness and efficiency of the developed method is demonstrated by numerically solving a series of examples for FMO of two dimensional and laminated composite plate structures.

VILLADS EGEDE JOHANSEN (DTU Mechanical Engineering, 15 minutes)

Structural Color Design

Colors reflected from surfaces are caused by either the absorptive properties of materials and/or light's interaction with structures having dimensions comparable to the wavelength of light (nm range). Light's interaction with structures is what is referred to as structural coloration, and is the effect seen when looking at CDs, peacock feathers and many other natural and man-made objects. In recent years more and more efforts have been made in investigating and analyzing these structures, Vukusic and Sambles (2003); Kinoshita and Yoshioka (2005); Saito (2011), but little efforts have been devoted to trying to create new colors and color effects by designing nanostructures (examples of existing designs are multilayer coatings, diffraction gratings and interferometric modulator displays). Applications for structural coloring include altering the color of certain products even though they are made of the same material by e.g. only changing the casting mold (LEGO brick coloration, pre-printed text), new color appearances for product design, extremely durable colors, improved optical materials (anti-reflective surfaces, color filters) and more eco-friendly production processes due to the saving of paint.

This presentation focuses on how color appearances from structures can be simulated and optimized and will furthermore contain results of structures optimized for a given color appearance.

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10:35 – 11:00 Coffee break

7 – FATIGUE AND FRACTURE

(Chairman: Henrik Myhre Jensen, Department of Engineering, Aarhus)

11:00 – 12:20 KIM LAU NIELSEN (DTU Mechanical Engineering, 20 minutes)

***It will take* Joint Efforts to Bridge the Gaps in Ductile Fracture Mechanics**

The ductile failure process governed by void nucleation and growth to coalescence has been studied widely by many research groups in decades. The individual mechanisms involved are well-known and have been described in both experimental and numerical investigations. The large amount of numerical simulations carried out includes most aspects of the failure process and important insight has been gained. From this, significant efforts have been made to develop both micro-mechanics based and phenomenological models for crack growth in large scale structures. Unfortunately, the numerical model results are often tied to controlled stress or strain conditions, e.g. through periodic cell-models. Such homogeneity is rare in engineering materials and conclusive insight into the mechanics at play during failure of a specific material, under specific loading conditions, typically relies on fracture testing. The task at hand is two-fold; i) Contradictions between state-of-art micro-mechanics based numerical models and experimental observations exist – some are accepted, while the general perception of others are transitional effects. Clear evidence for all observed effects needs revisions. ii) Developed models can often be tuned to fit given experimental results, but seldom for arbitrary loadings, and/or large variations in the plastic properties of the material – let alone changes in the damage parameters. The interplay between the different micro-mechanisms governing ductile failure has yet to be fully resolved. Both tasks are equally important as the overall structure response, crack surface morphology and responsible micro-mechanism are strongly related. In this talk, an effort will be made to bring forward some of the key elements that need to be understood in order to improve model predictions.

NIELS HØRBYE CHRISTIANSEN (DTU Mech. Eng., 15 minutes)

Hybrid Method Simulation of Slender Marine Structures

Slender marine structures such as flexible risers and mooring line systems exhibit large deflections in service. Reliable analysis of this behavior requires large nonlinear numerical models and long time-domain simulations. This combination or requirement makes dynamic analysis of these structures computationally expensive. Over the last decades an extensive variety of techniques and methods to reduce this computational cost have been suggested. One method that has shown promising preliminary results is a hybrid method which combines FEM models and artificial neural networks (ANN). The ANN is a pattern recognition tool that is often used in machine learning applications. In order to learn the underlying dynamics of a given structure the ANN relies on pre-generated data. That is why the method is a hybrid method that combines FEM models and ANN. However, after training of the ANN it is able to completely overtake the time domain simulation and do this at a remarkable pace.

One problem with the hybrid method is that the ANN can predict accurately only on known patterns i.e. load patterns that is part of the training data. Hence, if the load pattern changes the ANN must be trained over again. It is shown how training data for the ANN can be arranged and normalized in a way that makes the trained ANN capable of simulating for a large variety of sea states and thereby be able to perform accurate fatigue analysis a lot faster than traditional methods. The method is demonstrated on a mooring line system of a floating offshore platform where the ANN predicts tension forces two orders of magnitude faster than corresponding direct time integration. Hence, since the ANN is able to do complex nonlinear mapping between a given input and the corresponding output with great accuracy and without equilibrium iterations, it is possible to bypass the infuriating compromise between model sophistication and computational cost.

ÓLAFUR MAGNUS ÓLAFSSON (DTU Civil Engineering, 15 minutes)

Improved design bases for welded joints in seawater

This joint research project between the Technical University Denmark (DTU), FORCE Technology and Vestas Wind Systems A/S aims to investigate and establish a precise, thorough and detailed database from series of experimental testing of SAW welded specimens of various thicknesses. Welded structures of all sizes and shapes exhibit fatigue failure primarily in the welded region, rather than in the base material. The welded region has therefore received much attention from universities, research institutions calong with industry as it is of great practical importance for all fatigue loaded structures, such as e.g. offshore wind turbines.

As-welded SAW specimens were subjected to uni-axial tension loading at relatively high R-ratios in order to simulate tensile residual stresses of yield magnitude. The main goal was to confirm the thickness effect for the specific case of large transverse butt joints in the as-welded condition as well as to validate whether the thickness correction factor according to recommendations, codes and guidelines is too conservative when it comes to butt-welded joints. A conservative thickness effect factor results in larger, heavier and more expensive structures. The existing database of experiments that relate to the thickness effect is comprehensive and the effect is well proven experimentally and theoretically for various types of welded joints. However, in the case of large butt-welded joints there is room for improvement as details, quality and precise data which can influence the fatigue life of the welded joint is often lacking.

MICHELE CERULLO (DTU Mechanical Engineering, 15 minutes)
Application of Dang Van Criterion to Very High Cycle Fatigue in Wind Turbine Roller Bearings
A 2-D plane strain finite element program has been developed to investigate very high cycle fatigue (VHCF) in wind turbine roller bearings subjected to rolling contact. Focus is on fatigue in the inner ring, where the effect of residual stresses and hardness variation along the depth are accounted for. Both classic Hertzian and elastohydrodynamic lubrication (EHL) theories have been used to model the pressure distribution acting on the inner raceway and results are compared according to the Dang Van multiaxial fatigue criterion. The contact on the bearing raceway is simulated by substituting the roller with the equivalent contact pressure distribution. The material used for the simulations is taken to be an AISI 52100 bearing steel and linear elastic behavior is here assumed. The effect of different residual stress distributions are also studied , as well as the effect of variable hardness along the depth, relating its values to the fatigue limit parameters for the material. It is found that both for Hertzian and EHL contacts, Dang Van criterion predicts detrimental conditions in the subsurface region and that, regardless the specific pressure distribution used, hardness distribution can have a significant influence on the probability of failure for bearings subjected to VHCF loading.

MADS KRABBE (Department of Engineering, Aarhus, 15 minutes)
Crack Mechanisms and Crack Interaction in Thin Films
Hard coatings can be applied on materials to enhance their mechanical properties. In this project, focus is on cracking of hard coatings. Cracking plays a key role in the failure of hard coatings.
A description of the theory for through-surface channeling crack in thin film systems is presented. Key topics and mechanisms are described including channeling criteria, crack interaction and elastic mismatch in the system.
With knowledge of the crack mechanisms, the fracture mechanical properties of the coating can be derived. A case of radial cracks spreading from a Rockwell indenter is used to describe how the theory can be used to determine fracture toughness and residual stresses in a thin film.

12:20 – 13:20 Lunch

Programme for Friday afternoon, March 15th, 2013

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

13:20 – 14:40 CHRISTIAN BERGGREEN (DTU Civil Engineering, 20 minutes)

Testing of Composite Structures and Components in DTU Structural Lab

Structural and component testing have the recent years seen an increasing activity at DTU, and especially within composites new test methodologies and facilities have emerged which have promoted the field, both within research activities, commercial services and teaching, centered around DTU Structural Lab (Center for Mechanical Testing of Structures and Materials). The presentation will highlight both recent new test cases and the structural and component testing facilities of the center available for all DCAMM members and universities.

EMIL BUREAU (DTU Mechanical Engineering, 15 minutes)

Experimental bifurcation analysis using control based continuation

Control based continuation is a newly developed method, that has made it possible to perform experimental bifurcation analysis, e.g. to track frequency responses directly in experiments. The method bypasses mathematical models, and systematically explores how e.g. vibration characteristics of dynamical systems (e.g. steady state amplitudes) changes under variation of parameters. The fundamental idea is to apply a control force to the system under investigation, and use a predictor-corrector type path-following algorithm to systematically trace out branches of the bifurcation diagram. The controller locally stabilizes the state requested by the prediction-step, making it possible to observe unstable dynamics and deal with multiple co-existing dynamical states. The control scheme is designed to be non-invasive, meaning that the steady state dynamics of the controlled and the uncontrolled system should be identical, except in terms of stability.

We present the ongoing work of developing and applying the control-based continuation method to an experimental mechanical test-rig, consisting of a periodically forced nonlinear impact oscillator controlled by electromagnetic actuators. Furthermore we present newest results in our efforts to measure stability of the tracked bifurcation branches, and present the design and development of a new test-rig, in which we aim to show how the method can be used in actively controlled rotating machinery.

PENG WANG ((M-TECH, AAU, 15 minutes)

Optimized experimental characterization of PVC foam using DIC test and the virtual fields

Cellular polymer closed cell foams are broadly used as core material in lightweight sandwich structures. Common polymer closed cell foams include PVC, PMI, PU or PET foams. Ideally, polymer foam core materials are considered as homogenous isotropic materials. However, in practice most polymer foams exhibit both heterogeneous and anisotropic material behaviour due to the density variations and directionality of foam cells developed during the manufacturing process [1]. This work presents an effective methodology to characterize all the constitutive (elastic) parameters of an orthotropic polymeric foam material (Divinycell H100) in one single test using Digital

Image Correlation (DIC) in combination with the Virtual Fields Method (VFM). A modified Arcan fixture is used to induce various loading conditions ranging from pure shear or axial loading in tension or compression to bidirectional loading. A numerical optimization study was performed with different loading angles of the Arcan test fixture and off-axis angles of the principal material axes. The objective is to identify the configuration that gives the minimum sensitivity to noise and missing data on the specimen edges, which are the two major issues when identifying the stiffness components from actual DIC measurements. Two optimized Arcan test configurations were chosen. The experimental results obtained for these two optimized test configurations show a significant improvement of the measurement accuracy compared with a pure shear load configuration. The larger sensitivity of the pure shear test to missing data as opposed to the tensile test is also evident from the experimental data and confirms the analysis from the optimization study. The recovery of missing data along the specimen edges is a promising way to further improve the identification results. Although the experimental results of the optimized test configuration indicate a significant improvement of the measurement accuracy, the bias still exists due to the influence of spatial resolutions or other possible errors during DIC tests. The only way to assess this issue rigorously is to simulate the DIC measurements. The further work here is to simulate a series of synthetic images representative of that generated from actual experiments. Then Digital Image Correlation and the Virtual Fields Method are implemented into a routine to process the synthetic images. By introducing several different error sources, such as a reduction of measurement area, noise and by varying some of the measurement parameters like subset sizes and shift, an optimized test configuration can be identified.

JACOB H. HØGH (DTU Civil Engineering, 15 minutes)

High precision strain and displacement control by FBS and DIC

Mechanical testing is commonly performed by deformation or force control where the feedback signal to the servo loop is acquired from a gauge in the actuator, cf. PID control. If testing a specimen in a compliant setup the response measured in the actuator does not correlate with the response of the specimen. In this case it is beneficial to control a test by a feedback signal acquired directly on the specimen instead. This paper documents static deformation and strain control by digital image correlation and fibre Bragg grating sensors in a single input-single output control loop [1].

The fibre Bragg grating (FBG) sensors used are sensors imbedded into optical fibres. These are capable of measuring strain by a change in the reflected light of the grating [2]. Digital image correlation (DIC) is a technique where displacements and strains are determined by digital images [3].

In order to prove the functionality the control loop a three point bending setup was used. The data flow in control loop is shown by a flow chart in fig. Here, the desired response of the specimen is defined and the actuator applies this, hereafter the FBG sensors or DIC cameras controls the correct response is obtained. If the error between the desired and the obtained response is above a certain error tolerance the controller sends a new signal to move the actuator again.

The difference between the desired and the actual strain was found where the control loop was disabled. This resulted in an error of 259µm/m when a strain of 2800µm/m was applied the specimen, corresponding to an error of 9.25%. However, using strain control, it was possible to control the strain within an error of 50µm/m, corresponding to 1.79% error. The difference between the command signal and DIC measurement, when no control was performed, was 0.126mm for a deformation of 5.87mm, corresponding to 2.15%. When using deformation control by DIC it was possible to control the test within an error tolerance of 0.01mm, which is 0.17% of the deformation applied. The strain and deformation control by FBG sensors and DIC thereby improved the accuracy of the response.

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SANITA ZIKE (DTU Wind Energy, 15 minutes)

Micro-Scale Experiments and Models for composite Materials: Application of Strain Gauges in Soft Material Testing.

Current research presents measurement error evaluation of commonly used strain measuring devices – strain gauges. The gauge factor of the strain gauge is used to relate the relative electrical resistance change of the strain gauge with the strain of the underlying test sample. In practice, the gauge factor is found by the strain gauge manufacturer and is obtained from a calibration on relatively stiff materials. When the same gauge factor is applied for soft material testing, inaccurate measurements are obtained. In the current study, both experimental and numerical results showed significant errors even for moderately soft materials such as e.g. glass-fibre composites. Errors were found to be caused by the strain reduction in the specimen and the strain distortions in the strain gauge due to the stiffness discrepancy between the test sample and the strain gauge material. Experimentally strain field modifications were captured introducing digital image correlation method. Moreover, the effect of the specimen stiffness and geometry on different types of the strain gauges is presented by numerical parameter study based on 2D and 3D finite element calculations.

15:00 Departure from the hotel