PROGRAMME, LIST OF PARTICIPANTS and
ABSTRACTS

DCAMM
17th Internal Symposium

Monday, March 11 -
Wednesday, March 13,
2019

HOTEL COMWELL
KELLERS PARK

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

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

Organization:
DCAMM

General Information:

The language of presentation is English.

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

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

All presenters are requested to send the electronic presentations to Mathias Stolpe (mast@dtu.dk) no later than 12.00 on Wednesday 6 March 2019, also the slides for poster session must be submitted. This is to avoid delays and technical problems between the presentations. All presentations will be available on a provided computer in the conference room. Acceptable formats are Microsoft PowerPoint files (.ppt), Adobe Portable Document files (.pdf) and multimedia files which can be viewed by Windows Media or QuickTime player.

Programme for Monday afternoon, March 11th, 2019

11:30 Arrival

12:00 - 13:00 Lunch

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

13:05 – 14:45 COMPOSITES
(Chairman: Lars P. Mikkelsen, DTU Wind Energy)

RENÉ SØRENSEN (Siemens Gamesa Renewable Energy, 20 minutes)
The tool and trades of blade design

ESBEN LINDGAARD (AAU MP, 20 minutes)
Recent progress of the CraCS research group on simulation of progressive fatigue-driven damage in 3D composite structures

SIMON PETER HALD SKOVGGÅRD (AU, Department of Engineering, 15 minutes)
Compressive failure of fibre-reinforced and layered composites initiated by the development of kink bands

MAREEN TIEDEMANN (DTU Wind Energy, 15 minutes)
Determination of bending, torsional and coupling stiffness for a composite circular tube with and without material bend-twist coupling – a comparative study

PAOLA BERTOLINI (DTU Wind Energy, 15 minutes)
On the Cauchy stress tensor in thin-walled tapered beam with rectangular cross section

ASHISH KUMAR BANGARU (DTU Wind Energy, 15 minutes)
Crack propagation characteristics in off-axis layers of glass fibre composites under cyclic loading

14:45 - 15:15 Coffee break

15:15 – 16:50 OPTIMIZATION
(Chairman: Fengwen Wang, DTU Mechanical Engineering)

ANTON EVGRAFOV (DTU Mechanical Engineering, 20 minutes)
Fractional elasticity and Eringen’s model are just a kernel apart

CETIN DILGEN (DTU Mechanical Engineering, 15 minutes)
Transient shape optimization of vibro-acoustic problems using CutFEM

SUMER DILGEN (DTU Electrical Engineering, 15 minutes)
Optimization of vibro-acoustic problems using a level set based CutFEM method

WENJUN GAO (DTU Mechanical Engineering, 15 minutes)
Maximizing the quality factor for high-stress micro membrane resonators

ASGER LIMKILDE (DTU Compute, 15 minutes)
Shape optimization of a nano-antenna using isogeometric analysis

CIAN CONLAN-SMITH (DTU Mechanical Engineering, 15 minutes)
Shape optimization of aircraft wings using panel methods

17:00 – 17:40 POSTER PRESENTATIONS
(Chairman: Mathias Stolpe, DTU Wind Energy)

17:45 – 19:00 POSTER SESSION

Posters (started PhD after 1 April 2018 (20))

1 MORTEN NØRGAARD ANDERSEN (DTU Mechanical Engineering)
Modelling and design of 3D periodic cellular microstructures

2 HAMIDREZA MAHDAVI (DTU Mechanical Engineering)
Micromechanical investigation of rolling contact fatigue

3 KINGA SOMLÓ (DTU Mechanical Engineering)
Micromechanics of 3D printed metals

4 GORE LUKAS BLUHM (DTU Mechanical Engineering)
Design optimization for resilient composite material microstructures

5 TIM BRIX NERENST (DTU Mechanical Engineering)
Virtual assessment of structural robustness

6 ERIK TRÄFF (DTU Mechanical Engineering)
Simple single-scale microstructures based on optimal rank-3 laminates

7 DAAN JONAS HOTTENTOT CEDERLØF (DTU Wind Energy)
Control of fatigue delamination growth (Part of H2020 project: DACOMAT)

8 FEDERICO BELLONI (DTU Wind Energy)
Advanced methods for monitoring wind turbine blades during full-scale testing

9 RUBÉN I. ERIVES ANCHONDO (DTU Wind Energy)
Structural damage prediction of wind turbine blades under fatigue loading

10 WOJCIECH J. LASKOWSKI (DTU Compute)
Designing efficient p-multigrid strategies for the Laplace equation – with application to a spectral element fully nonlinear potential flow model

11 STIG ERIKSEN (SDU ITI)
Autonomous ships from the perspective of operation and Maintenance

12 JONAS GAD KJELD (SDU ITI)
Methodology for determination of vibration damping of an offshore wind turbine supporting structure

13 KARSTEN KRAUTWALD VESTERHOLM (SDU ITI)
Robust identification of modal parameters of nonlinear and time variant systems

14 MIKKEL L. LARSEN (SDU ITI)
Novel high strength steel node for offshore wind turbine jacket foundations (HiJack)

15 GORAN JELICIC (SDU ITI)
System identification of aeroelastic parameter-variant systems using real-time output-only modal analysis

16 NIMAI D. BIBBO (SDU ITI)
Analytical fatigue life assessment of a full scale wind turbine test bench

17 JESPER BERNTSEN (SDU ITI)
Experimental fatigue life assessment of a full scale wind turbine test bench

18 GUILLEM GALL TRABAL (AAU MP)
Getting the crack back on the track: fatigue-driven damage in laminated composite structures

19 SIMON MOSBJERG JENSEN (AAU MP)
Fatigue-driven delamination in laminated composite structures considering real load spectra

20 FREDERIK FOLDAGER (AU Department of Engineering)
Modelling and simulation of soil-tool interaction using the discrete element method

19:00 – Dinner

Programme for Tuesday morning, March 12th, 2019

07:00 - 09:00 Breakfast

09.00 – 10:45 DYNAMICS
(Chairman: Anders Brandt, SDU ITI)

CHRISTIAN KROGH (AAU MP, 15 minutes)
The issue of the tissue: determining feasible robot draping sequences for woven prepreg plies

DAN KIELSHOLM THOMSEN (AU Department of Engineering, 15 minutes)
Increasing UR robot performance by suppressing mechanical vibrations

EMIL MADSEN (AU Department of Engineering, 15 minutes)
Joint dynamics and adaptive feedforward control of lightweight industrial robots

RANDI NØHR MØLLER (DTU Mechanical Engineering, 15 minutes)
Damping system for long-span suspension bridges

OLIVER TIERDAD FILSOOF (AU Department of Engineering, 15 minutes)
Modal dynamics and design analysis of multi-rotor wind turbines

DAVID HOFFMEYER (DTU Mechanical Engineering, 15 minutes)
Active warping control for damping of torsional beam vibrations

LASSE LEDET (AAU MP, 15 minutes)
Riding the wave of bi-orthogonality: an application to solve partial differential equations in linear dynamics

10:45 – 11:15 Coffee break

11:15 – 12:00 INVITED PRESENTATION
(Chairman: Niels Leergaard Pedersen, DTU Mechanical Engineering)

IVAR LUND (SDU ITI, 45 minutes)
Formation and transport of droplets and sprays – fundamentals and applications

12:00 – 13:00 Lunch

Programme for Tuesday afternoon, March 12th, 2019

13:00 - 14:00 FLUIDS
(Chairman: Morten Brøns, DTU Compute)

ANNE RYELUND NIELSEN (DTU Compute, 15 minutes)
Topology bifurcations of vortex pair interactions

TAO SUN (AAU Civil, 15 minutes)
Semi-active feedforward control of a floating OWC point absorber for optimal power-take-off

HAILIANG LIU (AU Department of Engineering, 15 minutes)
The role of hydro power, storage and transmission in the decarbonization of the Chinese power system

CHRISTIAN ELKJÆR HØEG (AU Department of Engineering, 15 minutes)
Efficient time-domain hydrodynamic modelling for floating offshore wind turbines using rational filter approximations

14:10 - 18:00 Social Event (BUS ER BESTILT
MED AFGANG kl 14:00)

19:00 - Banquet

Programme for Wednesday morning, March 13th, 2019

07:00 - 09:00 Breakfast

09:00 – 10:20 MATERIALS
(Chairman: Henrik Myhre Jensen, AU Department of Engineering)

KONSTANTINOS POULIOS (DTU Mechanical Engineering, 20 minutes)
A curious case of mechanical reduction of sliding friction

SIMON HEIDE-JØRGENSEN (AU Department of Engineering, 15 minutes)
Fracture toughness of rugger/stainless steel bonding using nana-thick adhesive

INGRID HOLTE (DTU Mechanical Engineering, 15 minutes)
Void size and shape effects in a gradient enhanced continuum model

RASMUS GRAU ANDERSEN (DTU Mechanical Engineering, 15 minutes)
Ductile crack initiation: Void-by-void versus multiple void interaction

YUE XIAO (DTU Mechanical Engineering, 15 minutes)
Size effects in porous metals under shear load

10:20 - 10:50 Coffee break

10:50 – 12:15 MATERIALS II AND OPTIMIZATION II
(Chairman: Esben Lindgaard, AAU MP)

CASPER S. ANDREASEN (DTU Mechanical Engineering, 20 minutes)
Topology optimization using CutFEM

CHRISTIAN FELTER & CHRISTIAN K. CHRISTIANSEN (DTU Diplom, 20 minutes)
3D-operations, scanning, and printing

HANSOTTO KRISTIANSEN (DTU MECHANICAL ENGINEERING, 15 minutes)
Topology optimization of structural problems with contact and friction.

SMAIL KOZARCANIN (AU Department of Engineering, 15 minutes)
End-of-century climate impacts on the cost-optimal decision of decentralized heating technologies in Europe

KASPER RINGGAARD (AU Department of Engineering, 15 minutes)
Optimization of material removal rate in milling of thin-walled pocket structures using penalty cost function

12:15 – 13:15 Lunch

Programme for Wednesday afternoon, March 13th, 2019

13:15 – 14:15 DYNAMICS II
(Chairman: Jon Juel Thomsen, DTU Mechanical Engineering)

PAULIUS BUCINSKAS (AU Department of Engineering, 15 minutes)
Efficient modelling of ground and structure borne vibration

JOHAN FREDERIK TOFTEKÆR (DTU Mechanical Engineering, 15 minutes)
Resonant piezoelectric shunt tuning based on the electric current and voltage response to white noise excitation

SILAS SVERRE CHRISTENSEN (SDU ITI, 15 minutes)
Automated operational modal analysis (AOMA) on an offshore research platform

ZHONGYI LI (AAU MP, 15 minutes)
A novel joint able to varying stiffness in multi-modes

15:00 Departure from the hotel

List of Participants

DTU Mechanical Engineering-FAM:
Alexandersen, Joe
Andersen, Morten Nørgaard*
Andersen, Rasmus Grau*
Andreasen, Casper S.
Bluhm, Gore Lukas*
Brix Nerenst, Tim*
Christiansen, Rasmus E.
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Dilgen, Cetin Bartug*
Evgrafov, Anton
Ferrari, Federico
Fogt, Gerda Helene
Gao, Wenjun*
Groen, Jeroen
Hoffmeyer, David*
Holte, Ingrid*
Høgsberg, Jan B.
Krenk, Steen
Kristiansen, Hansotto*
Mahdavi, Hamidreza*
Møller, Randi Nøhr*
Nielsen, Kim Lau –
Niordson, Christian
Pedersen, Niels L.
Pedersen, Pauli
Poulios, Konstantinos
Sigmund, Ole
Somló, Kinga*
Thomsen, Jon Juel
Toftekær, Johan Frederik*
Träff, Erik
Tvergaard, Viggo
Wang, Fengwen
Wang, Yiqiang
Xiao, Yue*
Aage, Niels

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Limkilde, Asger*
Nielsen, Anne Ryelund*
Sørensen, Mads Peter

DTU Diplom
Felter, Christian Felter

DTU Electrical Engineering
Dilgen, Sümer Bartug*

DTU Wind Energy
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Bangaru, Ashish Kumar*
Belloni, Federico*
Bertolini, Paola*
Cederløf, Daan Jonas Hottentot*
Erives Anchondo, Ruben Isaac*
Haselbach, Philipp
Mikkelsen, Lars Pilgaard
Stolpe, Mathias
Tidemann, Mareen*

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Krogh, Christian*
Ledet, Lasse*
Li, Zhongyi*
Lindgaard, Esben
Lund, Erik
Mosbjerg Jensen, Simon*
Olhoff, Niels

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Sun, Tao*

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Andersen, Lars Vabbersgaard
Balling, Ole
Bräuner, Lars
Bucinskas, Paulius*
Dias, Marcello
Filsoof, Oliver Tierdad*
Foldager, Frederik*
Heide-Jørgensen, Simon*
Høeg, Christian Elkjær*
Jensen, Henrik Myhre
Kozarcanin, Smail*
Liu, Hailiang*
Madsen, Emil*
Pedersen, Mikkel Melters
Ringgaard, Kasper*
Skovsgaard, Simon*
Thomsen, Dan Kielsholm*
Vester-Petersen, Joakim
Zhang, Zili

ITI
University of Southern Denmark
Berntsen, Jesper*
Bibbo, Nimai*
Brandt, Anders
Christensen, Silas Sverre*
Eriksen, Stig*
Jelicic, Goran*
Kjeld, Jonas Gad*
Larsen, Mikkel*
Lund, Ivar
Shakibfar, Saeed
Vesterholm, Karsten Krautwald*
Wiggers, Sine L.

§8-members:
Buhl, Thomas
Christiansen, Christian Kim
Jørgensen, Jens Grandjean
Sørensen, René
Sørensen, Søren Nørgaard

	Ph.d.	andre
FAM	16	20
DTU Compute	3	2
DTU Diplom		1
DTU Elec. Eng.	1	0
DTU Wind	6	4
MP, AAU	5	4
CIVIL, AAU	1	1
ENG, Aarhus	11	9
ITI, SDU	8	4
§8-members		5
	51	50
I alt		101

* Ph.D.-student

Programme for Monday afternoon, March 11th, 2019

1 – COMPOSITES
(Chairman: Lars P. Mikkelsen, DTU Wind Energy)

13:05 – 14:45 RENÉ SØRENSEN (Siemens Gamesa Renewable Energy, 20 minutes)

The tool and trades of blade design

Wind turbine blades contain many different materials distributed across thousands of plies throughout the span of the blade. This level of complexity requires state-of-the-art software to keep track of each individual ply. Here at Siemens Gamesa Renewable Energy, we have developed an in-house code to keep track of the material placement, the Blade Structural Design Tool. It is built on the philosophy of single input, multiple outputs, meaning that the inputs are well defined, and can be used for various forms of outputs. These outputs can range from structural models used to validate the integrity of the blade, to documentation for manufacturing and certification, and optimization of the blade both with respect to material and geometry. In this presentation, we will give a short introduction of the tool and its capabilities.

ESBEN LINDGAARD (AAU MP, 20 minutes)

Recent progress of the CraCS research group on simulation of progressive fatigue-driven damage in 3D composite structures

This presentation will introduce the newly formed research group CraCS (Cracs in Composite Structures) at AAU and outline a new integral formulation for the analysis of delamination growth in layered composite structures, which the CraCS group developed in joint collaboration with the AMADE group from the University of Girona, Spain. A new computational method for simulating fatigue-driven delamination applicable to large and arbitrarily shaped fracture process zones is presented. The model uses an envelope load approach and avoids making use of any fitting parameters in the link between the damage rate and the crack growth rate. Thus, all the model input parameters are determined experimentally from coupon tests. Any variant of the Paris' law relying on the mode-decomposed energy release rates can be used to describe the crack growth rate. To compute the mode-decomposed energy release rates, the model incorporates a new formulation for evaluating the J-integral. The concept of the growth driving direction is introduced to render the integration paths across the cohesive zone and to decompose the J-integral into mode I, II, and III. The proposed method leads to accurate prediction of delamination propagation under mixed-mode and non-self-similar growth conditions. Finally, the model is validated against a new experimental benchmark case with varying crack growth rate and shape of the fracture process zone. The test configuration is based on wide double cantilever beam specimen with two reinforcements bonded on both faces of the specimen in order to promote a curved delamination that changes shape and crack growth rate during propagation. The delamination front is monitored with X-ray radiography, and the obtained results are compared to the numerical predictions producing excellent agreement.

SIMON PETER HALD SKOVGGÅRD (AU, Department of Engineering, 15 minutes)

Compressive failure of fibre-reinforced and layered composites initiated by the development of kink bands

Fibre-reinforced composites e.g. carbon- or glass fibre-reinforced polymers have excellent properties in tension in the direction of the fibres. Fibre-reinforced polymers are used in applications where a high specific stiffness and strength are required i.e. high stiffness and low mass. These excellent properties in tension comes with a price, that they can become unstable in compression. The strength in compression is often 50-60% of the strength in tension. There exists several different compressive failure mechanisms when regarding fibre composites. The phenomenon known as kink band formation or fibre kinking is one of the frequently observed failures and especially in fibre composites with a tough and ductile resin material. In laminates composed of several unidirectional plies, the kink band failure will initiate in the ply with fibres oriented in the direction of loading. Since the compressive failure initiates in the 0° ply, it makes it possible to study kink band formation using two-dimensional simulations. Fibre kinking includes non-linear material behaviour in the form of plasticity and undergoes large deformations and rotations.

The present work includes investigations of the kink band phenomenon using three substantially different methods, including a finite element, semi-analytical and an analytical model. The parameters influencing the initiation are investigated. Furthermore, the post-bifurcation behaviour is studied, including the propagating instability known as kink band broadening. The results are based on numerical and theoretical work, and are compared with experiments conducted by others.

Supervisor: Henrik Myhre Jensen

MAREEN TIEDEMANN (DTU Wind Energy, 15 minutes)

Determination of bending, torsional and coupling stiffness for a composite circular tube with and without material bend-twist coupling – a comparative study

A comparative study is performed to investigate different numerical tools used to determine cross-sectional bending, torsional and coupling stiffness of composite circular tubes with and without bend-twist coupling. Two specimens are used in this study and they are one bend-twist coupled beam and one non-bend-twist coupled beam. Their cross sections are shown in Figure 1.

The cross-sectional bending stiffness, torsional stiffness and bend-torsion coupling stiffness can be determined based the Euler-Bernoulli formulation, the Timoshenko formulation, 2D cross-sectional analysis tools or with high fidelity 3D finite element (FE) models. Experimentally these stiffnesses can be determined through measurements of displacements, twists and strains.

The methods to determine these stiffnesses are presented in this work. Firstly, the stiffnesses are computed with engineering equations, and then the cross-sectional stiffness matrix is derived based on a 2D FE model with a beam cross-sectional analysis tool and lastly a 3D FE model in a commercial software.

In the 3D FE model, a prismatic, slender cantilever composite beam with a tubular cross-section is analyzed when it is loaded with shear force, pure bending and torque at the free end. Subsequently the cross-sectional stiffnesses are derived from twist, displacement and strains. The results for

both the coupled and non-coupled composite beams are compared and their deviations discussed.
It is expected that different methods will show very little deviation for the non-coupled beam. However, for the coupled beam the engineering approach is expected to perform worst among all examined methods, whereas the 3D FE model and 2D FE model are expected to match with very little deviation from each other.

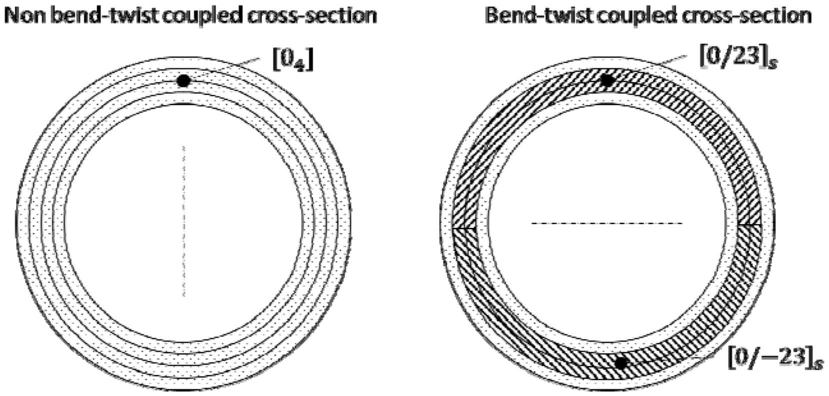

Figure 1: specimen cross-sections

In the scope of the PhD study this work shall establish a basis for determining torsional stiffness, coupling stiffness and bending stiffness of the non-bend-twist coupled and the coupled composite beams, starting with a simple structure.

Supervisor: Xiao Chen & Kim Branner

PAOLA BERTOLINI (DTU Wind Energy, 15 minutes)

On the Cauchy stress tensor in thin-walled tapered beam with rectangular cross section

Nowadays, engineers are challenged with bigger and lighter structures, such as bridges, aircraft, wind turbine blades and many other applications in mechanical and civil engineering. To increase the stiffness-to-mass ratio of beam type structures, composite materials together with lengthwise geometrical variations, e.g. curvature of the cross-section dimensions along the beam axis, twist and taper of the cross section, have been widely applied. *Taper* is defined as a variation of the cross-section dimensions along the beam axis according to the governing internal force distribution [1]. It has been well known since the last century that taper affects the global behaviour of a beam. Nevertheless, modern beam analysis neglects these effects leading to under- or overestimation of the stresses in the cross section.
A recent study [1] developed a method to derive the full Cauchy stress field of a vertically tapered thin-walled isotropic straight beam with rectangular and circular cross section. An extension of the above-mentioned method to a thin-walled isotropic straight beam with rectangular cross section where both the webs and flanges are tapered, as the one illustrated in Fi 1, is presented. The stress tensor shows components, such as the in-plane shear stress. The latter could drastically differ from the one expected in classical prismatic theory [2]
A comparison with finite element models validates the presented method. Furthermore, thanks to the analytical approach, a parametric study is carried out to highlight the relation between the stress variation and the taper.

The methodology could be directly extended to other symmetric thin-walled cross sections. Extra manipulations are instead required if asymmetric cross sections or anisotropic material are considered

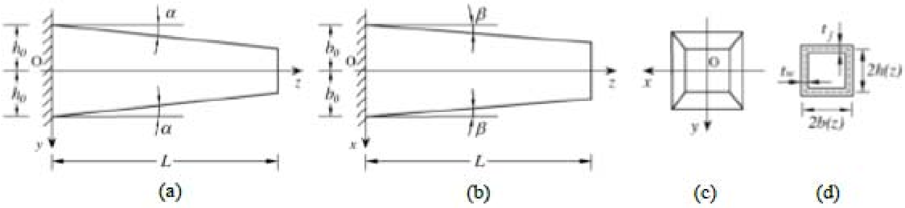

Figure 1: (a) Side, (b) top, (c) front view and (d) arbitrary cross section of a thin-walled tapered cantilever box beam of length L. Vertical α and horizontal β tapers are highlighted. Figure: courtesy of [3]

References

[1] P. Bertolini, M.A. Eder, L. Taglialegne and P.S. Valvo "Stresses in constant tapered beams with thin-walled rectangular and circular cross sections", Thin-Walled Structures, Vol. 119, 2019 (forthcoming).
[2] S. Timoshenko, J.N. Goodier, Theory of Elasticity, McGraw-Hill book Company, New York, 1951.
[3] P. Bertolini and L. Taglialegne "Analytical stress solutions for tapered thin-walled isotropic beams with rectangular cross sections", 2019 (submitted).

Supervisor: Mathias Stolpe

ASHISH KUMAR BANGARU (DTU Wind Energy, 15 minutes)
Crack propagation characteristics in off-axis layers of glass fibre composites under cyclic loading
The growth of mixed mode steady-state crack is analysed in the off-axis layers of glass fibre reinforced composite laminate with the lay-up [0/60/0/-60]s. With white light imaging and a crack counting algorithm, off-cracks are monitored in the thin and thick layers of the laminate. Detailed experimental observations are made with ex-situ X-ray computed tomography to understand the features of crack front. In this study, rectangular shaped specimens are subjected to tension-tension cyclic loading to take the advantage of edge effects for the initiation of cracks. It is observed that the cracks in the thick layer propagated much faster than the cracks in the thin layer. Two distinct damage modes - matrix cracking, fibre/matrix debonding tend to occur and interact with one another causing the advancement of crack.
Supervisor: Bent F. Sørensen

14:45 - 15:15 Coffee break

2 – OPTIMIZATION
(Chairman: Fengwen Wang, DTU Mechanical Engineering)

15:15 – 16:50 ANTON EVGRAFOV (DTU Mechanical Engineering, 20 minutes)
Fractional elasticity and Eringen's model are just a kernel apart
Nonlocal elasticity theories have a long history in continuum mechanics. Their common objective is to take into account long-range internal interaction forces between particles, which nowadays becomes even more important owing to the continuing miniaturization of mechanical devices. These theories aim to alleviate a variety of singularity problems that arise in classical, local models, such as for example stress singularities in the vicinity

of cracks. The beginning of non-local theory of elasticity goes back to the pioneering work of Kröner [1].
Arguably the most popular theory of non-local elasticity is due to Eringen [2]. This model has been utilized in a variety of mechanical applications, and it has recently attracted revitalized interest owing to its applicability to the modelling of nanobeams and nanobars [3]. In spite of such an interest in this model from the point of view of applications, even the most basic mathematical questions such as the existence and uniqueness of solutions have been rarely considered in the research literature for this model [4]. We will discuss precisely these questions, illustrating that the model is in general ill-posed in the case of smooth integral kernels, the case which appears rather often in numerical studies. We also consider the case of singular, non-smooth kernels and for the paradigmatic case of Riesz potential we establish the well-posedness of the model in fractional Sobolev spaces. For such a kernel, in dimension one the model reduces to the well-known fractional Laplacian (see for example the survey of applications [5] and the references therein), thereby providing a natural link between Eringen's integral model and fractional partial differential equations in the context of linear elasticity. Our development requires new ideas and tools, such as for instance a non-local version of Korn's inequality.
Time permitting, we will also discuss a surprisingly non-trivial question of possible extensions of Eringen's model with Riesz kernel to spatially heterogeneous material distributions, which is fuelled by our research interests in topology optimization.

[1] Kröner, E. Elasticity theory of materials with long range cohesive forces. Int J Solids Struct 1967; 3(5): 731–742.
[2] Eringen, AC. Nonlocal continuum field theories. New York: Springer Science & Business Media, 2002.
[3] Romano, G, Barretta, R, Diaco, M. On nonlocal integral models for elastic nano-beams. Int J Mech Sci 2017; 131: 490–499.
[4] Altan, S. Existence in nonlocal elasticity. Arch Mech 1989; 41(1): 25–36.
[5] Vázquez, JL. Recent progress in the theory of nonlinear diffusion with fractional Laplacian operators. Discrete Contin Dyn Syst Ser S 2014; 7(4): 857–885.

CETIN DILGEN (DTU Mechanical Engineering, 15 minutes)

Transient shape optimization of vibro-acoustic problems using CutFEM

Interaction between structural vibrations and acoustic pressure is vital for the performance of small acoustic devices such as hearing aids and smartphones. Accurate modelling of the coupled physical problem therefore holds great importance for the optimization of such devices. Current state-of-the-art usually involves a time-harmonic problem formulation. However, this approach can be very time consuming considering that a broad frequency content is of interest for most practical engineering applications. A time-dependent formulation, which also allows the possibility to investigate transient phenomena, is a promising alternative to partially remedy this limitation. Therefore, in this work we utilize a time-dependent formulation of the coupled vibro-acoustic problem. Moreover, using standard topology optimization can be problematic since the interaction takes place at the interface between solid and fluid. This is why we choose to work with an explicit boundary representation and subsequently shape optimization. Present work applies shape optimization with a level set approach where the zero level describes the geometry and hence the interface between solid and

acoustic regions. In order to utilize gradient based optimizers, the level set function is parametrized on a fixed mesh and its nodal points are used as design variables. The geometry described by the zero level set is captured and modelled using an immersed boundary method CutFEM which operates on fixed and unfitted meshes. Employing CutFEM approach in level set based shape optimization also allows to facilitate an efficient computational framework for large scale optimization problems. Advantages of transient optimization is demonstrated in problems including acoustic signal shaping and the minimization of acoustic pressure over a broad spectrum of frequencies in a certain objective domain.
Supervisor: Niels Aage

SUMER DILGEN (DTU Electrical Engineering, 15 minutes)
Optimization of vibro-acoustic problems using a level set based CutFEM method
Design of acoustic devices such as hearing aids and micro-loudspeakers are challenging engineering problems where intuitive solutions are non-trivial to achieve. This is mainly due to the complex mechanism of strong coupling between the acoustic pressure and mechanical vibrations. Also, operating with high pressure levels makes these devices exhibit a high degree of sensitivity to small geometric variations. This means that numerical methods must provide an accurate modeling of the multi-physical problem to capture the localized effects due to small geometric features. Hence, the modeling accuracy is paramount if the device performance is to be optimized. In this work we employ a time harmonic formulation of the coupled vibroacoustic problem. The modeling approach utilizes the immersed boundary method CutFEM in conjunction with a level-set representation of the geometry. The design configuration, hence the interface between solid and acoustic regions is provided from the zero-level contour. The Cut-FEM method utilizes a fixed background mesh and an advanced integration scheme to realize complex geometries and accurate physical solutions to the governing problem. In order to make use of gradient based optimization tools, the design parameterization is obtained with directly linking the nodal level set description to the mathematical design variables. The developed framework for the optimization of strongly-coupled acoustic mechanical interaction problems is first demonstrated by the benchmark design problem of determining an optimized elastic structure which acts as a partitioner in an acoustic channel to minimize the sound pressure towards the outlet section. Moreover, the design of a wave splitter is studied where the acoustic waves emitted by a vibrating mechanical structure are tailored to have a prescribed directivity dependent on the frequency of excitation. Finally, an application oriented optimization case is considered to improve the performance of a simplified 2D model of a hearing instrument by optimizing the shape of the suspension structure around the internal channel to damp the structural vibrations caused by the incoming acoustic signal from the receiver.
Supervisor: Jakob Søndergaard Jensen

WENJUN GAO (DTU Mechanical Engineering, 15 minutes)
Maximizing the quality factor for high-stress micro membrane resonators
Optomechanical systems have generated enormous interest because related researches that have pushed several frontiers of contemporary physics forward, such as frequency tunable receivers (Chen et al. 2013) and ultrasensitive mass detectors (Olcum et al. 2015). Among these systems,

mesoscopic mechanical resonators with ultrahigh quality factors play an important role in coupling light to mechanical motion. However, experiments involving this field so far are restricted by the need for cryogenic precooling (Teufel et al. 2011). One possible way to overcome cryogenic temperature and make realistic quantum experiments feasible at room temperature (293 K) is to enhance the mechanical frequency-quality factor Qf to a regime where Qf > k_B T_room/h ≈ 6.2×1012 Hz (h is Planck constant, and k_B is the Boltzmann constant) (Marquardt et al. 2007).
In this study, quality factors (Q) of high-stress membrane resonators are enhanced in novel designs created by topology optimization. The optimization targets the fundamental mode which is more easily identified in physical experiments compared to high-order modes embedded in a dense eigenfrequency range. Due to the improvement of Q, the mechanical frequency-quality factor (Qf) in the fundamental mode exceeds the ground state cooling limit (around 6×1012 Hz for Qf) and reaches 1013 Hz in numerical experiments. Gradient-based topology optimization is formulated, as well as the corresponding sensitivity analysis. Numerical problems caused by high prestress are addressed by special techniques to get convergent and black-and-white results. Both intrinsic and extrinsic damping are sufficiently considered in the optimization process. With different combinations of the two damping sources, topology optimization yields distinct designs. It reveals that damping mechanisms significantly affect optimal geometry of resonators.

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Supervisor: Ole Sigmund

ASGER LIMKILDE (DTU Compute, 15 minutes)
Shape optimization of a nano-antenna using isogeometric analysis
Shape Optimization with Isogeometric Analysis (IGA) has gained popularity in recent years, due to the prospect of seamless integration of such optimization strategies into already existing CAD software. In IGA the same basis functions, in this case B-splines from CAD technology, is used to represent the geometry as well as to discretize the governing equations, which justifies the name Isogeometric Analysis.
In this work we will use IGA for the shape optimization of a metallic nano-antenna. The goal is to concentrate electrical energy in a small target region, by optimization of the shape of the metallic antenna, parametrized using splines. This spline parametrization is given by a set of control points which will act as design variables.
One of the challenges when using IGA for shape optimization, is to go from the design variables, i.e. a spline representation of the boundary of the domain, to a parametrization of the interior, which will be (part of) the computational domain on which to perform the (isogeometric) analysis. We

will present some preliminary results from the optimization of the nano-antenna, with a focus on the choice of parametrization strategy. The method is implemented using the IGA library G+Smo and the optimization library Ipopt.
Supervisors: Jens Gravesen & Anton Evgrafov

CIAN CONLAN-SMITH (DTU Mechanical Engineering, 15 minutes)
Shape optimization of aircraft wings using panel methods
Panel methods were first developed in the 1960's and 70's within the aviation industry and have become a powerful tool for evaluating preliminary aircraft designs. Derived using a boundary integral method, panel methods only require a surface mesh of the geometry leading to less computational times in comparison to CFD methods which require a volume mesh of the entire fluid domain. These fast turnaround times make panel methods perfect for design optimization where it is required to solve the physics problem on each design iteration. To date, there has been little precedent in the literature to document the main considerations and challenges in applying panel methods to shape optimization problems. In this presentation we will discuss these considerations with respect to boundary conditions and parameterization of the wing geometry.
Typically two boundary conditions are enforced – the Kutta condition, and impermeability, where a Neumann or Dirichlet boundary condition (BC) can be used to satisfy the latter. The Neumann BC is appealing as it is the more intuitive of the two, however it will be shown that there are substantial time savings in solving the Dirichlet BC especially when applied to optimization routines.
Design optimization generally requires large changes in the geometry and as such a versatile parameterization method is required. Geometry is defined using local variables at a finite number of airfoil sections, rather than standard global definitions, such as taper ratio. Variables are filtered along the span in order to avoid numerical artefacts, such as clustering/isolation of design points and saw-tooth geometries.
Panel methods are based on potential flow theory where flow is assumed to be inviscid. Thus viscous and friction drag is neglected, however the wake model allows the user to calculate induced drag. Our 3D panel method utilizes a constant source-doublet surface distribution, solves the Prandtl-Glauert equation to account for compressible effects, and calculates sensitivities using an adjoint method. Optimization problems will be presented with an objective to minimize induced drag subject to lift and geometry constraints.
Supervisor: Casper Schousboe Andreasen

17:00 – 17:40 POSTER PRESENTATIONS
(Chairman: Mathias Stolpe, DTU Wind Energy)

17:45 – 19:00 POSTER SESSION

MORTEN NØRGAARD ANDERSEN (DTU Mechanical Engineering)

Modelling and design of 3D periodic cellular microstructures

The design of strong and lightweight materials is of great interest to many industries, especially the automotive and aerospace industries, who are highly interested in reducing fuel consumption through design optimization. Advances in additive manufacturing has facilitated the production of novel low-density periodic cellular materials with high stiffness and low weight [1]. However, as the thicknesses of plate walls and the cross sectional areas of trusses in microstructures decrease, the risk of buckling failure increases. State of the art microstructures optimized against buckling are still orders of magnitude away from their theoretical limit [2]. Recently, 2D microstructures have been optimized to enhance buckling strength using topology optimization methods[4]. The buckling strength of the optimized microstructures has been increased several times with little decrease in stiffness. However 3D microstructures with enhanced buckling strength are still missing due to high computational cost. The purpose of this work is to provide insight for 3D buckling strength optimization by analyzing the strength-stiffness property space of open-walled and closed-walled microstructures. As in [4], the microstructural buckling strength is predicted by utilizing homogenization theory and a linearized stability criterion, where both local buckling with short wavelength and global buckling with long wavelength are taken into account, using Floquet-bloch theory [3]. In this work, the analysis is implemented in the Portable and Extendable Toolkit for Scientific Computing (PETSc) framework, using a structured grid, which utilizes high performance computing and effective iterative solvers and thereby allows for a high-resolution mesh [5]. The studied microstructures are periodic cellular materials based on simple-cubic (SC), face-centered-cubic (FCC), body-centered-cubic (BCC) and a composition of these. The microstructures are subjected to a macroscopic hydrostatic stress. For each microstructure, the buckling strength is predicted from the buckling band diagram with the lowest critical stress in the full k-space determining the critical strength. The buckling strengths of the microstructures are compared to their bulk modulus, and the corresponding failure modes are further compared to analytical solutions. These comparisons lead to a method to quickly estimate microstructural buckling strength. Moreover, the influence of volume fractions on the buckling strength is investigated.

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Supervisor: Ole Sigmund

HAMIDREZA MAHDAVI (DTU Mechanical Engineering)

Micromechanical investigation of rolling contact fatigue

When two bodies in motion are in contact and their relative velocity at the contact point is close to zero, the two bodies are said to be in rolling contact [1]. Wind turbine bearings are one of the most relevant engineering elements that experience rolling contact loading during their operational life. In well-lubricated bearings, failure occurs due to sub-surface initiated spalling in which fatigue cracks initiate at non-metallic inclusions [2]. Accelerated spalling in the form of extensive White Etching Cracks (WECs) is a widespread failure mode in which bearings often fail at a fraction of their estimated lifetime, and preventing this mode of failure in bearings is of great interest. Final goal of this work is to better understand the failure mechanisms and thereby enable the development of new materials that are economically attractive, compared to expensive material systems, which do not exhibit WEC-failures.

For supporting the development of new materials, which are resistant against WECs, a two-scale numerical study will be conducted. First, macroscopic stress histories are determined by Hertzian contact theory at different depths below the surface of a typical roller element. These stress distributions are then used as far-field stresses for a micro-scale model. Different constitutive material models are used to quantify cyclic plasticity at the microscale. The effects of residual stresses and inclusion size, shape, and distribution on the fatigue life will be analyzed, and an optimal compressive residual stress distribution is determined. The effects of transient loads will also be investigated on the fatigue life and the extent of WECs. Finally, crack propagation modeling is performed to predict the fatigue crack growth around WECs.

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Supervisor: Christian Niordson

KINGA SOMLÓ (DTU Mechanical Engineering)

Micromechanics of 3D printed metals

Additive manufacturing is an emerging, highly attractive technology in both research and industry sector. This state-of-the-art process can compete with traditional manufacturing, in light-weight porous structures and in prototyping (one-of-a-kind production). On the other hand metal 3D printing is a complex, and not completely explored manufacturing alternative. The present PhD project aims specically to explore the interplay between the printed material microstructure and mechanical strength. Finally the ultimate goal is to integrate the obtained results in terms of strength properties, into a high-level

simulation environment. In order to support the design phase towards predictable mechanical properties, thus a stronger, more reliable 3D printed component will become feasible. The additive manufacturing process creates a unique material microstructure (grain size, shape, orientation and defects) and there are many factors which can affect both the formed microstructure and material strength. The final goal is to determine failure criteria for 3D printed metals, taking into account anisotropy, porosity and material/process length-scales. The PhD project contains two main areas, the experimental material testing, which is expected to verify the numerical poly-crystal simulations.
The experimental part entails tensile tests, fatigue crack growth tests and also experiments on component level. For tensile testing, dog-bone specimens have been printed in different lay-outs. The objectives of the different lay-outs are to explore anisotropy, effect of size, surface-finish and heat treatment. The component level testing is still to be designed, although a porous lattice structure seems to be a desirable option. Concerning the micromechanical simulations, multi-phase representative volume elements (RVEs) are going to be applied with a spectral crystal plasticity solver. One of the main advantages of the spectral method is the much lower memory requirement, and computation time, therefore higher resolution can be achieved.
Supervisor: Christian Niordson

GORE LUKAS BLUHM (DTU Mechanical Engineering)
Design optimization for resilient composite material microstructures
Imagine the benefit of a structural material that deals with overloads non-catastrophically. On one side, such a material will in many cases eliminate over-dimensioning as a means for dealing with occasional overloads and will thereby result in more lightweight components. Secondly, avoidance of catastrophic failures during the lifetime of a product will extend its life cycle and thereby minimize waste.
The aim of this project is to demonstrate this possibility by utilizing topology optimization to design composite material microstructures that combine an initially stiff with an ultimately resilient behavior. It will address the question of what constituents and which microstructure a manufacturable composite material should have to achieve the desired resilient behavior.
The two extremes of the material behavior intended, namely a stiff response at small deformations and an ultimately compliant but very resilient behavior, dictate the choice of constituents with corresponding characteristics. However, a sharp transition between the two regimes is only possible through a significant change in the microstructure across the transition point. At small deformations, the stiffer constituent has to govern the global response, while beyond the transition point the applied deformation has to be accommodated almost exclusively by the more compliant constituent. As a possible solution for triggering the transition between the two regimes the exploitation of local mechanical instabilities, such as micro-buckling, are explored.
Currently a study of the buckling behavior of various two-dimensional microstructures of different shape is performed, addressing both the resistance against the most critical buckling modes, but also the mechanical properties of the structure in the post-buckling regime. The analysis includes geometrical and material nonlinearities based on hyperelastic constitutive behavior and the results are compared to results from the literature based on linear models.

Through this the implementation will be validated before using it for the investigation of the requested more complex resilient microstructures and beside this, it will help to gain insight in the buckling phenomena.
Supervisor: Ole Sigmund

TIM BRIX NERENST (DTU Mechanical Engineering)
Virtual assessment of structural robustness
Over the last decades, simulation techniques such as finite element analysis (FEA) have substantially contributed to reducing the time and cost of developing new mechanical products. However, FEA is primarily carried out on nominal geometry, i.e. not taking into account the geometrical and material variation from production and use. This can result in overly conservative designs leading to unnecessary cost, or overly optimistic designs leading to unpredicted product failures, typically occurring during production ramp-up or after product launch. The objectives of this project are to make it simpler, faster and more accessible to assess the performance and robustness of a mechanical design within the full sample space, taking the relevant variation of the components and their parameters into account. Literature review and interviews will create the foundation to understand and map the academic and industry barriers for not utilizing robust design theory and FEA in stronger combination, which will include an attempt to quantify today's losses, e.g. lead-time, material waste, safety, etc. Based on gathered knowledge, the aim is to develop tools & methods to decompose mechanical systems and types of variance into manageable simulations. The goal is to link robust design theory, statistical methods, and FE analysis into a combined engineering instrument. The expected outcome will be trailed and tested tools & methods enabling designers and engineers to use FEA-based variance simulation in early stages of product development; minimizing waste and increasing prod-performance & safety.
Supervisor: Kim Lau Nielsen

ERIK TRÄFF (DTU Mechanical Engineering)
Simple single-scale microstructures based on optimal rank-3 laminates
With the goal of identifying optimal elastic single-scale microstructures for multiple loading situations, it can be shown that qualified starting guesses, based on knowledge of optimal rank-3 laminates, significantly improves chances of convergence to near optimal designs. Rank-3 laminates, optimal for a given set of anisotropic loading conditions, are approximated on a single scale using a simple mapping approach. We demonstrate that these mapped microstructures perform relatively close to theoretical energy bounds. Microstructures with a performance even closer to the bounds can be obtained by using the approximated rank-3 structures in a further step as starting guesses for inverse homogenization problems. Due to the nonconvex nature of inverse homogenization problems, the starting guesses based on rank-3 laminates outperform classical starting guesses with homogeneous or random material distributions. Furthermore, the obtained single-scale microstructures are relatively simple, which enhances manufacturability. Results, obtained for a wide range of loading cases, indicate that microstructures with performance within 5–8% of the theoretical optima can be guarantied, as long as feature sizes are not limited by minimium size constraints.
Supervisor: Ole Sigmund

DAAN JONAS HOTTENTOT CEDERLØF (DTU Wind Energy)

Control of fatigue delamination growth (Part of H2020 project: DACOMAT)

Initial imperfections are present in composite structures as soon as the product leaves the production floor. In the case of glass fibre wind turbine blades, this is for example in the form of large voids. These may in turn lead to delaminations, which grow throughout service life of the product. The EU project DACOMAT aims to accept these imperfections and to focus on developing composite materials which tolerate them.

The aim of the proposed phd study is to investigate and control delamination propagation in composite structures. Specically, fatigue delamination will be considered as this is one of the critical failure drivers of composite structures [1]. Previous experimental [2] and numerical [3] studies found that interface strength is a key parameter for inducing multiple cracks (see g. 1) and that each new crack may increase fracture resistance. Ongoing tests show that lamina interface properties may be influenced by plasma treating the glass fibres prior to infusion. It is hypothesized that such surface treatment may be used to control the formation of multiple cracks in a delamination sensitive region, such as a ply-drop. Experimental tests are planned to test this hypothesis and serve as a basis for validating a numerical model.

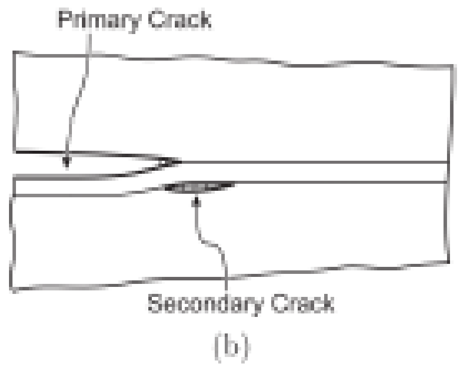

Figure 1: Multiple crack surfaces in a generic composite. Obtained from: [3]

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Supervisor: Bent F. Sørensen

FEDERICO BELLONI (DTU Wind Energy)

Advanced methods for monitoring wind turbine blades during full-scale testing

Full-scale blade testing is a crucial phase of the development of a wind turbine blade before its commercialization, being its main purpose to verify ultimate and fatigue strength of a composite structure which is expected to undergo highly dynamic loads for a lifespan of 20-25 years. Wind turbine manufactures rely on testing as the most accurate way to validate the numerical simulation tools used for blade design and to verify that reliability requirements are fulfilled according to the standards. Condition monitoring and non-destructive techniques are used to verify global and local structural response during every phase of testing. However, with the state-of-the-art rotor blades becoming more and more slender and presenting more complicated structural features, advanced methods need to be developed and implemented to monitor the global blade response and the local damage evolution which cannot be detected with standard measurement techniques.

Advanced methods that can be adopted for this purpose are Digital Image Correlation, fibre optic sensors and Infrared thermography. Aero-elastic and high-fidelity finite element models will be used to optimize test setups and will be validated against different multi-axial testing configurations. The experiments will be carried out on small-scale blades, which will be manufactured intact and with embedded artificial defects.

The present work aims at developing an experimental framework which, in combination with numerical models, is expected to increase blade design validation capabilities and to enhance understanding of global and local structural response during full-scale testing of the state-of-the-art rotor blades.

Based on the collaboration between BLAEST and DTU Wind Energy, the project will allow the implementation of advanced monitoring methods in an industrial environment.

Supervisor: Kim Branner

RUBÉN I. ERIVES ANCHONDO (DTU Wind Energy)

Structural damage prediction of wind turbine blades under fatigue loading

Wind energy offers a sustainable option to supply energy while, at the same time, drastically reducing CO2 emissions. One way to reduce the operational expenses of the energy systems is the improvement of the lifetime predictability and fatigue performance of the wind turbine blades. In order to improve these aspects, it is important to address the lack of knowledge regarding the development of fatigue damage mechanisms in wind turbine blades under operational conditions, and the effect these damages have on the structural behaviour of the blade’s components.

The PhD project aims at investigating and developing methodologies to model a relevant damage mechanism on wind turbine blades at different length scales i.e. material level, sub-component, and full-scale. The methodology is to first identify a relevant damage mechanism observed on wind turbine blades under fatigue loading. Correlations between the fatigue evolution and the consequent degradation of the material/structural properties is to be carried out. Furthermore, it is aimed to develop modelling techniques to predict the initiation and evolution of the selected damage mechanism, its effect on the structural response of the blade, and to validate against experimental data at different length scales.

The results of the proposed PhD project are expected to help to close the gap between the structural and material fatigue modelling, which is considered a

weak link of current fatigue predictions. In this context, this project is expected also to contribute not only to better designs of the next generation of wind turbine blades but also to better predict the remaining lifetime of already installed turbines, which would positively influence the development of the wind energy sector. This project is part of RELIABLADE project funded by EUDP and carried by a number of universities, research institutions and industry partners, and it expects to develop methodologies for design, operation and maintenance of wind turbine rotor blades using a digital twin.
Supervisor: Kim Branner

WOJCIECH J. LASKOWSKI (DTU Compute)
Designing efficient p-multigrid strategies for the Laplace equation – with application to a spectral element fully nonlinear potential flow model
The use of spectral element method (SEM) has seen increasing adoption and maturity towards industrial applications with progress in computational methods and many-core computing infrastructure. SEM is particularly attractive due to its ability to handle complex geometries and achieve high-order convergence rates. A broad range of problems that arise in scientific disciplines such as computational fluid dynamics and electromagnetics often involve structures of complex shapes and are computationally heavy with most of the CPU time centered around solving a boundary value problem in the form of a Poisson or Helmholz equation. Therefore, the demand for fast elliptic solvers tailored to deliver high algorithmic efficiency and expose enough concurrency for parallel computing is of key interest. To meet these requirements, we present a study on the design and implementation of geometric p-multigrid strategies for SEM type solvers. Our objective is to identify an iterative scheme suited for the efficient solution of linear systems of equations derived from high-order finite element discretisation. We consider the foundations of p-multigrid as well as recent developments from literature on this topic. We introduce the geometric multigrid method within variational finite element framework utilising three-dimensional prismatic domains. We employ static condensation to increase efficiency along with Weighted Additive Schwarz strategies that are used to improve the relaxation scheme in multigrid. The considered p-multigrid techniques can be viewed either as a stand-alone solver or as a preconditioner to other iterative methods in the form of a preconditioned defect correction and conjugate gradient. In numerical experiments, we examine the effectiveness of the developed solver against a Laplace problem that arises in Fully Nonlinear Potential Flow simulation, which has potential to be used for advanced marine hydrodynamics applications where water waves interact with floating bodies of complex shapes (wave energy devices, ships, etc). In our performance analysis we focus on convergence properties, numerical scaling, relative efficiency (in working units) and robustness to illuminate aspects that enable practical run times for such advanced solvers.
Supervisors: Mads Peter Sørensen & Allan P. Engsig-Karup

STIG ERIKSEN (SDU ITI)
Autonomous ships from the perspective of operation and maintenance
This project focuses on identifying the opportunities and challenges that on-board maintenance and practical operation of vessels poses in the development of autonomous ships. Inspired by the rapid development of autonomous vehicles considerable effort and interest is now invested in the development of autonomous ships. So far however, most of the research has focused on the legal aspect of unmanned vessels and on developing a system

enabling a vessel to operate within the maritime collision regulation without human interaction.
This Ph.D. study is planned in cooperation between Svendborg International Maritime Academy (SIMAC) and SDU. The project has been generously funded by the Danish Maritime Fund, Lauritzen Fonden and A/S D/S Orient's Fond.
Unlike in road transport where the driver is almost entirely occupied with driving the vehicle only a small portion of the workload on board most ships is devoted to the navigation. Much of the work of the crew is dedicated to maintenance and practical operation of the vessel.
The aim of this project is to investigate how and to what extend this workload can be handled on autonomous ships without a crew on board and how it can be expected to affect the vessels operation.
To be able to operate vessels autonomously they will need a high degree of automation and redundancy of machinery. How this affects the cost, reliability and utilization rate of the vessels will be investigated.
Besides reducing operational costs increased productivity is a major interest in the development of autonomous ships. Vessels are often inoperable with loss in revenue as a result. This project will by case studies of different vessels investigate if and to what extend automation can be expected to improve on the vessels productivity.
Research questions:
• How is autonomous technology going to affect the workload required for operating and maintaining modern cargo vessels?
• How is autonomous technology going to affect the operational patterns of the vessels?
• How is autonomous technology going to affect the reliability and utilization rate of the vessels?
Supervisor: Marie Lützen

JONAS GAD KJELD (SDU ITI)

Methodology for determination of vibration damping of an offshore wind turbine supporting structure

Offshore wind turbine generator (WTG) foundations are designed through a procedure involving highly dynamic and sophisticated integrated simulations of the whole system exposed to both dynamic wind and wave loads and the active control system of WTG itself. Due to the complexity of the system, and existing knowledge gaps, designers are forced to introduce a number of assumptions and simplifications into their calculations. One of them is a total damping of the system which is a decisive parameter in determination of e.g. level of fatigue loads acting on the structure. The overall objective of this project is to verify those design assumptions with regard to damping by measurement of vibrations and subsequent evaluation of the damping components of an existing WTG foundation including aerodynamic, hydrodynamic, structural and soil damping. Secondly, comparison of design assumptions regarding dynamic properties, including damping and natural frequencies, with measured values and assessment of degree of conservatism built-in in an original design will be carried out.
This Industrial PhD research project will help to bridge the gap between scientific knowledge on damping quantification and current industry practice. With more accurately assessed damping properties, it will be possible to revisit our design assumptions and simulation models. It is anticipated that the enhanced simulation models will produce lower fatigue loads. Moreover,

more accurate fatigue load assessments will enable more cost effective and trustworthy asset management of existing structures. Improved damping assessment models will increase quality of simulation results and will allow assessment of fatigue loads with much higher accuracy than ever before, hence with less degree of conservatism and uncertainty. That alone will open not yet explored opportunities for optimized design of WTG supporting structures at new offshore windfarms and better educated integrity management of existing assets.
Supervisor: Anders Brandt

KARSTEN KRAUTWALD VESTERHOLM (SDU ITI)

Robust identification of modal parameters of nonlinear and time variant systems

The identification of modal parameters of systems under ambient or operational vibrations is termed Operational Modal Analysis (OMA). One of the basic assumptions in OMA is that the system being analysed is linear, and time invariant. This limits the applicability of OMA.
The Danish Hydrocarbon Research and Technology Centre is working on extending the life time of the off-shore oil and gas platforms in the North Sea, through structural health monitoring. This is done by monitoring the vibrations of the structures, which is relevant for fatigue, wear, and possibly damage detection. One of the analysis steps in structural health monitoring is OMA. The off-shore platforms are generally considered nonlinear systems. The main concern is the nonlinearity that come from the friction in the sliding bridge bearings on the bridges connecting the platforms. The topside weight of the platforms is constantly varying due to emptying and filling of storage tanks. This means the platforms cannot be considered time invariant, which is another limitation regarding the application of OMA. These challenges in applying OMA on these structures gives reason to improving the existing OMA tools, that allow a robust identification of modal parameters, when the system includes nonlinearities and is not considered time invariant.
Supervisor: Anders Brandt

MIKKEL L. LARSEN (SDU ITI)

Novel high strength steel node for offshore wind turbine jacket foundations (HiJack)

The typical offshore jacket foundation for wind turbine generators (WTG’s) is manufactured using circular hollow sections (CHS), which are welded together to form a truss structure. The welded connections between the truss members, which are denoted nodes, are especially prone to extreme and fatigue loads, as the geometry of the nodes gives rise to high stresses and the weld geometry and possible weld defects lead to stress concentrations [1].
An EUDP (administered by the Danish Energy Agency) funded project denoted “A novel node design using HIgh strength steel for JACKet structures” (abbreviated HiJack) has begun, in which a novel node design will be developed using high strength steel. The project is a collaboration between University of Southern Denmark, Bladt Industries, Ramboll Energy, SSAB Special Steels and FORCE Technology.
In this project, a high strength steel node which utilizes post-weld treatment, such as HFMI (high-frequency-mechanical-impact), will be designed considering different manufacturing and optimization parameters. High strength steel will increase the ultimate capacity of the node, but will not improve the fatigue performance, as the fatigue performance still is governed by the welds. To increase the fatigue performance HFMI will be applied to

the welds, as it has been found that high strength steel considerably improves the benefit of HFMI [2]. In this PhD project, research will be carried out to optimize the new node for fatigue performance by using different fatigue estimation methods and by considering stochastic manufacturing variables. Parameter-based stochastic finite element model updating methods will be implemented to produce the optimized node design.

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Supervisor: Vikas Arora

GORAN JELICIC (SDU ITI)

System identification of aeroelastic parameter-variant systems using real-time output-only modal analysis

Introduction

The dynamics of a linear time-invariant system can be described with few modal parameters such as eigenfrequencies, modes of vibration, damping ratio. These are determined experimentally during a Ground Vibration Test for newly-developed aircraft. The modal parameters vary during flight under the influence of nonstationary aerodynamic forces as functions of air density and wind speed. Under particular conditions an aeroelastic system can become unstable by extracting energy from the surrounding fluid and thus dangerously increasing the amplitude of vibration: this phenomenon is called flutter.

A technique for real-time identification of eigenfrequencies and damping ratios using operational modal analysis methods during a Flight Vibration Test on a research aircraft is presented. The measured acceleration signals from turbulence excitation are used for output-only modal identification. The evolution of eigenfrequencies and damping ratios is tracked as a function of time and flight conditions. The damping trend of selected eigenmodes is monitored while operating points that are critical in terms of flutter are being approached. This technique can also be employed in wind tunnel tests and on other aeroelastic systems.

Supervisor: Anders Brandt

NIMAI D. BIBBO (SDU ITI)

Analytical fatigue life assessment of a full scale wind turbine test bench

Lindø Offshore Renewables Center (LORC) owns and operates two wind turbine test benches, a HALT (Highly Accelerated Life-time Test) Test Bench and a Function Test Bench. The objective of the project is to develop a "Digital Twin" of the wind turbine test benches operated by LORC. The model will be used as a theoretical frame-work to study the degradation of residual life-time of the test benches caused by the complex 3D-loading patterns imposed during commercial testing. The theoretical approach will drive the development of experimental tools and instrumentation which will render an on-line monitoring of the degradation of life-time.

Supervisor: Vikas Arora

JESPER BERNTSEN (SDU ITI)

Experimental fatigue life assessment of a full scale wind turbine test bench

The objective of the project is to develop a methodology to monitor and track the successive degradation of the residual lifetime of wind turbine test benches operated by Lindø Offshore Renewables center. The approach is highly experimental relying on a comprehensive instrumentation of the test benches, and on-line monitoring of parameters of relevance to the degradation of the life-time of the test benches. The work will include EMA and OMA, where the OMA should be scaled accordingly. A MATLAB GUI that computes cumulated fatigue from input acceleration data are to be conducted. The tools developed will be of both technical and economic importance to LORC.

Supervisor: Anders Brandt

GUILLEM GALL TRABAL (AAU MP)

Getting the crack back on the track: fatigue-driven damage in laminated composite structures

Laminated composite structures are widely used in numerous industrial applications such as aeronautical structural elements and wind turbine blades. Numerous advances have been done in the past decades in order to model the behavior of such structures. However, existing models that account for fatigue-driven damage in laminated structures suffer from several drawbacks that make them unable to have good damage and failure predictive capabilities.

The aim of the present PhD project is to obtain a novel unified progressive damage model and finite element formulation for predicting combined intra- and inter-laminar damage in layered composites subjected to static and fatigue loads. In order to achieve such objective, a broad review regarding the progressive failure of laminate composite structures is being done, focusing in three main areas: the physics behind the failure of laminated composite structures and predictive models of damage initiation, interaction and propagation. The poster presents the main conclusions found in this survey and some of the questions that arise from the findings.

This project is part of the Cracks in Composite Structures (CraCS) research group at Aalborg University with the overall aim of developing new modelling tools to predict progressive damage in laminated composite structures.

Supervisor: Esben Lindgaard

SIMON MOSBJERG JENSEN (AAU MP)

Fatigue-driven delamination in laminated composite structures considering real load spectra

Laminated fibrous composite materials are widely used in modern engineering structures due to their high in-plane specific stiffness and strength in favorable directions. However, the relatively low strength at the interface of individual laminae make composite structures prone to delamination initiation and propagation which pose a serious risk of sudden structural collaps. The operational loads on many composite structures, such as wind turbine blades, are a complex mix of deterministic and irregular load cycles, as the load events do not repeat with any particular period. This causes random sequences of loads, frequent transitions in the load amplitude etc, which are ill-represented in the conventional load idealizations of current crack growth rate models.

The first objective of this project is an experimental campaign to gain a deeper understanding of the progression of mechanisms in fatigue-driven delamination under complex load spectra. A recently developed optical technique for automated tracking of delamination fronts in translucent materials is applied to fracture mechanical coupon specimens made of glass fiber reinforced epoxy. The coupon specimens are subjected to variable amplitude loading, and events in the applied load spectrum are correlated to the damage progression. The findings are supported by micro- and macroscopic observations of underlying fatigue mechanisms. Secondly, the project will innovate the damage accumulation laws of conventional crack growth rate models. The aim is to develop a physical-based fatigue model to be able to predict the propagation of delaminations in composite structures subjected to complex load spectra.
Supervisors: Esben Lindgaard & Brian Lau Bak

FREDERIK FOLDAGER (AU Department of Engineering)
Modelling and simulation of soil-tool interaction using the discrete element method
Within the last decades, the tendency in agricultural machine development has been focused on increasing size, weight and tractive requirements. In our research, we apply modelling and simulation to assess soil-engaging tool geometries in order to accommodate site-specific and agronomical needs while only deploying the required soil disturbance and energy. Traditionally, performance assessment of tillage tool geometries is laborious and involves multiple design- and test-iterations. Our aim was to develop a numerical soil-model to predict reaction forces and soil displacements of a sweeping tool as a function of the tool geometry, working depth and velocity as well as soil parameters such as the bulk density and cohesion. We propose the use of the Discrete Element Method as the governing method for simulating the soil-tool interaction. The simulations were conducted using the C++ multi-physics engine, Chrono. The model parameters were obtained using standard soil-mechanical tests conducted in a virtual setting in order to capture the soil mechanical properties.
Supervisor: Ole Balling

19:00 - Dinner

Programme for Tuesday morning, March 12th, 2019

3 – DYNAMICS
(Chairman: Anders Brandt, SDU ITI)

09:00 – 10:45 CHRISTIAN KROGH (AAU MP, 15 minutes)

The issue of the tissue: determining feasible robot draping sequences for woven prepreg plies

In an effort to reduce cost in the manufacturing of composite parts for the aerospace industry, an automatic layup or draping solution is under development. By means of a grid of grippers, the robot system can pick-up entire woven prepreg plies and manipulate the plies onto double-curved mold surfaces of low curvature. This process is intended to substitute the current manual draping operation. Naturally, the quality requirements are the same, i.e. alignment of the ply within prescribed tolerances on the mold and zero wrinkling. Based on numerical simulations of the process and preliminary drape trials with the robot, it was concluded that the proper choice of robot draping sequences, i.e. gripper movements, is essential to meet the quality requirements. To this end, the current study attempts to generate such feasible draping sequences. The idea is to apply an approximate but computationally efficient ply model in an optimization framework where the gripper movements constitute the design variables. Rather than attempting to find the optimal draping sequences, the optimization criteria are chosen in a way that the generated drape movement will mimic the manual process. In this way, the solution space is greatly reduced.
Supervisor: Johnny Jakobsen

DAN KIELSHOLM THOMSEN (AU Department of Engineering, 15 minutes)

Increasing UR robot performance by suppressing mechanical vibrations

Current development of industrial robots includes higher requirements in terms of productivity, safety and energy efficiency. A light weight robot allows to perform rapid motions with low power consumption and low level of kinetic energy during motion, leading to a reduced risk in case of a collision.

The downside of introducing light weight designs, is that reduced mass comes with reduced stiffness and damping of the mechanical system. The reduced stiffness and damping introduce increased sensitivity to unwanted mechanical vibrations during motion, especially for high accelerations. These vibrations are unwanted, because they affect robot precision, accuracy, wear, power consumption and productivity in a negative way. This presentation includes the thoughts and efforts on increasing robot performance by reducing mechanical vibrations.

In the recent decades many different strategies have been investigated, in order to find a suitable method of reducing mechanical vibrations in light weight, i.e. low impedance, robotic systems. Generally, the different strategies can be divided into hardware design, trajectory optimization, feedback control, and feed-forward control methods.

One feed-forward vibration suppression method, which has gained a lot of attention for its simplicity and efficiency is called Input Shaping. The basic principle of Input Shaping is to convolve a reference signal with a vibration free impulse train in order to obtain a new (shaped) reference signal, which is sent to the system.

I will cover the challenges and proposed solutions in implementing Input Shaping in industrial robots, which has configuration dependent dynamic behavior.
Supervisor: Xuping Zhang

EMIL MADSEN (AU Department of Engineering, 15 minutes)
Joint dynamics and adaptive feedforward control of lightweight industrial robots
Sales of industrial robots continue to experience huge growth. The tendency is towards the so-called collaborative robots that can work safely alongside human co-workers because they respect some safety standards unlike traditional industrial robots that need to be fenced off away from humans.
The company Universal Robots is a world leader in developing and manufacturing collaborative robots. Universal Robots seeks to further enhance the precision, accuracy, and safety of their robots. Mechanical wear, temperature changes, etc. do however introduce uncertainties and disturbances to the governing mathematical models.
This project aims to improve the robot performance by; 1) developing an accurate mathematical description of the robot considering in particular the joint dynamics effects such as flexibility and friction, and 2) designing a new controller architecture enabling the robot to monitor and evaluate its performance and use this information to adapt to changes.
Knowing always accurately the dynamic characteristics of the robot joints is of great value, for instance; 1) in the design of model-based feedforward and feedback controllers for effectively increasing the end-effector precision and accuracy, 2) in the safety system, where external disturbances such as human interference can be better identified, and 3) for predictive maintenance in the case of mechanical degradation or failure of the robot joint.
The findings from this project should be implemented as a software update on existing and future robots.
Supervisor: Xuping Zhang

RANDI NØHR MØLLER (DTU Mechanical Engineering, 15 minutes)
Damping system for long-span suspension bridges
For long-span suspension bridges the dynamic response due to turbulent wind loading and especially the flutter limit are design-driving factors. The flutter limit is the point at which the wind-structure interaction causes unstable vibrations of the bridge. The flutter vibrations are governed by the lowest asymmetric and lowest symmetric heave and torsional modes, a total of four modes. Common for these four structural modes is that the main suspension cables undergo large relative displacements similar to the first asymmetric mode or to the first symmetric mode of a free suspended cable. This observation suggests a system of dampers that effectively add damping to the four structural modes of interest by extracting energy via the suspension cables.
The proposed damping system consist of four symmetrically positioned spring-damper devices connected via pre-stressed cables between the pylons and the suspension cables. The figure shows a rendering of a long-span suspension bridge to the left and a possible device positioning to the right. Due to symmetry of the system including external devices, the four dampers should undergo equal tuning. However, optimal tuning of the damper system brings a number of considerations into play: Firstly, the four modes of interest naturally have different vibrational properties whereby optimal tuning of each mode is different and a suitable compromise is to be found. Secondly, the

modal frequencies, modal damping as well as the mode-shapes of an aero-elastic system changes with the mean wind speed and significant changes are especially seen close to the flutter limit. Thereby, optimal damping at zero wind speed is not necessarily effective at high wind speeds.
An investigation of the effectiveness of the proposed damping system is carried out for several calibration choices. The effectiveness is studied by considering the aerodynamic bridge response including self-excited forces at a wind speed range from still-air up until the flutter limit. Furthermore, the effect on the bridge stability limit is evaluated by examining the development of the modal frequencies and damping ratios for increasing mean wind speeds around the flutter limit.

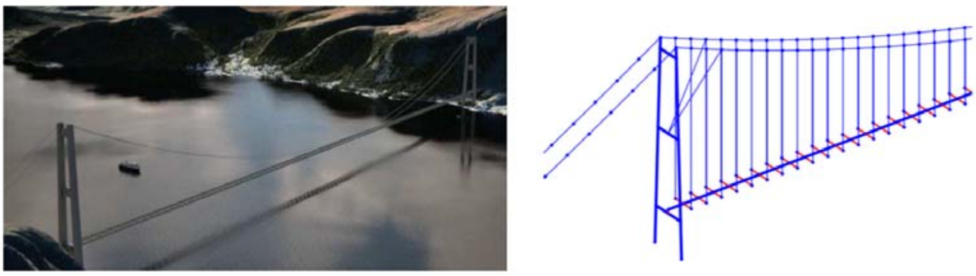

Figure: Left: Suspension bridge rendering, Right: External device positioning.

Supervisor: Steen Krenk & Jan Høgsberg

OLIVER TIERDAD FILSOOF (AU Department of Engineering, 15 minutes)
Modal dynamics and design analysis of multi-rotor wind turbines
This presentation is about analyzing the characteristic dynamics of the Vestas multi-rotor wind turbine concept demonstrator using output-only experimental analysis methods. The characteristic dynamics are represented in terms of modal parameters i.e., natural frequencies, damping ratios, and mode-shapes. Output signals from eight accelerometers are analyzed by using the Frequency Domain Decomposition method and Ibrahim time domain method in order to extract the modal parameters.
The main assumptions in these methods are that the structure behaves linear, is time-invariant and that the excitation forces are randomly and uncorrected distributed on the whole structure. To achieve steady-state conditions the four rotors must rotate at an approximately constant speed and the wind speed must be stable and not fluctuate around the mean wind speed. However, for an operating wind turbine the excitation force conditions do not meet the assumed conditions because of two reasons 1) harmonic forces from the rotors 2) the excitation forces are not uncorrelated. These issues have been addressed in the publications for single-rotor wind turbines. However, they become much more complicated and challenging for multi-rotor wind turbine due to multiple harmonics from the rotors. The experimental results and analysis are providing essential insight and guidance to the design of wind turbines with multiple-rotors and can be used to validate simulations models.
Supervisor: Xuping Zhang

DAVID HOFFMEYER (DTU Mechanical Engineering, 15 minutes)
Active warping control for damping of torsional beam vibrations
Slender structures like long bridge decks, aircraft wings, wind turbine blades and general thin-walled beams may be prone to vibrations due to loads like

wind, traffic etc. If the loads act with an eccentricity relative to the shear center or if the cross-section lacks double symmetry torsional vibrations may be induced. For some structures the aerodynamic instability flutter may occur when flexural and torsional vibrations couple. To potentially avoid flutter, to reduce fatigue stresses and limit accelerations, supplemental damping may be required.

Torsion of thin-walled beams generates out-of-plane, axial warping displacements that are often significant at the boundaries of beams with open cross-sections. Thus, for these types of thin-walled beams the restraining of warping results in an often considerable increase in natural frequency and change in vibration characteristics. The localized effect of restrained warping is used to introduce a substantial amount of supplemental damping, by applying an active damping concept. A position feedback signal is passed by a sensor through a simple linear filter to an actuator which produces an active force stroke. The damping concept is applied with a beam element and compared with a full three-dimensional FE analysis. In an actual structures the dampers are placed as discrete actuators on a beam cross-section and thus only partially restrains warping. This is associated with an additional flexibility that lowers the infinitely damped frequency and thereby the damping ratio. This flexibility is incorporated into the beam element, and it is shown that substantial damping ratios may be obtained for the lowest torsional mode. For the position feedback a stability limit is reached when the damper gain becomes large enough. This limit, however, is based on a static condition and it is shown how the additional flexibility from restraining warping partially affects this limit.

Supervisor: Jan Høgsberg

LASSE LEDET (AAU MP, 15 minutes)

Riding the wave of bi-orthogonality: an application to solve partial differential equations in linear dynamics

As has been demonstrated in a recent paper by the authors, the bi-orthogonality relation is a powerful tool to find analytical solutions of complicated (unbounded) waveguide problems involving infinite eigenfunction expansions. Further studies have proved that these relations are equally powerful for solving the subsequent boundary value problem (e.g. eigenfrequency analysis). In this presentation, we thus seek to promote the method of bi-orthogonality to solve problems in linear dynamics – in whichever realm of physics. We shall not focus here on the details of the mathematical proofs but rather strive to explain the essential features provided by this method. It will be demonstrated how we, in a surprisingly simple way, can solve complicated problems in various realms of physics and how the bi-orthogonality relation can enhance our physical understanding of the behaviour of linear dynamical systems. This insight is gained through the analytical expressions provided by the bi-orthogonality relation (unavailable by use of the conventional methods) as well as through the re-interpretation of the course, in which evanescent and travelling waves join to form standing waves that satisfy boundary conditions. By this, we hope to entertain participants with mathematical as well as engineering background.

Supervisor: Sergey Sorokin

10:45 - 11:15 Coffee break

4 – INVITED PRESENTATION
(Chairman: Niels Leergaard Pedersen, DTU Mechanical Engineering)

11:15 – 12:00 IVAR LUND (SDU ITI, 45 minutes)

Formation and transport of droplets and sprays – fundamentals and applications

Droplets can be found in nature as dew, fog and rain and produced by spray devices for personal and industrial uses such as pharmaceutical sprays, spray paint, combustion, selective catalytic reduction systems (SCR) and agricultural sprays.

Fundamental studies of the physics of water liquid sheet break-up into droplets has been conducted during the last decades, but parameters like droplet interaction with the surrounding turbulent air, droplet-droplet interaction and evaporation are also important issues in connection with the transport of the sprays.

This knowledge gives better understanding on how to design and optimize industrial application systems where spray generators are involved.

The presentation includes theoretical, numerical as well as experimental methods for investigating of the behavior of the spray droplets used in SCR systems and in agricultural pesticide applications.

NOx in exhaust gasses from diesel engines are the most relevant for air pollution. NOx can be converted to nitrogen and water by a chemical reaction with ammonia produced by evaporation of urea-water droplets sprayed into the exhaust gas in the mixer chamber in a SCR system. To optimize this process a computational fluid dynamics (CFD) simulation of the spray formation and the transport of the droplets in the mixer chamber was developed based on a Discrete Phase Model (DFM), where the droplets are tracked in a lagrangian reference frame with one-way coupling to the continuous gas phase. The continuous phase was modeled using a turbulent k-eps model.

Application of pesticides are always associated with a certain degree of soil surface losses and spray drift, which may cause pollution of surface- and groundwater, contamination of non-target organisms as well as human hazards. By reducing the amount of small drift prone droplets in the spray, it will be possible to reduce the spray drift. Better understanding of the spray generation process and knowledge of design optimization parameters for the internal nozzle geometry can help us to develop new optimized sprayer nozzles. This research also includes CFD analysis of the spray and droplet generation and transport by implementation of a Discrete Phase Model.

The numerical results were verified and validated against experimental results from Phase Doppler Anemometry (PDA) analysis of droplet size and – velocity distribution, results of the spray volume distribution using a high resolution mechanical patternator and wind tunnel experiments of off-target spray drift in different distances from the nozzle, both airborne and sedimentation.

Finally, an empirical model for spray drift potential was developed based on nozzle spray characteristics obtained from experimental data.

12:00 – 13:00 Lunch

Programme for Tuesday afternoon, March 12th, 2019

5 – FLUIDS
(Chairman: Morten Brøns, DTU Compute)

13:00 – 14:00 ANNE RYELUND NIELSEN (DTU Compute, 15 minutes)
Topology bifurcations of vortex pair interactions
Interactions of vortices affects the overall organization and distribution of a flow. In our research we make use of a topological approach to describe the qualitative changes in the structure of a flow. We focus on a two dimensional flow where a single pair of vortices are interacting. The topological structure of a vortex is inextricably linked to the way we choose to define vortices mathematically. In the present study we choose to identify vortices based on the widely used Q-criterion. In general a positive Q-value implies that the rotation dominates the strain and in two dimensions a vortex is therefore defined as a region where $Q = \det(\nabla \mathbf{v}) > 0$. With a dynamical system approach any sudden change of the vortex topology can be viewed as a bifurcation of the level set $Q = 0$. In our studies we develop a bifurcation theory that classifies all possible topological changes as different bifurcations. To model the two interacting vortices, we use the idealised core growth model and compare with two-dimensional Navier-Stokes simulations. In both cases our bifurcation theory serve as a template that facilitate the construction of a bifurcation diagram. The bifurcation diagram gives an exhaustive description of the flow and we conclude, that a pair of co-rotating vortices merges only if their relative strength ratio, $\alpha = \Gamma_1/\Gamma_2$, is small enough. We prove that the threshold for merging appears as a cusp singularity on a bifurcation curve. In the bifurcation diagram for the core growth model we find that the threshold for merging appears at $\alpha = 4{:}58$. By comparison with Navies-Stokes simulations at different Reynolds numbers, we conclude that the merging threshold varies only slightly for Reynolds numbers up to 100. Furthermore, we observe an excellent agreement between the core growth model and the numerical simulations for Reynolds numbers below 10. In this range the only disadvantage of the core growth model is the intrinsic symmetry, which of course will be broken in the simulations. We therefore conclude that instead of solving the Navier-Stokes equation numerically we can in some cases apply the core growth model that is a simple, analytically-tractable model with a low dimension.
Supervisor: Morten Brøns

TAO SUN (AAU Civil, 15 minutes)
Semi-active feedforward control of a floating OWC point absorber for optimal power-take-off
The performance of a floating oscillating water column wave energy converter is depending on the variation of the pressure above atmospheric pressure in the pressure chamber above the water column. The pressure can be semi-actively controlled by the opening and closure of a valve between the pressure chamber and the generator. In the paper a control is suggested, where the closure time intervals of the valve are taken as a fixed fraction of the peak period of a given sea-state. The control relies on an estimation of the external wave loads, which in turn depend on the prediction of the future surface elevation in a given prediction interval, for which reason it is classified as a feedforward (open loop) control strategy. A Kalman-Bucy filter has been devised for the indicated prediction. The optimal fraction of time of the sub-

optimal controller with a closed valve is determined by comparison with the performance of the optimal control obtained by nonlinear programming.
For a given sea-state it is demonstrated that the sub-optimal controller in average absorbed energy somewhat is less than the optimal controller, and that the reduction is primarily related to the estimation error of the wave loads.
Supervisor: Søren R.K. Nielsen

HAILIANG LIU (AU Department of Engineering, 15 minutes)
The role of hydro power, storage and transmission in the decarbonization of the Chinese power system
Deep decarbonization of the electricity sector can be provided by a high penetration of renewable sources such as wind, solar PV and hydro power. Flexibility from hydro and storage complement the high temporal variability of wind and solar, and transmission infrastructure helps the power balancing by moving electricity in the spatial dimension.
We study cost optimal Chinese power systems under ambitious CO2 emission reduction targets, by deploying a 31-node hourly-resolved techno-economic optimization model supported by a validated weather-converted 38-year-long renewable power generation and electricity demand dataset.
We focus on 41 large-scale reservoir-based hydro stations in China, determine their corresponding basin areas, estimate their inflow based on gridded surface runoff data from the global reanalysis dataset CFSR and calculate their daily inflow time series in terms of both flow volume and potential power generation. One important character of hydro dams in China is that, they are usually part of a hydro station cascade, such as Three Gorges-Gezhouba, Xiluodu-Xiangjiaba. In such cascades, the dams are chained along the same river, and the downstream dams' inflow largely depends on their upstream stations' turbine control or spillage. This is also accounted for in the model optimization, assuming water flows into the downstream reservoir instantly.
With this new reservoir hydro model, we find that if CO2 emission reduction is limited below 40% the system can sustain without hydro and storage, and above 70% these flexibility units become necessary to maintain reasonable system cost. We look into the role of reservoir hydro and storage, by exploring the temporal dimension of the 90% CO2 reduction scenario. These flexibility components, can lower renewable curtailment by two thirds, allow higher solar PV share by a factor of two, decrease transmission cost significantly. We find that nodes with hydro stations need no investment in thermal power plants and they also contribute to covering the national summer peak demand thanks to the seasonal alignment to the inflow.
Supervisors: Martin Greiner & Gorm Andresen

CHRISTIAN ELKJÆR HØEG (AU Department of Engineering, 15 minutes)
Efficient time-domain hydrodynamic modelling for floating offshore wind turbines using rational filter approximations
High-fidelity dynamic models of FOWTs must take into account the fluid-structure interaction (FSI) regarding the hydrodynamic loads. Within the linear framework, the hydrodynamic loads can be superposed by contributions from waves (diffraction), from platform motions (radiation) and from buoyancy (hydrostatics). The radiation force vector is related to the frequency-dependent added mass and damping matrices in the frequency domain. When transformed to the time domain, the radiation force vector

involves 6 by 6 convolution integrals, which is time consuming to solve during the dynamic analysis of FOWTs.

This paper investigated the use of rational approximations to obtain the radiation force vector in the time domain for efficient simulations. The idea is to fit the numerically obtained hydrodynamic transfer functions (frequency response functions with the structural velocity being the input and the radiation force being the output) by rational functions, which further enables replacing the convolution integrals by a state-space model with limited numbers of internal degrees-of-freedom (DOF). The state-space model of the radiation force vector can then be coupled to the aeroelastic model of FOWT, leading to the extended state vector formulation of the FOWT-fluid system that can be efficiently solved in the time domain.

First, a 17-degree-of-freedom (17-DOF) aero-hydro-servo-elastic model of a spar-type FOWT is established using the Euler-Lagrange equation. Next, rational approximations are performed on the hydrodynamic transfer functions numerically obtained from the boundary element methods. Extended state vector formulation is then obtained for the FOWT with FSI included, which is subjected to turbulent wind and irregular wave excitations. Comparisons of the hydrodynamic loads using rational approximations and the convolution integral is performed to investigate the precision of the method at different wind and wave states. Further, a comparison with a simple hydrodynamics model, the widely used classical Morison equation, is also carried out.

Supervisor: Zili Zhang

14:10 - 18:00 Social Event (BUS ER BESTILT MED AFGANG kl 14:00)

19:00 - Banquet

Programme for Wednesday morning, March 13th, 2019

07:00 - 09:00 Breakfast

6 – MATERIALS
(Chairman: Henrik Myhre Jensen, AU Department of Engineering)

09:00 – 10:20 KONSTANTINOS POULIOS (DTU Mechanical Engineering, 20 minutes)

A curious case of mechanical reduction of sliding friction

Consider a rigid circular cylinder loaded and sliding against the flat surface of a hyperelastic solid. For Coulomb friction with a coefficient μ between the contacting surfaces and small normal loads, the ratio of the total tangential to normal forces on the sliding cylinder is approximately equal to μ. With increasing normal load and consequently indentation depth however, the globally observed coefficient of friction may deviate from the locally imposed value μ. Interestingly enough, there are cases where the observed global coefficient of friction actually becomes lower than the locally imposed friction coefficient μ.

This work demonstrates and discusses this phenomenon based on parametric study results from a finite-element model for this steady-state problem. The deviation between the global and local coefficients of friction are shown to mainly depend on the normal load and Poisson's ratio of the substrate. Inertia effects can also become significant at sufficiently large sliding speeds. All results are presented in terms of appropriately chosen dimensionless parameters and special attention is directed to cases resulting in a lower global coefficient of friction than the local one for compressible substrate materials.

SIMON HEIDE-JØRGENSEN (AU Department of Engineering, 15 minutes)

Fracture toughness of rugger/stainless steel bonding using nana-thick adhesive

A novel approach is proposed to bond rubber to metal utilizing metal anchored nanometer thick polymer brushes in the interface. Further, a new specimen geometry enabling multiscale evaluation is proposed. Chemical analysis and macroscale mechanical testing are performed on the same specimen. This presentation will focus on evaluation of the mechanical properties of the proposed bonding solution. The limited bonded area of the specimen leads to a non-smooth debonding and changes in the crack growth path. These aspects are investigated using the load response data and post-mortem three-dimensional scanning technique. Specifically, contrary to a normal peel experiment [1], a two-stage load response curve i.e. loading stage and steady-state, 'smooth' crack growth stage, is replaced by a four stages, i.e. 1) elastic loading, 2) stable crack propagation, 3) unstable crack propagation, and 4) loss of load carrying capacity. To validate this novel approach, results are compared against specimens bonded using reference system with no alteration of the crack growth path. A good qualitative agreement is found between both approaches in terms of peeling energy. Moreover, contrary to the reference specimens, in which a crack locus migrates from the interface into the rubber leading to peel arm failure, the present configuration with the finite size of the bonded zones allows the crack locus, and therefore crack path, to be recovered.

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Supervisor: Michael Budzik

INGRID HOLTE (DTU Mechanical Engineering, 15 minutes)

Void size and shape effects in a gradient enhanced continuum model

The combined effect of length scales and void shape in a strain hardening porous solid is investigated using the Gurson-Tvergaard (GT) [1,2] and Gologanu-Leblond-Devaux (GLD) [3,4] models, enriched by a constitutive length parameter. The results are compared with unit cell calculations of regularly distributed voids embedded in a strain gradient enhanced matrix material. The strain gradient theory proposed by Fleck and Willis [5], extended to finite strains [6], is adopted for the cell model. The gradient model allows for a material length parameter to enter the constitutive framework for dimensional consistency. The enriched GT model has the length parameter introduced through prefactors to the usual q1 and q2 factors, which has been proven to capture gradient effects until localization or severe void shape change [7]. The GLD model will allow for analyses of a wide range of void aspect ratios and their effect on the macroscopic yield behaviour. Extending this model with an intrinsic length parameter will provide the basis for investigation of the coupled effects of void size and void shape on both void growth and yield behaviour of porous metals.

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Supervisors: Christian Niordson & Kim Lau Nielsen

RASMUS GRAU ANDERSEN (DTU Mechanical Engineering, 15 minutes)

Ductile crack initiation: Void-by-void versus multiple void interaction

Ductile crack initiation, comprising void growth to coalescence, is controlled by either of two distinct mechanisms; the void-by-void growth, where the void closest to the crack tip experiences substantial void growth independent of other voids, and multiple void interaction, where voids grow simultaneously and the crack advances due to an interaction between voids in the vicinity of the crack tip. Tvergaard and Hutchinson (2002) [Int. J. Solids and Struct, 39: 3581-3597] have documented these two mechanisms under

far-field mode I loading conditions and several other studies have investigated the importance of e.g. the void spacing and void size. The present numerical work focuses on mixed mode loading conditions (mode I-mode II and mode I-mode III) with a focus on how a change in the far-field loading conditions will affect the shift between the two mechanisms. Six discrete modeled voids are located in front of a pre-existing straight crack and an elastic-plastic material is considered. The numerical finite element study is carried out by exploiting a specialized 2D plane strain element formulation capable of out-of-plane displacements to allow for mode III loading conditions. The study reveals details of the void-by-void growth versus the multiple void interaction mechanisms for a range of different load cases and geometrical void configurations. The void-by-void growth is favored for increasing mode mixity and requires a higher load intensity on the far-field boundary to initiate the crack even for geometrical void configurations that exhibits multiple void interaction under pure mode I load intensity. The change between the two mechanisms is related to a change in the deformation field that surrounds the voids as the voids rotate when a shear mode is applied to the far-field boundary. This rotation is dependent on both the type of mode mixity (mode I-mode II or mode I-mode III) and the shear mode contribution.
Supervisor: Kim Lau Nielsen

YUE XIAO (DTU Mechanical Engineering, 15 minutes)
Size effects in porous metals under shear load
Experiments have revealed that metals exhibit strong size effects on the micron scale. The general trend that smaller is stronger has been confirmed in e.g. wire torsion, beam bending and indentation. However, the classical continuum theory possesses no material length scale, failing to predict non-uniform deformation in plastic range. Strain Gradient Plasticity (SGP) models are proposed to connect the classical continuum theory and micron scale dislocations. A popular SGP model thermodynamic consistent SGP model was developed by (Gudmundson 2004), and employs the plastic strain rate and displacement as the primary variables. For this theory Fleck and Willis (Fleck and Willis 2009) proposed the minimum principle on which numerical solution are conveniently based. Its 2D finite element implementation is formed in this study, aiming at studying the shearing effects of voided metals. Comparisons between the flow theory model and the visco-plastic version of gradient the enhanced model are conducted. The present work aims to broaden the use of the gradient enhanced constitutive models in engineering applications of ductile failure.
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Supervisor: Christian Niordson

10:20 - 10:50 Coffee break

7 – MATERIALS II AND OPTIMIZATION II
(Chairman: Esben Lindgaard, AAU MP)

10:50 – 12:15 CASPER S. ANDREASEN (DTU Mechanical Engineering, 20 minutes)

Topology optimization using CutFEM

In this work we present a parametric level set method for shape and topology optimization based on a density type design representation and the CutFEM method (Hansbo & Hansbo, 2004). The CutFEM method introduces a crisp boundary representation and ensures a strict partitioning of solid and void regions on a fixed background mesh. CutFEM introduce a special integration scheme which does have some drawbacks concerning artificially high stiffness in slender notches. This artifact can, and will, be exploited by the optimization procedure and hence must be remedied. We alleviate this problem by introducing a robust formulation which is directly adopted from density based methods. This is possible since the underlying parametric level-set field is treated exactly as done in density methods, using the same convolution and smoothed Heaviside filters and this allows us to introduce and ensure a certain length scale in the optimized design.

The combined shape and topology optimization procedure is implemented in Matlab/MEX using mathematical programming for the shape update and a heuristic scheme for the topology update. That is, we compute the design sensitivities for the shape optimization only for the cut elements using the semi-analytical adjoint method. The level-set is then updated using the Method of Moving Asymptotes.

Although the shape optimization approach allows for holes to close, it cannot nucleate holes in the interior of structure. That is, new holes can only form by evolving from the design boundary, which is a situation very unlikely to occur for most topology optimization problems. It is also well-known that pure shape optimization is extremely sensitive to the choice of initial configuration. To alleviate this severe drawback, we introduce a hole-nucleation scheme that enables the optimizer to start from a full material design without holes. The heuristic hole-nucleation is, for the minimum compliance example in Fig. 1, based on the strain energy density computed in the solid elements, which for the simple case of static compliance is nothing more than a scaled topological derivative.

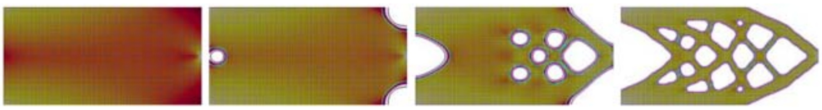

Figure 1: Example of a cantilever (fixed support left face and loaded vertically on the center part of the right face) optimized for minimum compliance subject to a 50% volume constraint using the hole-nucleation scheme. The figures show design iteration 1, 14, 38, 200 and are colored by the strain energy density. The black, magenta and cyan lines correspond to the dilated, blueprint and eroded designs, respectively.

The designs seen in Fig. 1 shows four snapshots of the design evolution and demonstrates how the design evolves from a solid structure to an optimized structure meeting the volume constraint while maintaining the prescribed length scale on the solid. The proposed density based level-set optimization method has also been extended to compliant mechanism design problems.

References:

Hansbo, A., & Hansbo, P. (2004). A finite element method for the simulation of strong and weak discontinuities in solid mechanics. Computer Methods in Applied Mechanics and Engineering, 193(33–35), 3523–3540. https://doi.org/10.1016/j.cma.2003.12.041

Jansen, M. (2018). Explicit level set and density methods for topology optimization with equivalent minimum length scale constraints. Structural and Multidisciplinary Optimization, Online. http://doi.org/10.1007/s00158-018-2162-5

CHRISTIAN FELTER & CHRISTIAN K. CHRISTIANSEN (DTU Diplom, 20 minutes)

3D-operations, scanning, and printing

Students more and more often ask about the meaning of a certain course, or perhaps any course, into which they are enrolled. As something new, even people outside of University, politicians, industry, etc, start to ask the same question. In the good old days, a course could be justified be simply being a prerequisite for another course. However, times are changing and facing these changes in a positive manner can actually improve on status quo in the palette of courses at a university department. At DTU Ballerup the first steps in giving a new meaning to a few courses have been made. The course 62799 Geometric operations in Plane and Space has always rated as a good course, but students are not able to fully grasp how an engineer can use the methods and topics learnt. Recently, a new course assignment has been designed in which a simplified model of the in-house 3D scanner is analyzed. This will be supplemented by a new course on 3D scanning. The already available 3D printing lab closes the loop. The talk will provide details on all three topics using a concrete example. It is a goal for the future to find more cases like this one, which clearly exemplifies for students, industry, and politicians how the course portfolio is relevant for engineers of today and tomorrow. It is also a goal to look inside the department and have a health check on the courses provided for students.

HANSOTTO KRISTIANSEN (DTU MECHANICAL ENGINEERING, 15 minutes)

Topology optimization of structural problems with contact and friction.

During the recent decades, topology optimization has given researchers a new set of tools to design structural parts in new ways to enhance the parts' structural performance. Researchers have successfully applied the methods of density based topology optimization been applied to research fields like solid mechanics, fluid mechanics, acoustics, etc. and many interesting problems have been solved by this method, but many remain. One type of such problem is found at the intersection with frictional contact mechanics.

In this work, we have studied how to combine methods for frictional contact mechanics with the modern density based topology optimization methods. The goal has been to achieve feasible solid-void designs to this type of mechanics problem.

We start by finding new solid-void designs as solutions to a traditional benchmark problem from the literature, and we extend the problem to include Coulomb friction up to a friction coefficient of 0.2. Furthermore, we vary the design of the contact region for the reference example to demonstrate the possibilities of including friction to the problem. The results demonstrate how to exploit the potential contact, on a priori unknown, contact area for the

optimization of the structure. We verify the optimizations by a small parameter-study and crosscheck the performance of the obtained designs.
Secondly, we investigate the case of a static compression of an elastic L-shaped domain and we optimize the material distribution inside a domain to achieve more uniform contact force distribution on the lower side of the domain. For this problem we propose a new p-norm based cost function to measure the uniformity of the resulting contact pressure on a priory unknown interface region between the elastic domain and the rigid obstacle. Not surprisingly, we found that a structural stiffness constraint was required to obtain meaningful designs.
The contact formulation of this work is a Lagrange multiplier based friction formulation. The formulation directly imposes impenetrability, friction, and corresponding complementarity conditions as a semi-smooth Newton scheme.
Lastly, we extended our work to include dynamic contact, and we show how this leads to interesting results for drop-test-like design problems.
Supervisor: Niels Aage

SMAIL KOZARCANIN (AU Department of Engineering, 15 minutes)
End-of-century climate impacts on the cost-optimal decision of decentralized heating technologies in Europe
Today, it is well accepted that energy related CO2-emission is a key driver in global warming. In fact, the production of electricity and heating alone in the EU27 in 2015 was accounted for approximately 30% of the total CO2-emission. Political and regulatory actions have had, so far, a key role in pursuing clean options for heat generation. In this talk, we adapt a technical standpoint and assess the impact of climate change on the cost optimal generation of heat. Reconstructed CO2-concentration pathways, RCP, provided by the Intergovernmental Panel on Climate Change, IPCC, are applied to simulate various climatic conditions for the 21st Century. Nine climate models provide temperature data with a spatial and temporal resolution of 12km x 12km and 3h, respectively, based on the RCPs. We model the demand side by calculating the heat load factors at each grid location. The supply side is modelled by a simple approach to the economics of heat generation. We find that CO2-emission from space heating decrease by at most 5% in low and intermediate concentrations pathways. This value reaches 10% for an extreme concentration pathway. For the historical period, we find that countries that are dominated by the cold Atlantic climate unveil high heat load factors. Mediterranean countries show a similar behaviour, reasoned by a high ratio between the hot water and space heat demand. In both cases, heat pumps serve as a cost optimal option of heat generation. Mainland European countries show a low heat load factor for which gas boilers serve as a cost optimal choice of heat generation. Increasing ambient temperatures toward the end-century force an increasing penetration of heat pumps in all concentration pathways.
Supervisor: Gorm Andresen

KASPER RINGGAARD (AU Department of Engineering, 15 minutes)
Optimization of material removal rate in milling of thin-walled pocket structures using penalty cost function
Thin-walled aluminium pocket components are widely used in aerospace components, such as fuselages and wings. The pocket structures are typically manufactured in a monolithic process where large amounts of material is machined from one solid block. Thus, it is key to perform the machining operations as fast as possible to lower production cost. When performing

semi-finishing operations, where the pocket wall rigidity is low, vibrations are unavoidable. If the vibration amplitude becomes too large, or if the process goes unstable, the parts will have poor surface quality and in severe cases, the parts might have to be scrapped. Current practice in industry to increase the Material Removal Rate (MRR) without causing instability or excessive vibrations is mainly application of craftsman-knowledge and iteratively testing the manufacturing process.

This presentation will introduce an optimization method capable of maximizing the material removal rate while obeying constraints related to forced vibrations and chatter instability. Predictions rely on a model of the workpiece and a cutting force model. The cost function is formulated using penalty terms, and a resampling strategy is implemented to minimize the risk of selecting local minima instead of the global minima. The method is applied to a thin-walled aluminium pocket, which is modelled using finite strip modelling to ensure high computational efficiency. The method is formulated in a general manner, which ensures applicability to general flexible machining setups. The applicability of the optimization strategy is initially validated using numerical simulation tools. Milling experiments are conducted to validate that the method is capable of picking parameters, which are in fact valid in real life applications.

Supervisor: Ole Balling

12:15 – 13:15 Lunch

Programme for Wednesday afternoon, March 13th, 2019

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

13:15 – 14:15 PAULIUS BUCINSKAS (AU Department of Engineering, 15 minutes)

Efficient modelling of ground and structure borne vibration

Environmental vibrations, propagating through soil and entering buildings through foundations, is a serious concern in densely populated urban areas. With rail and road traffic being the main sources of environmental vibrations, new transportation infrastructure projects need to evaluate and take steps to mitigate these effects. Here, computational models are extremely useful, as the vibration levels can be evaluated even before the construction begins and different design configurations can be easily tested. Ideally, the computational model should be able to model the full vibration propagation path from the source to the receiver, while keeping the computational times low.

The talk will introduce some of the work done during the PhD project, focusing on creation of efficient computational tools for prediction of environmental vibrations. The presented approach uses a semi-analytical formulation for the soil body. Thus, offering relatively short computation times, especially when compared to more commonly used finite or boundary element approaches. Further, finite element structures can be easily added to the system, creating a fully coupled three-dimensional soil-structure system. The talk will provide and introduction to the methodology and some example use cases.

Supervisor: Lars Vabbersgaard Andersen

JOHAN FREDERIK TOFTEKÆR (DTU Mechanical Engineering, 15 minutes)

Resonant piezoelectric shunt tuning based on the electric current and voltage response to white noise excitation

Piezoelectric materials are characterized by their ability to couple mechanical strains and stresses with electric fields and displacements. This property is used to convert mechanical energy of a vibrating structure into electric energy, which subsequently is dissipated in a so-called electric shunt circuit. The shunt circuit containing a resistance (R) results in viscous damping of the structure, while resonant damping is achieved by the addition of an electric inductance (L). The resonant piezoelectric damper possesses characteristics similar to the mechanical tuned mass absorber, where the resistance and inductance are equivalent to, respectively, a dashpot and a mass (inerter), while the inherent capacitance of the piezoelectric material is equivalent to a mechanical spring. Tuning strategies similar to those used for the mechanical absorber may thus be applied to determine the optimum design of the resonant piezoelectric damper. In [1] a tuning procedure, accounting for the influence from the non-resonant vibration modes, is derived for the mechanical absorber. An analogy to resonant piezoelectric shunt damping and the implementation in commercial finite element software is presented in [2]. In the present work, the method is validated experimentally, and it is demonstrated that the required tuning parameters may be determined through simple tests. The procedure consists of imposing a random white noise to the structure with the piezoelectric material, while the piezoelectric electrodes are subsequently either in short- or open circuit configuration. In the two individual cases a time response series is attained by measuring, respectively, the electric current and voltage with a high quality multimeter. Then a Fast-Fourier-Transform is used on these time-series to determine the frequency response functions (FRF) for both the electric current and voltage. Finally, the optimum resonant shunt inductances and resistances are determined from the corresponding modal properties, directly extracted from the measured FRFs. The method is demonstrated for a free beam with two pairs of piezoceramic patches, one pair for vibration excitation and the other for vibration mitigation.

References

[1] Krenk S., Høgsberg J. Tuned resonant mass or inerter-based absorbers: Unified calibration with quasidynamic flexibility and inertia correction. Proc. R. Soc. A, 472(2016) 20150718.

[2] Toftekær J.F., Benjeddou A., Høgsberg J. General numerical implementation of a new piezoelectric shunt tuning method based on the effective electromechanical coupling coefficient. Mech. Adv. Mater. Struc. (2019).

Supervisor: Jan Høgsberg

SILAS SVERRE CHRISTENSEN (SDU ITI, 15 minutes)

Automated operational modal analysis (AOMA) on an offshore research platform

The Forschungsplattform in Nord- und Ostsee Nr. 3 (FINO3) is a research platform located 80 km off Sylt in the midst of German offshore wind farms. During its operation, numerous scientific research projects are taking part. The primary goal is to understand the surrounding environment. One of these projects involve structural health monitoring (SHM), which help to detect changes and therefore have a potential to save money. To get a better understanding of how the structure respond to these external loads, we shall adopt operational modal analysis (OMA), which is the estimation of modal parameters during operation (MPE). Modal parameters, i.e. frequencies, damping ratios and mode shapes are dependent on the mass and stiffness of the structure. Furthermore, environmental factors like, temperature, wind and wave velocity, wind and wave direction, water/wave height etc. influence the modal parameters. Modal parameter extraction involves operator interaction and can therefore be a time-consuming task, hence methods for automated operational modal analysis (AOMA) are of great interest. This PhD Project focus on developing a method for AOMA that subsequently is used to estimate the remaining lifetime of structures using the concept of virtual sensing. The method for AOMA proposed require a stabilization diagram, a plot of the model order as a function of the estimated frequencies. Physical modes tend to stabilize on the frequency axis for different model orders, while spurious modes do not. By overlaying this plot by its probability distribution, the physical modes are easily identified using a threshold. Subsequently all output data undergoes a decision rule that is based on the Modal Assurance Criterion (MAC). This is to ensure consistency and to remove more spurious modes. Finally, the methods select one representative pole for each mode in the output data. The proposed method for automated operational modal analysis (AOMA) has shown successful in detecting physical modes in an automated manner on the FINO3 platform.

Supervisor: Anders Brandt

ZHONGYI LI (AAU MP, 15 minutes)

A novel joint able to varying stiffness in multi-modes

Compliant joint can find their applications in wearable exoskeletons, rehabilitation robots and collaborative robots. These compliant joints are generally used for increasing safe physical human-robot interaction (pHRI) or improving the dynamical adaptability with environment, which show valuable advantages over the stiff joints.

In this presentation, a novel compliant joint of variable stiffness with reconfigurability is presented. The joint is designed with a four-bar linkage of singularity, and is able to vary widely its stiffness in multiple modes, namely, linear, hardening and softening modes. The new joint has a compact structure, and can be integrated in exoskeleton. Up to date, a prototype of the joint has been constructed, and test results showed its validity.

Supervisor: Shaoping Bai

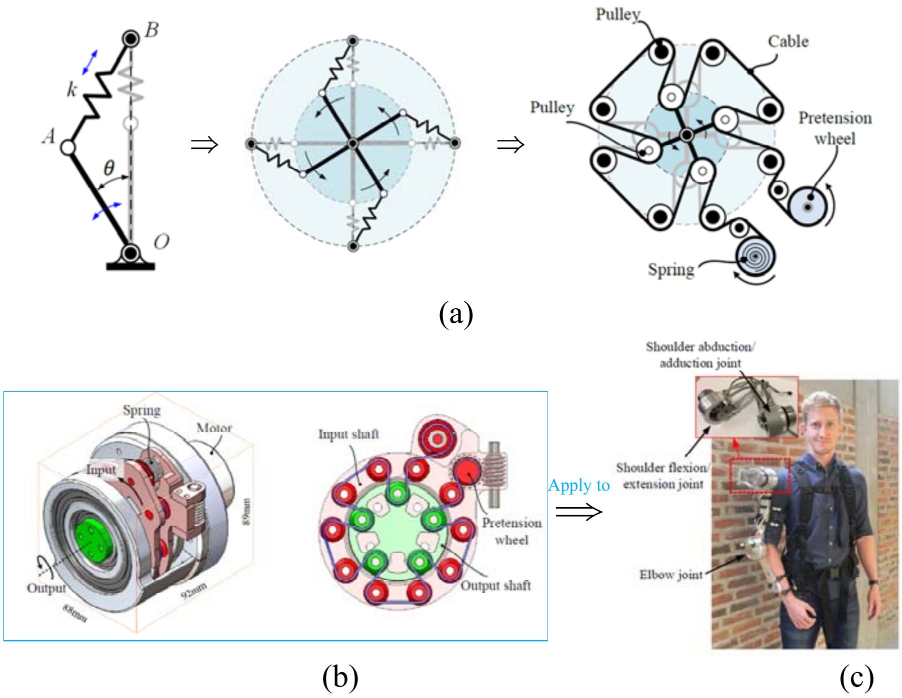

Figure 2. (a) The design of joint mechanism, (b) an embodiment of the mechanism, (c) an upper-body exoskeleton.

15:00 Departure from the hotel