A strain gauge
The invention relates to a strain gauge of a carrier layer and a meandering measurement grid (101) positioned on the carrier layer, wherein the measurement grid comprises a number of measurement grid sections placed side by side with gaps in between, and a number of end loops (106) interconnecting the measurement grid sections at their ends. The end loops at both ends of the measurement grid extend a length (L, 500) in the axial direction in millimetres of a factor times a ratio between a width of a grid section and the gap distance, wherein the factor is larger or equal to 1.5. The invention further relates to a method for manufacturing a strain gauge as mentioned above.

General information
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Authors: Mikkelsen, L. P. (Intern), Gili, J. (Ekstern)
Publication date: 19 Jan 2017

Publication information
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Main Research Area: Technical/natural sciences
Source: espacenet
Source-ID: WO2017009365
Publication: Research › Patent – Annual report year: 2017
Individual fibre segmentation from 3D X-ray computed tomography for characterising the fibre orientation in unidirectional composite materials

The aim of this paper is to characterise the fibre orientation in unidirectional fibre reinforced polymers, namely glass and carbon fibre composites. The compression strength of the composite is related to the orientation of the fibres. Thus the orientation is essential when designing materials for wind turbine blades. The calculation of the fibre orientation distribution is based on segmenting the individual fibres from volumes that have been acquired through X-ray tomography. The segmentation method presented in this study can accurately extract individual fibres from low contrast X-ray scans of composites with high fibre volume fraction. From the individual fibre orientations, it is possible to obtain results which are independent of the scanning quality. The compression strength for both composites is estimated from the average fibre orientations and is found to be of the same order of magnitude as the measured values.

General information
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Organisations: Department of Applied Mathematics and Computer Science, Image Analysis & Computer Graphics, Department of Wind Energy, Composites and Materials Mechanics
Authors: Emerson, M. J. (Intern), Jespersen, K. M. (Intern), Dahl, A. B. (Intern), Conradsen, K. (Intern), Mikkelsen, L. P. (Intern)
Pages: 83–92
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BFI (2014): BFI-level 2
Scopus rating (2014): SJR 1.725 SNIP 2.57
BFI (2013): BFI-level 2
Scopus rating (2013): SJR 1.616 SNIP 2.878
ISI indexed (2013): ISI indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): SJR 1.59 SNIP 2.759
ISI indexed (2012): ISI indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): SJR 1.508 SNIP 2.513
ISI indexed (2011): ISI indexed yes
BFI (2010): BFI-level 2
Scopus rating (2010): SJR 1.555 SNIP 2.243
BFI (2009): BFI-level 2
Scopus rating (2009): SJR 1.583 SNIP 2.009
BFI (2008): BFI-level 2
Scopus rating (2008): SJR 1.382 SNIP 1.899
Scopus rating (2007): SJR 1.195 SNIP 2.149
Scopus rating (2006): SJR 1.202 SNIP 2.283
Scopus rating (2005): SJR 1.116 SNIP 2.162
Scopus rating (2004): SJR 1.186 SNIP 1.659
Scopus rating (2003): SJR 1.16 SNIP 1.46
Scopus rating (2002): SJR 1.329 SNIP 1.539
Scopus rating (2001): SJR 1.472 SNIP 1.318
Scopus rating (2000): SJR 1.302 SNIP 1.307
Scopus rating (1999): SJR 0.856 SNIP 1.116
Original language: English
Polymer-matrix composites (PMCs), Strength, Non-destructive testing Misalignment
Mechanical properties of biaxially strained poly(l-lactide) tubes: Strain rate and temperature dependence

Poly(l-lactide) (PLLA) is a bioabsorbable polymer with high stiffness and strength compared to the other commercially available bioabsorbable polymers. The properties of PLLA can be improved by straining, causing deformation-mediated molecular orientation. PLLA tubes were biaxially strained above their $T_g$ for improvement of their strength, in a two-step process (sequential straining). Mechanical properties and crystal morphology were investigated as a function of processing strain rate and temperature. DSC revealed that a low processing strain rate allows molecular chain relaxation in the direction of strain and the crystallization is suppressed. Faster strain rates on the other hand suppress chain relaxation, and results in crystalline tubes. The mechanical properties are influenced by both processing strain rate and temperature. Low strain rates allow chain relaxation resulting in the lowest strength and stiffness, whereas a larger stiffness and strength is achieved by increasing strain rate and temperature. Isotropic mechanical properties are only observed at high processing strain rates.

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State: E-pub ahead of print
Organisations: Department of Micro- and Nanotechnology, Amphiphilic Polymers in Biological Sensing, Department of Energy Conversion and Storage, Imaging and Structural Analysis, Department of Wind Energy, Composites and Materials Mechanics, Mixed Conductors
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Publication date: 2017
Main Research Area: Technical/natural sciences

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BFI (2013): BFI-level 1
Scopus rating (2013): SJR 0.631 SNIP 1.093
ISI indexed (2013): ISI indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): SJR 0.661 SNIP 1.087
ISI indexed (2012): ISI indexed yes
BFI (2011): BFI-level 1
Scopus rating (2011): SJR 0.603 SNIP 0.966
ISI indexed (2011): ISI indexed yes
BFI (2010): BFI-level 1
Scopus rating (2010): SJR 0.683 SNIP 0.908
BFI (2009): BFI-level 1
Scopus rating (2009): SJR 0.699 SNIP 0.826
BFI (2008): BFI-level 1
Scopus rating (2008): SJR 0.646 SNIP 0.82
Scopus rating (2007): SJR 0.675 SNIP 0.932
Scopus rating (2006): SJR 0.781 SNIP 1.144
Scopus rating (2005): SJR 0.776 SNIP 0.911
Scopus rating (2004): SJR 0.765 SNIP 0.955
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Scopus rating (2002): SJR 0.854 SNIP 1.081
Uncovering fatigue damage development in unidirectional composites using x-ray computed tomography

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Organisations: Department of Wind Energy, Composites and Materials Mechanics
Authors: Mikkelsen, L. P. (Intern)
Number of pages: 1
Publication date: 2017
Main Research Area: Technical/natural sciences
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Abstract

Bibliographical note
http://talks.cam.ac.uk/talk/index/69642
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Unidirectional Fibre Composite Characterisation from X-ray Tomography

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Main Research Area: Technical/natural sciences
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A strain gauge
The invention relates to a strain gauge of a carrier layer and a meandering measurement grid positioned on the carrier layer, wherein the strain gauge comprises two reinforcement members positioned on the carrier layer at opposite ends of the measurement grid in the axial direction. The reinforcement members are each placed within a certain axial distance to the measurement grid with the axial distance being equal to or smaller than a factor times the grid spacing. The invention further relates to a multi-axial strain gauge such as a bi-axial strain gauge or a strain gauge rosette where each of the strain gauges comprises reinforcement members. The invention further relates to a method for manufacturing a strain gauge as mentioned above.

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Organisations: Department of Wind Energy, Composites and Materials Mechanics
Authors: Mikkelsen, L. P. (Intern), Zike, S. (Intern)
Publication date: 11 Feb 2016
3D X-ray CT of fatigue damage in fibre composites

General information
State: Published
Organisations: Department of Wind Energy, Composites and Materials Mechanics, University of Manchester
Authors: Jespersen, K. M. (Intern), Zangenberg Hansen, J. (Ekstern), Lowe, T. (Ekstern), Withers, P. J. (Ekstern), Mikkelsen, L. P. (Intern)
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Main Research Area: Technical/natural sciences
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Source-ID: 127609168
Publication: Research › Poster – Annual report year: 2016

Approach for investigations of progressive fatigue damage in 3D in fibre composites using X-ray tomography

Understanding fatigue damage initiation and evolution in the load carrying laminates inside wind turbine blade plays a key factor designing longer and lighter turbine blades. Thereby, it is possible to lower the Cost of Energy for the wind energy based electricity production either by simply building larger wind turbines or by upgrading existing turbines for lower wind classes’. In the presented work, a Zeiss Xradia Versa 520 scanner has been used in connection with ex-situ fatigue testing with the purpose of identifying fibre failure during the fatigue loading. The load carrying laminates is typically based on stacking of a number of non-crimp fabrics in where the load carrying fibres are oriented in the axial direction of the wind turbine blade. In order to ease the handling of the fabric during the dry fabric layup and ensure a good alignment of the final laminates, approximately 10% of the fibres are oriented in secondary directions. Thereby, the non-crimp fabric is given some shear stiffness. The figures below show the results from a scanning of a fatigue damaged material. The width of the full scanned cross section is 15 mm, while the size of the zoomed scan is approximately 2.5 mm. The small black points visible in the two lower slices taken from the zoomed scan indicate fibre failure. From the red slice, the fibre failure is seen to be located in regions with the backing bundles are located. The backing bundles in the red slice are pointing out of the figure plan. In the green slice, it can be seen that the fibre failure in the load carrying fibres, are following the 45 degree orientation of the backing bundles where the 45 degree backing bundle can be seen at the left side of the green slice figure. In addition, to the scan case shown here, an ex-situ study of the fibre progression (Jespersen & Mikkelsen, 2016) has been performed. An ex-situ study where it has been important to design a good gripping strategy inside the scanning machine. Doing this, it has been possible to scan the same region multiple times. Thereby, a progressive fatigue damage evolution has been observed.

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Bibliographical note
A simplified model predicting the weight of the load carrying beam in a wind turbine blade

Based on a simplified beam model, the loads, stresses and deflections experienced by a wind turbine blade of a given length is estimated. Due to the simplicity of the model used, the model is well suited for work investigating scaling effects of wind turbine blades. Presently, the model is used to predict the weight of the load carrying beam when using glassfibre reinforced polymers, carbon fibre reinforced polymers or an aluminium alloy as the construction material. Thereby, it is found that the weight of a glass fibre wind turbine blade is increased from 0.5 to 33 tons when the blade length grows from 20 to 90 m. In addition, it can be seen that for a blade using glass fibre reinforced polymers, the design is controlled by the deflection and thereby the material stiffness in order to avoid the blade to hit the tower. On the other hand if using aluminium, the design will be controlled by the fatigue resistance in orderto making the material survive the 100 to 500 million load cycles experience of the wind turbine blade throughout the lifetime. The aluminium blade is also found to be considerably heavier compared with the composite blades.

Characterization Of Biaxial Strain Of Poly(L-Lactide) Tubes

Poly(L-lactide) (PLLA) in its L-form has promising mechanical properties. Being a semi-crystalline polymer, it can be subjected to strain-induced crystallization at temperatures above Tg and can thereby become oriented. Following a simultaneous (SIM) biaxial strain process or a sequential (SEQ) biaxial strain process, the mechanical properties of biaxial strained tubes can be further improved. This study investigated these properties in relation to their morphology and crystal orientation. Both processes yield the same mechanical strength and modulus, yet exhibit different crystal orientation. Through further WAXS analysis it was found that the SEQ biaxial strain yields larger interplanar spacing and distorted
crystals and looser packing of chains. However, this does not influence the mechanical properties negatively. A loss of orientation in SEQ biaxial strained samples at high degrees of strain was detected, but not seen for SIM biaxial strain, and did not correlate with mechanical performance in either case. However, post-annealing reduced the orientation to the same level in both cases, and the modulus and strength is decreased for both SIM and SEQ biaxial. It is therefore concluded that mechanical properties after biaxial strain are related to strain-induced amorphous orientation and the packing of crystals, rather than strain-induced crystallinity.
Experimental determination of the micro-scale strength and stress-strain relation of an epoxy resin

An approach is developed for determining the stress-strain law and a failure stress appropriate for micro-mechanical models of polymer materials. Double cantilever beam test specimens, made of an epoxy polymer with notches having finite root radius, were subjected to pure bending moments in an environmental scanning electron microscope. The recorded images were used to measure strains around the notch with a 2D digital image correlation method. The strain in front of the notch was found to reach 20% before the failure initiation, which significantly exceeds the failure strain measured at the macro-scale (5–6%). The hardening exponent of a power law hardening material was obtained by the use of the J-integral, estimating the strain energy density around the notch. The hardening exponent was found to be within the range of 5–6 and the corresponding micro-scale failure stress was in the range of 220–300 MPa. Furthermore, the experimentally measured strains around the notch edge were compared with the strain field of the HRR-field. In addition, our experimental study shows that the strain fields between the notches with different notch root radii are comparable, if all length parameters are normalized with the width of deformed notch.

General information
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Organisations: Department of Wind Energy, Composites and Materials Mechanics
Authors: Zike, S. (Intern), Sørensen, B. F. (Intern), Mikkelsen, L. P. (Intern)
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Scopus rating (2014): SJR 2.446 SNIP 3.493
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 2.047 SNIP 3.298
ISI indexed (2013): ISI indexed no
BFI (2012): BFI-level 1
Scopus rating (2012): SJR 2.002 SNIP 3.254
ISI indexed (2012): ISI indexed no
BFI (2011): BFI-level 1
Scopus rating (2011): SJR 1.412 SNIP 2.55
ISI indexed (2011): ISI indexed no
BFI (2010): BFI-level 1
Scopus rating (2010): SJR 1.074 SNIP 1.819
BFI (2009): BFI-level 1
Scopus rating (2009): SJR 0.972 SNIP 1.813
BFI (2008): BFI-level 1
Scopus rating (2008): SJR 0.941 SNIP 1.371
Scopus rating (2007): SJR 0.834 SNIP 1.678
Scopus rating (2006): SJR 0.669 SNIP 1.444
Scopus rating (2005): SJR 0.658 SNIP 1.374
Scopus rating (2004): SJR 0.517 SNIP 1.131
Scopus rating (2003): SJR 0.573 SNIP 1.236
Scopus rating (2002): SJR 0.599 SNIP 1.161
Scopus rating (2001): SJR 0.381 SNIP 0.642
Scopus rating (2000): SJR 0.256 SNIP 0.689
Micro-scale test, Micro-mechanical models, In-situ testing, Polymer/fibre composites, Epoxy matrix

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Ex-situ time-lapse x-ray CT study of 3D micro-structural fatigue damage evolution in uni-directional composites

In this study, the progress of damage under tension-tension fatigue of a uni-directional (UD) glass fibre composite made from a non-crimp fabric is studied using transilluminated white light imaging (TWLI) and X-ray computed tomography (CT). TWLI images are automatically captured throughout the fatigue test, and at two damage levels the test is stopped and the sample is examined by X-ray computed tomography. From the TWLI observations it is apparent that part of the measured initial stiffness drop might be caused by edge effects rather than off-axis cracking. Some of the off-axis cracks are seen to initiate already after the first cycle, whereas some grow gradually and others appear suddenly during cycling. The off-axis cracks are observed to saturate after a few thousand cycles. The UD fibre fracture damage in the region observed by X-ray CT is probably already saturated at the first interruption point, as no significant change is seen between the two X-ray images. However, the study indicates how TWLI can be used as an initial indicator to locate damage regions at an early stage for the future ex-situ X-ray CT experiments.

Fatigue damage assessment of uni-directional non-crimp fabric reinforced polyester composite using X-ray computed tomography

In this study, the progression of tension-tension fatigue (R=0.1) damage in a unidirectional (UD) composite made from a non-crimp glass fibre fabric used for wind turbine blades is investigated using multi-scale 3D X-ray computed tomography (CT). Initially, a representative volume is examined at one specific damage level. UD fibre fractures are only observed close to the supporting thin transverse backing layers. Furthermore, UD fibre fractures are only observed at locations where backing fibre bundles intersect one another and are at the same time locally close to a UD bundle. In addition, to study the progression of damage as a function of stiffness degradation at higher resolution four samples are subjected to different numbers of cycles before examination by CT. One sample is examined during the initial stiffness drop, two samples during stable stiffness degradation, and one close to final failure. Damage is observed to occur as chains of individual fibre breaks or clusters of fibre fractures rather than large fracture planes. Our work indicates how fracture of UD fibres initiates from intersecting ±80° backing bundles extending progressively further into the UD layer. The fibre fracture zone becomes more diffuse further from the backing layer. Our work supports a scheme explaining stiffness degradation in terms of UD fibre damage accumulation and demonstrates the importance of 3D and ideally time-lapse imaging studies.

General information
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Organisations: Department of Wind Energy, Composites and Materials Mechanics, University of Manchester
Authors: Jespersen, K. M. (Intern), Wang, Y. (Ekstern), Zangenberg Hansen, J. (Ekstern), Lowe, T. (Ekstern), Withers, P. J. (Ekstern), Mikkelsen, L. P. (Intern)
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Conference: 17th European Conference on Composite Materials , Munich, Germany, 26/06/2016 - 26/06/2016
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State: Published
Organisations: Department of Wind Energy, Composites and Materials Mechanics, University of Manchester
Authors: Jespersen, K. M. (Intern), Zangenberg Hansen, J. (Ekstern), Lowe, T. (Ekstern), Withers, P. J. (Ekstern), Mikkelsen, L. P. (Intern)
Pages: 94–103
Publication date: 2016
Main Research Area: Technical/natural sciences

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Volume: 136
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Fatigue damage observed non-destructively in fibre composite coupon test specimens by X-ray CT

This study presents a method for monitoring the 3D fatigue damage progression on a micro-structural level in a glass fibre/polymer coupon test specimen by means of laboratory X-ray Computed Tomography (CT). A modified mount and holder made for the standard test samples to fit into the X-ray CT scanner along with a tension clamp solution is presented. Initially, the same location of the test specimen is inspected by ex-situ X-ray CT during the fatigue loading history, which shows the damage progression on a micro-structural level. The openings of individual uni-directional (UD) fibre fractures are seen to generally increase with the number of cycles, and new regions of UD fibre fractures also appear. There are some UD fibre fractures that are difficult to detect since their opening is small. Therefore, the effect of tension on the crack visibility is examined afterwards using a tension clamp solution. With applied tension some additional cracks become visible and the openings of fibre fractures increases, which shows the importance of applied tension during the scan.

General information
State: Published
Organisations: Department of Wind Energy, Composites and Materials Mechanics
Authors: Jespersen, K. M. (Intern), Mikkelsen, L. P. (Intern)
Number of pages: 9
FBG_SiMul V1.0: Fibre Bragg grating signal simulation tool for finite element method models

FBG_SiMul V1.0 is a tool to study and design the implementation of fibre Bragg grating (FBG) sensors into any kind of structure or application. The software removes the need of an fibre optic expert user, becoming more obvious the sensor response of a structural health monitoring solution using FBG sensors. The software uses a modified T-Matrix method to simulate the FBG reflected spectrum based on the stress and strain from a finite element method model. The article describes the theory and algorithm implementation, followed by an empirical validation.
A novel method to assess a crack growing/damage event in fibre reinforced plastic, using conventional single mode Fibre Bragg Grating sensors embedded in the host material is presented in this article. Three different damage mechanisms that can change the sensor output, longitudinal strain $\varepsilon_{xx}$, transversal stress $\sigma_{yy}$, and non-uniform strain $\varepsilon_{x(x)}$, were identified. These damage mechanisms were identified during the experimental testing and linked with the sensor output using a digital image correlation technique. A dedicated algorithm to extract information from the reflected spectrum that enables crack detection was developed. Double Cantilever Beams specimens made with glass fibre and bonded with structural adhesive, were instrumented with a Fibre Bragg Grating array embedded in the host material, and tested using an experimental fracture procedure. This method was successfully validated in three different loading conditions, where were obtained very promising results that enable crack growth monitoring.
Multi-life-stage monitoring system based on fibre Bragg grating sensors for more reliable wind turbine rotor blades:
Experimental and numerical analysis of deformation and failure in composite materials

One of today’s greatest global challenges is the need for clean, reliable, and renewable sources of energy, and wind energy has a key role in this process. However, in order to compete with other less “green” sources of energy the cost to produce wind made electricity needs to be reduced. One way to achieve this is by improving the reliability of wind turbine components and optimising operation and maintenance strategies. This PhD project is part of the European research project MareWint, where the main objective is to develop an innovative approach for coupled multi physics cosimulation, testing, design and optimisation of offshore wind turbines. The MareWint main scientific objective is to optimise the design of offshore wind turbines, maximise reliability, and minimise maintenance costs. Integrated within the innovative rotor blades work-package, this PhD project is focused on damage analysis and structural health monitoring of wind turbine blades. The work presented sets the required framework to develop a monitoring system based on fibre Bragg gratings (FBG), which can be applied to the different life stages of a wind turbine blade. In this concept, the different measured physical parameters are used to improve the design process, and the implemented sensor are used to control the manufacturing and operation stage of a wind turbine rotor blade. The FBG sensors measurement principle is analysed from a multi-life-stage (design, material testing, manufacturing, and operation) perspective, and supported/validated by numerical models, software tools, signal post-processing, and experimental validation. The damage in the wind turbine rotor blade is analysed from a material perspective (fibre reinforced polymers) and used as a design property, meaning that damage is accepted in an operational wind turbine as long as it is monitored. Thus, a novel crack/damage detection method using FBG sensors is presented, and software/tools are developed for signal simulation and post-processing. The first part of the thesis is an introduction to the multi-life-stage monitoring system based on FBG sensors and the damage tolerant design of fibre reinforced materials, where the different theory and numerical models used are presented.
second part of the thesis is a compilation of scientific journal papers, in which the use of FBG sensors to monitor the different life-stages of the wind turbine rotor blade is described in more detail. In Paper P1, a methodology for reliable design and maintenance of wind turbine rotor blades based on a damage tolerance and structural health monitoring approach is presented. Paper P2 presents a novel method to obtain independent strain and temperature measurements using embedded FBG sensors in polymeric tensile tests. In paper P3, a novel method for assessing crack growth in fibre reinforced polymer or structural adhesive bonded structures by combining conventional measured parameters with parameters associated with measurement errors is presented. Paper P4 presents a FBG signal post-processing tool. In paper P5, a software development tool to simulate the FBG signal from a finite element method model is described. Paper P6 fits within the manufacturing stage, describing a residual strain measurement solution based on FBG sensors. In paper P7, the fracture process zone length in double cantilever beam specimens is analysed analytically and numerically.

**General information**
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Organisations: Department of Wind Energy, Composites and Materials Mechanics
Authors: Pereira, G. F. (Intern), Mikkelsen, L. P. (Intern), McGugan, M. (Intern), Sørensen, B. F. (Intern)
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DTU Wind Energy PhD-0062, DTU Wind Energy PhD-62
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PhD_Thesis_Gilmar_F_Pereira_Final_Version.pdf

**Residual Strains and Their Relation to the Fatigue Damage Evolution in Composite Materials**
The fatigue performance of unidirectional glass fibre reinforced epoxy is found to be highly dependent on at which curing temperature the composite is manufactured. Performing the curing at 110C instead of at 40C is found to reduce the lifetime dramatically with a factor of 10. Even though, the volumetric shrinkage of the epoxy at the two curing cycles is identical, the resulting residual strain in an embedded optical fibre measured using fibre Bragg Grating is found to be increased with a factor of 3. Together with, 3D x-ray tomography of partly fatigued test specimens there is an indication of a link between the measured increased residual strains with the governing fatigue damage mechanism.

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Conference: 24th International Congress of Theoretical and Applied Mechanics, Montreal, Canada, 21/08/2016 - 21/08/2016
Source: PublicationPreSubmission
Source-ID: 125556130
Publication: Research - peer-review › Article in proceedings – Annual report year: 2016
Segmentation of individual fibres in a uni-directional composite from 3D X-ray computed tomography data

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Organisations: Department of Applied Mathematics and Computer Science, Image Analysis & Computer Graphics, Department of Wind Energy, Composites and Materials Mechanics
Authors: Emerson, M. J. (Intern), Jespersen, K. M. (Intern), Dahl, A. B. (Intern), Conradsen, K. (Intern), Mikkelsen, L. P. (Intern)
Number of pages: 1
Publication date: 2016
Main Research Area: Technical/natural sciences
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Source-ID: 127748374
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**Strong and light-weight materials made of reinforced honeycomb sandwich structures**
In the transport sector, new strong and light-weight materials can reduce the weight of airplanes, cars and containers. This will lead to a reduction in CO2 emissions as less weight needs to be transported. The requirements for these light-weight materials are that they need to be strong and have a low cost, in order for them to compete with conventionally used materials like steel or aluminum. A great candidate for a material that can fulfill these requirements of being light, strong and low cost is a sandwich material. A sandwich material is a material that is made of a light-weight core with a thin layer of steel or fibre composite on top and bottom of the core. The core in a sandwich material is typically made of a honeycomb structure. Honeycomb structures have been used for more than 50 years. Until now honeycombs have been expensive to produce. However, with a new production method it is now possible to produce honeycombs structures at a low cost. In a large collaborative European project called INCOM, the possibility of reinforcing the honeycomb structure is investigated. The honeycomb structure is reinforced with sustainable fibres as the fibres are extracted from saw dust.

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http://www.sustain.dtu.dk/

**Bibliographical note**
Sustain Abstract M-2
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**X-ray based micromechanical finite element modeling of composite materials**
This is a study of a uni-directional non-crimp fabric reinforced epoxy composite material typically used as the load carrying laminate in wind turbine blades. Based on a 3D x-ray tomography scan, the bundle and fibre/matrix structure of the composite is segmented. This segmentation is used in a multi-scale finite element model bridging the gap from the individual fibers organized in bundles to the stitched non-crimp fabric used for building up the load carrying laminates.

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Crack Detection in Fibre Reinforced Plastic Structures Using Embedded Fibre Bragg Grating Sensors: Theory, Model Development and Experimental Validation

In a fibre-reinforced polymer (FRP) structure designed using the emerging damage tolerance and structural health monitoring philosophy, sensors and models that describe crack propagation will enable a structure to operate despite the presence of damage by fully exploiting the material's mechanical properties. When applying this concept to different structures, sensor systems and damage types, a combination of damage mechanics, monitoring technology, and modelling is required. The primary objective of this article is to demonstrate such a combination. This article is divided in three main topics: the damage mechanism (delamination of FRP), the structural health monitoring technology (fibre Bragg gratings to detect delamination), and the finite element method model of the structure that incorporates these concepts into a final and integrated damage-monitoring concept. A novel method for assessing a crack growth/damage event in fibre-reinforced polymer or structural adhesive-bonded structures using embedded fibre Bragg grating (FBG) sensors is presented by combining conventional measured parameters, such as wavelength shift, with parameters associated with measurement errors, typically ignored by the end-user. Conjunctly, a novel model for sensor output prediction (virtual sensor) was developed using this FBG sensor crack monitoring concept and implemented in a finite element method code. The monitoring method was demonstrated and validated using glass fibre double cantilever beam specimens instrumented with an array of FBG sensors embedded in the material and tested using an experimental fracture procedure. The digital image correlation technique was used to validate the model prediction by correlating the specific sensor response caused by the crack with the developed model.
Crack Growth Monitoring by Embedded Optical Fibre Bragg Grating Sensors: Fibre Reinforced Plastic Crack Growing Detection

This article presents a novel method to assess a crack growing/damage event in fibre reinforced plastic, or adhesive using Fibre Bragg Grating (FBG) sensors embedded in a host material. Different features of the crack mechanism that induce a change in the FBG response were identified. Double Cantilever Beams specimens made with glass fibre glued with structural adhesive, were instrumented with an array of FBG sensors embedded in the material and tested using an experimental fracture procedure. A digital image correlation technique was used to determine the presence of the specific phenomena caused by the crack, and to correlate with the FBG sensor. A Material-Sensor model was developed in order to predict the sensor output response under a crack/delamination situation, which can be used as an analysis tool for future application of this measurement technology in more complex structures.

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Crack growth monitoring in composite materials using embedded optical Fiber Bragg Grating sensor
In this paper a novel method to assess a crack growing/damage event in fiber reinforced plastic, or adhesive using Fiber Bragg Grating (FBG) sensors embedded in a host material is shown. Different features of the crack mechanism that induce a change in the FBG response were identified. Double Cantilever Beams specimens made with glass fibre glued with structural adhesive, were instrumented with an array of FBG sensors embedded in the material and tested using an experimental fracture procedure. A digital image correlation technique was used to determine the presence of the specific phenomena caused by the crack, and to correlate with the FBG sensor. An algorithm was developed that analyses the reflected peak at each measurement time, and calculates the contribution of each fracture phenomenon to the change in the FBG response. This Material-Sensor model was implemented in a Finite Element Method (FEM) Model of the DCB specimen, to simulate the response of the FBG sensor during the process of crack growth, proving that this Material-Sensor model can be used as an analysis tool for future application of this measurement technology in more complex structures.

General information
Damage tolerant design and condition monitoring of composite material and bondlines in wind turbine blades: Failure and crack propagation

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

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Elastocaloric cooling device: Materials and modeling

In the last decade we have witnessed the development of alternative solid-state cooling technologies based on so-called ferroic (caloric) effects. A large effort nowadays is devoted to investigating solid-state refrigeration using the magnetocaloric effect (change of temperature upon application of a magnetic field). However, the possibility of inducing a thermodynamic transition by means of mechanical stress (martensitic transformation), i.e. the elastocaloric effect in
superelastic materials, opens up new routes for solid-state refrigeration. In the recent years a large elastocaloric effect was demonstrated in Ni-Ti-based, Cu-based as well as Fe-based shape memory alloys. Although these studies showed a great potential of the elastocaloric effect, there has not yet been much activities on development of elastocaloric cooling devices. Some ideas on elastocaloric cooling device have already been presented, but there is still a lack of knowledge and information about its actual cooling potential.

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Elastocaloric effect of Ni-Ti wire for application in a cooling device
We report on the elastocaloric effect of a superelastic Ni-Ti wire to be used in a cooling device. Initially, each evaluated wire was subjected to 400 loading/unloading training cycles in order to stabilize its superelastic behavior. The wires were trained at different temperatures, which lead to different stabilized superelastic behaviors. The stabilized (trained) wires were further tested isothermally (at low strain-rate) and adiabatically (at high strain-rate) at different temperatures (from 312 K to 342 K). We studied the impact of the training temperature and resulting superelastic behavior on the adiabatic temperature changes. The largest measured adiabatic temperature change during loading was 25 K with a corresponding 21 K change during unloading (at 322 K). A special focus was put on the irreversibilities in the adiabatic temperature changes between loading and unloading. It was shown that there are two sources of the temperature irreversibilities: the hysteresis (and related entropy generation) and the temporary residual strain immediately after unloading, respectively. The latter results in the temporary bending of the wire and reduced negative adiabatic temperature change. The paper also shows the impact of the applied strain on the adiabatic temperature changes as well as the distribution of the elastocaloric effect over the wire during loading in the case of two wires trained at different temperatures and the virgin wire, respectively. In the end, we propose guidelines about the required material properties for an efficient elastocaloric cooling device. © 2015 AIP Publishing LLC.

Elastocaloric effect of Ni-Ti wire for application in a cooling device
We report on the elastocaloric effect of a superelastic Ni-Ti wire to be used in a cooling device. Initially, each evaluated wire was subjected to 400 loading/unloading training cycles in order to stabilize its superelastic behavior. The wires were trained at different temperatures, which lead to different stabilized superelastic behaviors. The stabilized (trained) wires were further tested isothermally (at low strain-rate) and adiabatically (at high strain-rate) at different temperatures (from 312 K to 342 K). We studied the impact of the training temperature and resulting superelastic behavior on the adiabatic temperature changes. The largest measured adiabatic temperature change during loading was 25 K with a corresponding 21 K change during unloading (at 322 K). A special focus was put on the irreversibilities in the adiabatic temperature changes between loading and unloading. It was shown that there are two sources of the temperature irreversibilities: the hysteresis (and related entropy generation) and the temporary residual strain immediately after unloading, respectively. The latter results in the temporary bending of the wire and reduced negative adiabatic temperature change. The paper also shows the impact of the applied strain on the adiabatic temperature changes as well as the distribution of the elastocaloric effect over the wire during loading in the case of two wires trained at different temperatures and the virgin wire, respectively. In the end, we propose guidelines about the required material properties for an efficient elastocaloric cooling device. © 2015 AIP Publishing LLC.
This article presents a novel method to simulate the sensor output response of a Fibre Bragg Grating (FBG) sensor when embedded in a host material (Composite material or adhesive), during a crack growing/damage event. A finite element model of the crack growth mechanisms was developed, and different fracture modes were addressed. Then an output algorithm was developed to predict the sensor spectrum change during the different stages of the crack growing. Thus, it is possible to identify specific phenomenon that will only happen within the proximity of a crack, as compression field ahead the crack or non-uniform strain, and then identify the presence of such damage in the structure. Experimental tests were conducted in order to validate this concept and support the model. The FBG sensor response model was applied in a delamination of a Wind Turbine trailing edge, to demonstrate the applicability of this technique to more complicated structures, and to be used as a structural health monitoring design tool.
Fatigue damage evolution in fibre composites for wind turbine blades

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Finite Element Verification of Non-Homogeneous Strain and Stress Fields during Composite Material Testing
Uni-directional glass fiber reinforced polymers play a central role in the task increasing the length of wind turbine blades and thereby lowering the cost of energy from wind turbine installations. During this, optimizing the mechanical performance regarding material stiffness, compression strength and fatigue performance is essential. Nevertheless,
From Measurements Errors to a New Strain Gauge Design

Significant over-prediction of the material stiffness in the order of 1-10% for polymer based composites has been experimentally observed and numerically determined when using strain gauges for strain measurements instead of non-contact methods such as digital image correlation or less stiff methods such as clip-on extensometers. In the present work, this has been quantified through a numerical study for three different strain gauges. In addition, a significant effect of a thin polymer coating or biaxial layer in the erroneous using strain gauges has been observed. An erroneous which can be significantly decreased using an enhanced grid design of the measuring grid.
Micromechanical Investigation of Fatigue Damage in Uni-Directional Fibre Composites
In this study, 3D x-ray computed tomography (XCT) is used to study fatigue damage mechanisms of a uni-directional (UD) glass fibre composite used in wind turbine blades. The challenges related to using 3D XCT for fatigue damage assessment over time is outlined, and a cut-out of a specimen previously subjected to tension-tension fatigue loading is examined. Broken UD load-carrying fibres are observed locally close to the thin off-axis backing support layers and are spreading out in a local damage zone in the UD bundle close to the backing. The common factors of the fatigue damaged regions found in this study were intertwining backing bundles in direct contact with the UD bundle and a locally high fibre volume fraction at the backing. Other factors like fibre misalignment and fibre radii could have an effect; however this is not obvious from the obtained results. Further studies on a larger dataset should be performed to examine this in more detail.

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Micromechanical Time-Lapse X-ray CT Study of Fatigue Damage in Uni-Directional Fibre Composites
This study considers fatigue damage evolution in a uni-directional (UD) glass fibre composite used for wind turbine blades which is manufactured from a non-crimp fabric. It is the initial part of a time-lapse study where the damage progression is followed in a sample during a fatigue test. In the current study 3D X-ray Computed Tomography (XCT) is used to characterise the fatigue damage in the material at three different stages of the fatigue life of a tension-tension fatigue test. 3D XCT is performed on rectangular samples (4x4x110mm) cut out from pre-fatigued full-size fatigue test specimens. The geometry of the cut-out is similar to that which will be used in the time-lapse study. As the micro-mechanical damage mechanisms are small features, it is necessary to obtain a high scan resolution which sets a limit to how large the field of view can be. Therefore, it is necessary to perform several scans on each sample to locate damaged regions even for the cut out sample geometry. For the chosen down-scaled sample geometry it was possible to visualize individual broken UD fibres, matrix cracks, and delaminations in the scans. Broken UD fibres are observed locally close to intertwining regions of the supporting backing bundles where they are in direct contact with the UD bundles. Additionally matrix cracks are observed in the off-axis backing layer at locations where the UD fibres are broken.

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Micro-Scale Experiments and Models for Composite Materials with Materials Research

Numerical models are frequently implemented to study micro-mechanical processes in polymer/fibre composites. To ensure that these models are accurate, the length scale dependent properties of the fibre and polymer matrix have to be taken into account. Most often this is not the case, and material properties acquired at macro-scale are used for micro-mechanical models. This is because material properties at the macro-scale are much more available and the test procedures to obtain them are well defined. The aim of this research was to find methods to extract the micro-mechanical properties of the epoxy resin used in polymer/fibre composites for wind turbine blades combining experimental, numerical, and analytical approaches. Experimentally, in order to mimic the stress state created by a void in a bulk material, test samples with finite root radii were made and subjected to a double cantilever beam test in an environmental scanning electron microscope. Deformation around the notches was measured using a digital image correlation method. Analytically, the experimental results were related to the HRR theory, and the concept of strain energy density was used to find the micro-scale stress-strain relationship and failure strength. In the numerical approach, the experimentally measured strain fields were matched with the numerically predicted strain fields for different power law hardening material models. In addition, this study includes evaluation of the strain gauge accuracy, when devices are applied on polymer and polymer/composite materials.
Small scale plasticity and compressive properties of composites

The compression strength of uni-directional composite materials is mainly governed by the fiber-misalignment and the plasticity of the matrix material [1]. Therefore, in order to improve the compression behavior of uni-directional composite materials, a focus on those terms is necessary. In the present work, the influence of the mechanical properties of the matrix material on the compression strength is studied by changing the temperature during mechanical testing and thereby making it possible changing the matrix properties keeping all other properties in the experimental setup constant. It is demonstrated how going from the more ductile high temperature case to the brittle low temperature case will increase the compression strength significantly with more than 30%. This behavior are validated experimentally as well as numerically using a non-linear smeared out composite material law [2] implemented in the commercial finite element code Abaqus [3]. In addition, in a supplementary study, taken into account the length scale effect of the yielding behavior using a strain gradient dependent plasticity law [4] implemented as a user element [5], it is possible investigating the scale effect on the yielding behavior sub-micron small region between the fibers in a conventional composite material. During this, the effect of higher order boundary condition suppressing the plastic deformation at the fiber/matrix interfaces is analyzed. It is demonstrated that taken such effects into account significantly enhanced the stresses level during shear deformation. Shear deformation governing the compressive failure mechanism in uni-directional composite materials.

Structural health monitoring method for wind turbine trailing edge: Crack growth detection using Fibre Bragg Grating sensor embedded in composite materials

In this article a novel method to assess a crack growing/damage event in composite material using Fibre Bragg Grating (FBG) sensors embedded in a host material and its application into a composite material structure, Wind Turbine Trailing Edge, is presented. A Structure-Material-FBG model was developed, which simulates the FBG sensor output response, when embedded in a host material, during a crack growing/damage event. This Structure-Material-FBG model provides a tool to analyse the application of this monitoring technique in other locations/structures, by predicting the sensor output and deciding, based on this, the optimal sensor distribution/configuration. All the different features in the fracture (cracking) mechanism that can induce a change in the FBG response were identified. With this, it was possible to identify specific phenomenon that will only happen in the proximity of a crack, such as compression fields ahead the crack or non-uniform strain fields, and then identify the presence of such damage in the structure. Experimental tests were conducted to fully characterize this concept and support the model. Double Cantilever Beams (DCB), made with two glass fibre beams glued with structural adhesive, were instrumented with one array of FBG sensors embedded into the host material, and digital image correlation technique was used to determine the presence of the specific phenomena caused by the crack, and to correlate with the FBG sensor.
The Elastocaloric Effect: A Way to Cool Efficiently

3D X-Ray Computed Tomography (XCT) of Fatigue Damage Evolution in UD Glass Fibre Composite
Consequence of reduced necrotic bone elastic modulus in a Perthes' hip

Introduction
Perthes is a destructive hip joint disorder characterized as a malformation of the femoral head which affects young children. Several studies have shown the change of mechanical properties of the femoral head in Perthes' disease. However, the consequence of the changes in bone mechanical properties in a Perthes' hip is not well established. Due to the material differences, changes in bone mechanical properties might lead to localization of stress and deformation. Thus, the objective of this study was to investigate the effects of reduced elastic modulus of necrotic bone in the femoral head using Finite Element Analysis (FEA).

Methods
The femoral and necrotic bone of the affected hip of a Perthes' patient was segmented from the MR images using Simpleware. The segmented parts were exported to SolidWorks to build the 3D solid model and Comsol for FEA. A load of 750 N (300% body weight) was applied on the top of the femoral head. The distal part of the femur was fixed. The same
Poisson's ratio 0.3 was set for the femoral and necrotic bone. The elastic modulus (E) of femoral bone was 500 MPa. To investigate the effects of reduced elastic modulus, the necrotic bone E was reduced as 400 MPa, 100 MPa, 10 MPa and 1 MPa.

Results
The results show that the bone deformation markedly increased when the necrotic bone E was 1 MPa. The maximum displacements were 1.79 mm, 1.80 mm, 1.92 mm and 3.74 mm for E = 400 MPa, E = 100 MPa, E = 10 MPa and E = 1 MPa, respectively. The displacement patterns were uniformly distributed when the necrotic bone E was 400 MPa and 100 MPa. Conversely, the displacements were more localized (concentrated at the necrotic bone) when the necrotic bone E was 10 MPa and 1 MPa.

Conclusions
The deformation patterns of a Perthes' hip reveals that the disease may be more aggravated due to localization of bone deformation as a result of reduction of the elastic modulus of necrotic bone. The method in this study may be useful in surgical planning.
In this work an experimental investigation on damage initiation and evolution in laminates under cyclic loading is presented. The stacking sequence [0/θ2/0/-θ2]s has been adopted in order to investigate the influence of the local multiaxial stress state in the off-axis plies and the possible effect of different thickness between the thin (2-plies) and the thick (4-plies) layers. Results are presented in terms of S–N curves for the initiation of the first cracks, crack density evolution, stiffness degradation and Paris-like curves for the crack propagation phase. The values of the off-axis angle θ has been chosen in order to obtain local multiaxial stress states in the off-axis plies similar to those in previous studies for biaxially loaded tubes. Results concerning damage initiation and growth for these two specimen configurations are shown to be consistent for similar local multiaxial stress states.

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Damage tolerant design: failure and crack propagation in composites

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FEM model of Embedded Fibre Bragg Grating Sensor Response: Crack Growing Detection
Optimal Design of Composite Structures Under Manufacturing Constraints

This thesis considers discrete multi-material and thickness optimization of laminated composite structures including local failure criteria and manufacturing constraints. Our models closely follow an immediate extension of the Discrete Material Optimization scheme, which allows simultaneous determination of the appropriate laminate thickness and the material choice in the structure. The optimal design problems that arise are stated as nonconvex mixed integer programming problems. We resort to different reformulation techniques to state the optimization problems as either linear or nonlinear convex mixed integer 0–1 programming problems. The manufacturing constraints have been treated by developing explicit models with favorable properties.

In this thesis we have developed and implemented special purpose global optimization methods and heuristic techniques for solving this class of problems. The continuous relaxation of the mixed integer programming problems is being solved by an implementation of a primal–dual interior point method for nonlinear programming that updates the barrier parameter adaptively. The method is chosen for its excellent convergence properties and the ability of the method to react swiftly to changes of scale in the problem. As opposed to the original Discrete Material Optimization methodology, we obtain discrete feasible solutions to the stated mixed 0–1 convex problems by the application of advanced heuristic techniques. Our heuristics are based on solving a finite sequence of well-posed optimization problems. They provide us with a discrete feasible solution or correctly determine problem infeasibility. Our aim is to solve the considered problems to proven global optimality. We propose a combination of the convergent Outer Approximation and Local Branching algorithms to perform the global optimization. The efficiency of the proposed models is examined on a set of well-defined discrete multi-material and thickness optimization problems originating from the literature. The inclusion of manufacturing limitations along with structural considerations in the early design phase results in structures with better structural performance reducing the need of manually post-processing the found designs.

Orientation of PLLA tubes under simultaneous biaxial strain

This thesis considers discrete multi-material and thickness optimization of laminated composite structures including local failure criteria and manufacturing constraints. Our models closely follow an immediate extension of the Discrete Material Optimization scheme, which allows simultaneous determination of the appropriate laminate thickness and the material choice in the structure. The optimal design problems that arise are stated as nonconvex mixed integer programming problems. We resort to different reformulation techniques to state the optimization problems as either linear or nonlinear convex mixed integer 0–1 programming problems. The manufacturing constraints have been treated by developing explicit models with favorable properties.

In this thesis we have developed and implemented special purpose global optimization methods and heuristic techniques for solving this class of problems. The continuous relaxation of the mixed integer programming problems is being solved by an implementation of a primal–dual interior point method for nonlinear programming that updates the barrier parameter adaptively. The method is chosen for its excellent convergence properties and the ability of the method to react swiftly to changes of scale in the problem. As opposed to the original Discrete Material Optimization methodology, we obtain discrete feasible solutions to the stated mixed 0–1 convex problems by the application of advanced heuristic techniques. Our heuristics are based on solving a finite sequence of well-posed optimization problems. They provide us with a discrete feasible solution or correctly determine problem infeasibility. Our aim is to solve the considered problems to proven global optimality. We propose a combination of the convergent Outer Approximation and Local Branching algorithms to perform the global optimization. The efficiency of the proposed models is examined on a set of well-defined discrete multi-material and thickness optimization problems originating from the literature. The inclusion of manufacturing limitations along with structural considerations in the early design phase results in structures with better structural performance reducing the need of manually post-processing the found designs.
Strain Gauge Design for Compliant Materials

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DCB Test Sample Design for Micro-Mechanical Testing

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Authors: Zike, S. (Intern), Mikkelsen, L. P. (Intern), Sørensen, B. F. (Intern)
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Influence of Temperature on Mechanical Properties of Jute/Biopolymer Composites

Biopolymers and natural fibers are receiving wide attention for the potential to have good performance composites with low environmental impact. A current limitation of most biopolymers is however their change in mechanical properties at elevated temperatures. This study investigates the mechanical properties of two biomass-based polymers, polyactic acid (PLA) and cellulose acetate (CA), as a function of ambient temperature in the range from 5 to 80°C. Tests were done for neat polymers and for jute fiber/biopolymer composites. Micromechanical models were applied to back-calculate the reinforcement efficiency of the jute fibers. The elastic modulus of neat PLA is constant until a temperature of about 45°C, after which it is decreased rapidly. For neat CA, the elastic modulus is almost constant in the whole temperature range. The maximum stress of the neat biopolymers is consistently reduced. For the jute fiber composites, both the elastic modulus and maximum stress are reduced when the temperature is increased. For the elastic modulus, this is shown to be due to a reduction in the reinforcement efficiency of the jute fibers; i.e., a reduction in the back-calculated effective elastic modulus of the fibers. Altogether, the results demonstrate that the thermal sensitivity parameters typically provided for polymers, e.g., the glass transition temperature and the heat deflection temperature, cannot be used as sole
parameters for determining the gradual change in mechanical properties of polymers and composites. © 2012 Wiley Periodicals, Inc.

Mesh dependency of smeared-out non-linear composite finite element models of compressive failure mechanism in composite materials
Stress effects during load introduction into unidirectional composite test coupons

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Testing composites for wind turbine blades

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Challenges Testing Composite Materials for Wind Turbine Blades

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Electronic versions:
Workshop_Proceedings_24_10.pdf
Failure analysis of steel/polyester composites - compression properties

General information
State: Published
Organisations: Department of Wind Energy, Composites and Materials Mechanics
Authors: Raghavalu Thirumalai, D. P. (Intern), Mikkelsen, L. P. (Intern), Lilholt, H. (Intern)
Number of pages: 522
Publication date: 2012

Host publication information
Publisher: Indian Institute of Technology
ISBN (Print): 978-81-8487-248-4
Main Research Area: Technical/natural sciences
Conference: 3rd Asian Conference on Mechanics of Functional Materials and Structures (ACMFMS 2012), New Delhi, India, 05/12/2012 - 05/12/2012
Publication: Research - peer-review › Article in proceedings – Annual report year: 2012

Material Selection and Design Aspects of Small Wind Turbine Blades

General information
State: Published
Organisations: Department of Wind Energy, Composites and Materials Mechanics, Imperial College London, Politecnico di Milano
Authors: Mikkelsen, L. P. (Intern), Bottoli, F. (Ekstern), Pignatti, L. (Ekstern), Legstrup Andersen, T. (Intern), Madsen, B. (Intern)
Pages: 15-16
Publication date: 2012

Host publication information
Title of host publication: Abstracts. Indo-Danish Workshop On Future Composites Technologies for Wind Turbine Blades
Main Research Area: Technical/natural sciences
Conference: Indo-Danish Workshop On Future Composites Technologies for Wind Turbine Blades, Delhi, India, 08/10/2012 - 08/10/2012
Publication: Research - peer-review › Conference abstract in proceedings – Annual report year: 2012

Measuring the stress field around an evolving crack in tensile deformed Mg AZ31 using three-dimensional X-ray diffraction

The stress field around a notch in a coarse grained Mg AZ31 sample has been measured under tensile load using the individual grains as probes in an in situ high energy synchrotron diffraction experiment. The experimental set-up, a variant of three-dimensional X-ray diffraction microscopy, allows the position, orientation and full stress tensor of each illuminated grain to be determined and, hence, enables the study of evolving stress fields in coarse grained materials with a spatial resolution equal to the grain size. Grain resolved information like this is vital for understanding what happens when the traditional continuum mechanics approach breaks down and fracture is governed by local heterogeneities (e.g. phase or stress differences) between grains. As a first approximation the results obtained were averaged through the thickness of the sample and compared with an elastic–plastic continuum finite element simulation. It was found that a full three-dimensional simulation was required to account for the measured transition from the overall plane stress case away from the notch tip to the essentially plane strain case observed near the notch tip. The measured and simulated stress contours were shown to be in good agreement except at the highest applied load, at which stress relaxation at the notch tip was observed in the experimental data. This stress relaxation is attributed to the initiation and propagation of a crack. Finally, it was demonstrated that the measured lattice rotations could be used as a qualitative measure of the shape and extent of the plastic deformation zone.

General information
State: Published
Organisations: Department of Physics, Composites and Materials Mechanics, Department of Wind Energy, Technische Universität Berlin, Argonne National Laboratory
Authors: Oddershede, J. (Intern), Camin, B. (Ekstern), Schmidt, S. (Intern), Mikkelsen, L. P. (Intern), Sørensen, H. O. (Intern), Lienert, U. (Ekstern), Poulsen, H. F. (Intern), Reimers, W. (Ekstern)
The Influence of Steel Fiber Plasticity on Kink-Band Formation

General information
State: Published
Organisations: Department of Wind Energy, Composites and Materials Mechanics
Authors: Mikkelsen, L. P. (Intern), Raghavalu Thirumalai, D. P. (Intern)
Publication date: 2012

Host publication information
Title of host publication: Proceedings of XXIII International Congress on Theoretical and Applied Mechanics
Main Research Area: Technical/natural sciences
Conference: ICTAM 2012, Beijing, China, 19/08/2012 - 19/08/2012
Applying the MECO principle to assess the environmental impact of conventional and bio-based composite materials in a case study of a small-scale wind turbine blade

General information
State: Published
Organisations: Composites and Materials Mechanics, Materials Research Division, Risø National Laboratory for Sustainable Energy, Politecnico di Milano
Authors: Markussen, C. M. (Intern), Bottoli, F. (Ekstern), Pignatti, L. (Ekstern), Madsen, B. (Intern), Mikkelsen, L. P. (Intern), Brøndsted, P. (Intern), Løgstrup Andersen, T. (Intern)
Pages: 365-375
Publication date: 2011
Main Research Area: Technical/natural sciences

Publication information
Volume: 32
ISSN (Print): 0907-0079
Ratings:
BFI (2017): BFI-level 1
BFI (2015): BFI-level 1
BFI (2014): BFI-level 1
BFI (2013): BFI-level 1
ISI indexed (2013): ISI indexed no
BFI (2012): BFI-level 1
ISI indexed (2012): ISI indexed no
BFI (2011): BFI-level 1
ISI indexed (2011): ISI indexed no
BFI (2010): BFI-level 1
BFI (2009): BFI-level 1
BFI (2008): BFI-level 1
Original language: English
Light strong materials for energy purposes
Source: orbit
Source-ID: 283859
Publication: Research - peer-review » Conference article – Annual report year: 2011

Biomechanical study of a drop foot brace

General information
State: Published
Organisations: Composites and Materials Mechanics, Materials Research Division, Risø National Laboratory for Sustainable Energy
Authors: Mikkelsen, L. P. (Intern), Skorini, R. Í. (Ekstern), Løgstrup Andersen, T. (Intern)
Publication date: 2011

Host publication information
Title of host publication: Proceedings
Main Research Area: Technical/natural sciences
Conference: Simulia Customer Conference, Barcelona (ES), 01/01/2011
Electronic versions:
Biomechanical study of a drop foot brace.pdf
Source: orbit
Source-ID: 314884
Publication: Research » Article in proceedings – Annual report year: 2011

Compression strength of continuous steel fiber reinforced polymers
Measuring the stress field around an evolving crack in tensile deformed Mg AZ31 using 3DXRD grain centre mapping

General information
State: Published
Organisations: Metal Structures in Four Dimensions, Materials Research Division, Risø National Laboratory for Sustainable Energy, Composites and Materials Mechanics
Authors: Oddershede, J. (Intern), Camin, B. (Ekstern), Schmidt, S. (Intern), Mikkelsen, L. P. (Intern), Sørensen, H. O. (Intern), Lienert, U. (Intern), Poulsen, H. F. (Intern), Reimers, W. (Ekstern)
Publication date: 2011
Event: Abstract from MECASENS VI, Hamburg (DE), Sep, .
Main Research Area: Technical/natural sciences
Materials characterization and modelling
Source: orbit
Source-ID: 285479
Publication: Research › Conference abstract for conference – Annual report year: 2011

Measuring the stress field around an evolving crack in tensile deformed Mg AZ31 using 3DXRD grain centre mapping

General information
State: Published
Organisations: Metal Structures in Four Dimensions, Materials Research Division, Risø National Laboratory for Sustainable Energy, Composites and Materials Mechanics
Authors: Oddershede, J. (Intern), Camin, B. (Ekstern), Schmidt, S. (Intern), Mikkelsen, L. P. (Intern), Sørensen, H. O. (Intern), Lienert, U. (Intern), Poulsen, H. F. (Intern), Reimers, W. (Ekstern)
Publication date: 2011
Event: Abstract from Workshop to promote the use of high-energy X-ray diffraction experiments and detailed computational analyses for understanding multiscale phenomena in crystalline materials, APS, Chicago (US), Oct, .
Main Research Area: Technical/natural sciences
Materials characterization and modelling
Source: orbit
Source-ID: 285481
Publication: Research › Conference abstract for conference – Annual report year: 2011

A Parametric study of an Ankle-Foot Orthosis

General information
State: Published
Organisations: Composites and Materials Mechanics, Materials Research Division, Risø National Laboratory for Sustainable Energy, Ortopad Ingeniørerne
Authors: Í Skorini, R. (Ekstern), Mikkelsen, L. P. (Intern), Løgstrup Andersen, T. (Intern), Falkenman, L. (Ekstern)
Publication date: 2010
Event: Poster session presented at 2nd Annual Meeting of the Danish Biomedical Society, Aalborg (DK), 29 Oct, .
Main Research Area: Technical/natural sciences
Materials and energy storage, Light strong materials for energy purposes
Electronic versions:
A Smeared-out Material Model Predicting Compressive Failure of Composites

General information
State: Published
Organisations: Composites and Materials Mechanics, Materials Research Division, Risø National Laboratory for Sustainable Energy, Aalborg University, Aarhus University
Authors: Mikkelsen, L. P. (Intern), Sørensen, K. (Ekstern), Jensen, H. (Ekstern)
Publication date: 2010

Host publication information
Title of host publication: Proceedings
Main Research Area: Technical/natural sciences
Conference: NAFEMS Nordic Seminar, Esbjerg, Denmark, 02/02/2010 - 02/02/2010
Materials and energy storage, Light strong materials for energy purposes
Electronic versions:
Mikkelsen_nafems.pdf
Source: orbit
Source-ID: 270724
Publication: Research - peer-review › Article in proceedings – Annual report year: 2010

Professor Plum - in the Library - with a Wrench: The Forensic Study of Skull Fracture with Realistic Simulation

General information
State: Published
Organisations: Composites and Materials Mechanics, Materials Research Division, Risø National Laboratory for Sustainable Energy, University of Copenhagen
Authors: Mikkelsen, L. P. (Intern), Lynnerup, N. (Ekstern)
Pages: 25-25
Publication date: 2010
Main Research Area: Technical/natural sciences

Publication information
Journal: Insights
Issue number: Sep/Oct
Original language: English
Materials and energy storage, Light strong materials for energy purposes
Links:
Source: orbit
Source-ID: 270720
Publication: Communication › Journal article – Annual report year: 2010

Biomechanical Investigation of Scull Fracture

General information
State: Published
Organisations: Composites and Materials Mechanics, Materials Research Division, Risø National Laboratory for Sustainable Energy
Authors: Mikkelsen, L. P. (Intern)
Pages: 36-37
Publication date: 2009

Host publication information
Title of host publication: Program, list of participants and abstracts
Publisher: DCAMM, Technical University of Denmark
Main Research Area: Technical/natural sciences
Conference: DCAMM 12th Internal Symposium, Ringsted, Denmark, 23/03/2009 - 23/03/2009
Finite element implementation and numerical issues of strain gradient plasticity with application to metal matrix composites

A framework of finite element equations for strain gradient plasticity is presented. The theoretical framework requires plastic strain degrees of freedom in addition to displacements and a plane strain version is implemented into a commercial finite element code. A couple of different elements of quadrilateral type are examined and a few numerical issues are addressed related to these elements as well as to strain gradient plasticity theories in general. Numerical results are presented for an idealized cell model of a metal matrix composite under shear loading. It is shown that strengthening due to fiber size is captured but strengthening due to fiber shape is not. A few modelling aspects of this problem are discussed as well. An analytic solution is also presented which illustrates similarities to other theories.

General information
State: Published
Organisations: Composites and Materials Mechanics, Materials Research Division, Risø National Laboratory for Sustainable Energy, KTH - Royal Institute of Technology
Authors: Frederiksson, P. (Ekstern), Gudmundson, P. (Ekstern), Mikkelsen, L. P. (Intern)
Pages: 3977-3987
Publication date: 2009
Main Research Area: Technical/natural sciences

Publication information
Journal: International Journal of Solids and Structures
Volume: 46
Issue number: 22-23
ISSN (Print): 0020-7683
Ratings:
BFI (2017): BFI-level 2
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 1.597 SNIP 1.764
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 1.703 SNIP 2.037
BFI (2013): BFI-level 2
Scopus rating (2013): SJR 1.658 SNIP 2.181
ISI indexed (2013): ISI indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): SJR 1.635 SNIP 2.298
ISI indexed (2012): ISI indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): SJR 1.72 SNIP 1.944
ISI indexed (2011): ISI indexed yes
BFI (2010): BFI-level 2
Scopus rating (2010): SJR 1.646 SNIP 1.835
BFI (2009): BFI-level 2
Scopus rating (2009): SJR 1.937 SNIP 1.776
BFI (2008): BFI-level 1
Scopus rating (2008): SJR 1.843 SNIP 1.907
Scopus rating (2007): SJR 1.722 SNIP 1.844
Scopus rating (2006): SJR 1.715 SNIP 2.02
Scopus rating (2005): SJR 1.848 SNIP 1.759
Scopus rating (2004): SJR 1.961 SNIP 1.848
Scopus rating (2003): SJR 2.241 SNIP 1.746
Scopus rating (2002): SJR 2.212 SNIP 1.461
Scopus rating (2001): SJR 1.533 SNIP 1.655
Forensic FE study of skull fracture

General information
State: Published
Organisations: Composites and Materials Mechanics, Materials Research Division, Risø National Laboratory for Sustainable Energy, Novo Nordisk A/S, University of Copenhagen
Authors: Mikkelsen, L. P. (Intern), Sölvadóttir, A. (Ekstern), Thomsen, H. (Ekstern), Lynnerup, N. (Ekstern), Jacobsen, C. (Ekstern)
Publication date: 2009
Event: Poster session presented at Stiftende generalforsamling og første årsmøde i Dansk Biomekanisk Selskab, Göteborg (SE), 17-18 Sep., .
Main Research Area: Technical/natural sciences
Materials characterization and modelling, Materials research
Electronic versions:
Mikkelsen_Poster-SkullFracture.pdf
Source: orbit
Source-ID: 253827
Publication: Research › Poster – Annual report year: 2009

Plastic deformation suppression due to material length scales at crack tips

General information
State: Published
Organisations: Composites and Materials Mechanics, Materials Research Division, Risø National Laboratory for Sustainable Energy
Authors: Mikkelsen, L. P. (Intern), Goutianos, S. (Intern)
Pages: 253-259
Publication date: 2009
Main Research Area: Technical/natural sciences
Publication information
Suppressed plastic deformation at blunt crack tips due to strain gradient effects

Large deformation gradients occur near a crack-tip and strain gradient dependent crack-tip deformation and stress fields are expected. Nevertheless, for material length scales much smaller than the scale of the deformation gradients, a conventional elastic-plastic solution is obtained. On the other hand, for significant large material length scales, a conventional elastic solution is obtained. This transition in behaviour is investigated based on a finite strain version of the Fleck-Hutchinson strain gradient plasticity model from 2001. The predictions show that for a wide range of material parameters, the transition from the conventional elastic-plastic to the elastic solution occurs for length scales ranging from 0.001 times the size of the plastic zone to a length scale of the same order of magnitude as the plastic zone.

General information
State: Published
Organisations: Composites and Materials Mechanics, Materials Research Division, Risø National Laboratory for Sustainable Energy
Authors: Mikkelsen, L. P. (Intern), Goutianos, S. (Intern)
Pages: 4430-4436
Publication date: 2009
Main Research Area: Technical/natural sciences

Publication information
Journal: International Journal of Solids and Structures
Volume: 46
Issue number: 25-26
ISSN (Print): 0020-7683
Ratings:
BFI (2017): BFI-level 2
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 1.597 SNIP 1.764
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 1.703 SNIP 2.037
BFI (2013): BFI-level 2
Scopus rating (2013): SJR 1.658 SNIP 2.181
ISI indexed (2013): ISI indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): SJR 1.635 SNIP 2.298
ISI indexed (2012): ISI indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): SJR 1.72 SNIP 1.944
ISI indexed (2011): ISI indexed yes
User Subroutine for Compressive Failure of Composites

General information
State: Published
Organisations: Composites and Materials Mechanics, Materials Research Division, Risø National Laboratory for Sustainable Energy, Aalborg University, Aarhus University
Authors: Sørensen, K. D. (Ekstern), Jensen, H. M. (Ekstern), Mikkelsen, L. P. (Intern)
Pages: 618-632
Publication date: 2009

Host publication information
Title of host publication: Proceedings of 2009 SIMULIA Customer Conference
Main Research Area: Technical/natural sciences
Materials research, Light strong materials for wind turbines and for transportation
Source: orbit
Source-ID: 250277
Publication: Research - peer-review › Journal article – Annual report year: 2009

Interface Fracture in Composite Materials and Structures

General information
State: Published
Organisations: Composites and Materials Mechanics, Materials Research Division, Risø National Laboratory for Sustainable Energy, Solid Mechanics, Department of Mechanical Engineering
Authors: Østergaard, R. C. (Intern), Mikkelsen, L. P. (Intern), Tvergaard, V. (Intern), Sørensen, B. F. (Intern)
Number of pages: 140
Publication date: Apr 2008

Publication Information
ISBN (Print): 978-87-89502-67-0
Original language: English
Main Research Area: Technical/natural sciences
Electronic versions:
DCAMM_report_S102.pdf
Length-scale dependency of crack tip fields under mode I loading

General information
State: Published
Organisations: Composites and Materials Mechanics, Materials Research Division, Risø National Laboratory for Sustainable Energy
Authors: Mikkelsen, L. P. (Intern), Goutianos, S. (Intern)
Publication date: 2008

Host publication information
Title of host publication: International Congress of Theoretical and Applied Mechanics
Publisher: International Congress of Theoretical and Applied Mechanics
ISBN (Print): 09-80-51421-5
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 228610
Publication: Research - peer-review › Article in proceedings – Annual report year: 2008

Numerical studies of shear damped composite beams using a constrained damping layer
Composite beams containing one or more damping layers are studied numerically. The work is based on a semi-analytical model using a Timoshenko beam theory and a full 2D finite element model. The material system analysed, is inspired by a train wagon suspension system used in a EUREKA project Sigma!1841. For the material system, the study shows that the effect of the damping layer is strongly influenced by the presence of a stiff constraining layer, that enforces large shear strain amplitudes. The thickness of the damping rubber layer itself has only a minor influence on the overall damping. In addition, a large influence of ill positioned cuts in the damping layer is observed.

General information
State: Published
Organisations: Solid Mechanics, Department of Mechanical Engineering, Composites and Materials Mechanics, Materials Research Division, Risø National Laboratory for Sustainable Energy, Technical University of Denmark
Authors: Kristensen, R. (Ekstern), Nielsen, K. L. (Intern), Mikkelsen, L. P. (Intern)
Pages: 304-311
Publication date: 2008
Main Research Area: Technical/natural sciences

Publication information
Journal: Composite Structures
Volume: 83
Issue number: 3
ISSN (Print): 0263-8223
Ratings:
BFI (2017): BFI-level 2
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 2.408 SNIP 2.144
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 2.434 SNIP 2.517
BFI (2013): BFI-level 2
Scopus rating (2013): SJR 2.11 SNIP 2.961
ISI indexed (2013): ISI indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): SJR 1.943 SNIP 2.861
ISI indexed (2012): ISI indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): SJR 1.739 SNIP 2.607
ISI indexed (2011): ISI indexed yes
Simulation of kink-band formation in fiber reinforced composites

General information
State: Published
Organisations: Composites and Materials Mechanics, Materials Research Division, Risø National Laboratory for Sustainable Energy
Authors: Mikkelsen, L. P. (Intern)
Publication date: 2008
Event: Abstract from Seminar at Australian Composite Structures Society, Melbourne (AU), 2nd Sep, .
Main Research Area: Technical/natural sciences
Electronic versions:
2008_126.pdf
Source: orbit
Source-ID: 228714
Publication: Research › Conference abstract for conference – Annual report year: 2008

Eksempel på anvendelse af en gradientafhængig plasticitetsteori i en kommerciel finite element kode

General information
State: Published
Organisations: Composites and Materials Mechanics, Materials Research Division, Risø National Laboratory for Sustainable Energy
Authors: Mikkelsen, L. (Intern)
Publication date: 2007
Event: Paper presented at 11th Danish Center for Applied Mathematics and Mechanics, Silkeborg, Denmark.
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 215499
Publication: Research › Paper – Annual report year: 2007

From interface laws to composite behaviour

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy, Materials Research Division, Composites and Materials Mechanics
Authors: Sørensen, B. F. (Intern), Mikkelsen, L. P. (Intern), Østergaard, R. (Ekster), Goutianos, S. (Intern)
Implementing a gradient dependent plasticity model in ABAQUS

General information
State: Published
Organisations: Composites and Materials Mechanics, Materials Research Division, Risø National Laboratory for Sustainable Energy
Authors: Mikkelsen, L. P. (Intern)
Pages: 482-492
Publication date: 2007

Host publication information
Title of host publication: Proceedings (CD-ROM)
Place of publication: Paris
Publisher: SIMULIA
Main Research Area: Technical/natural sciences
Links:
Source: orbit
Source-ID: 215781
Publication: Research › Article in proceedings – Annual report year: 2007


General information
State: Published
Organisations: Composites and Materials Mechanics, Materials Research Division, Risø National Laboratory for Sustainable Energy
Number of pages: 301
Publication date: 2007

Publication information
Place of publication: Roskilde
Publisher: Risø National Laboratory
ISBN (Print): 978-87-550-3626-0
Original language: English
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 216041
Publication: Research - peer-review › Book – Annual report year: 2007
Length-scale dependent crack-growth

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy, Materials Research Division, Composites and Materials Mechanics
Authors: Mikkelsen, L. P. (Intern)
Pages: 235-240
Publication date: 2007

Host publication information
Title of host publication: Interface design of polymer matrix composites - mechanics, chemistry, modelling and manufacturing. Proceedings
Place of publication: Roskilde
Publisher: Risø National Laboratory
Editors: Sørensen, B., Mikkelsen, L., Liholt, H., Goutianos, S., Abdul-Mahdi, F.
ISBN (Print): 978-87-550-3626-0
Main Research Area: Technical/natural sciences
Electronic versions:
2008_48.pdf
Source: orbit
Source-ID: 216035
Publication: Research - peer-review › Article in proceedings – Annual report year: 2007

Non-linear finite element modeling

General information
State: Published
Organisations: Composites and Materials Mechanics, Materials Research Division, Risø National Laboratory for Sustainable Energy
Authors: Mikkelsen, L. P. (Intern)
Number of pages: 14
Publication date: 2007

Publication information
Place of publication: Roskilde
Publisher: Risø National Laboratory
ISBN (Print): 978-87-550-3644-4
Original language: English
Series: Denmark. Forskningscenter Risoe. Risoe-R
Number: 1625(EN)
ISSN: 0106-2840
Main Research Area: Technical/natural sciences
Risø-R-1625, Risø-R-1625(EN)
Electronic versions:
ris_r_1625.pdf
Source: orbit
Source-ID: 215666
Publication: Research › Report – Annual report year: 2007

On the simulation of kink bands in fiber reinforced composites

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy, Materials Research Division, Composites and Materials Mechanics
Authors: Sørensen, K. (Ekstern), Mikkelsen, L. P. (Intern), Jensen, H. (Ekstern)
Pages: 281-288
Publication date: 2007

Host publication information
Title of host publication: Interface design of polymer matrix composites - mechanics, chemistry, modelling and manufacturing. Proceedings
Strain gradient dependent crack-growth at an elastic/elastic-plastic material interface

General information
State: Published
Organisations: Composites and Materials Mechanics, Materials Research Division, Risø National Laboratory for Sustainable Energy
Authors: Mikkelsen, L. (Intern)
Publication date: 2007
Event: Abstract from Summer ASME applied mechanics and materials conference, Austin, TX (US),

Main Research Area: Technical/natural sciences
Links:
Source: orbit
Source-ID: 215780
Publication: Research › Conference abstract for conference – Annual report year: 2007

Crack-growth in a strain gradient dependent plasticity model

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy
Authors: Mikkelsen, L. (Intern)
Pages: 210-213
Publication date: 2006

Host publication information
Title of host publication: Proceedings
Place of publication: Lund
Publisher: Lund University, Faculty of Engineering
Editors: Dahlblom, O., Fuchs, L., Persson, K., Ristinmaa, M., Sandberg, G., Svensson, I.
Main Research Area: Technical/natural sciences
Links:
Source: orbit
Source-ID: 309737
Publication: Research › Article in proceedings – Annual report year: 2006

Delamination of thin elastic films on elastic-plastic substrates including length scales

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy
Authors: Mikkelsen, L. (Intern), Hutchinson, J. (Ekstern)
Publication date: 2006
Event: Abstract from IUTAM symposium on plasticity at the micron scale, Lyngby (DK), 21-25 May,
Damage evolution in laminated composite materials

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy
Authors: Megnis, M. (Intern), Brøndsted, P. (Intern), Mikkelsen, L. (Intern)
Pages: 33-42
Publication date: 2004

Host publication information
Title of host publication: Materialeopførsel og skadesanalyse
Place of publication: Lyngby
Publisher: DMS
Editor: Somers, M.
ISBN (Print): 87-87535-33-5
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 306840
Publication: Research › Article in proceedings – Annual report year: 2004

Sustainable natural and polymeric composites - science and technology. Proceedings

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy
Authors: Lilholt, H. (Intern), Madsen, B. (Intern), Toftegaard, H. L. (Intern), Cendre, E. (Ekstern), Megnis, M. (Ekstern), Mikkelsen, L. P. (Intern), Sørensen, B. F. (Intern)
Number of pages: 371
Publication date: 2002

Publication information
Place of publication: Roskilde
Publisher: Risø National Laboratory
ISBN (Print): 87-550-3091-2
Original language: English
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 304483
Publication: Research - peer-review › Book – Annual report year: 2002

A nonlocal two-dimensional analysis of instabilities in tubes under internal pressure

General information
State: Published
Organisations: Department of Solid Mechanics
Authors: Mikkelsen, L. P. (Intern), Tvergaard, V. (Intern)
Pages: 953-969
Publication date: 1999
Main Research Area: Technical/natural sciences

Publication information
Journal: Journal of the Mechanics and Physics of Solids
Volume: 47
ISSN (Print): 0022-5096
Ratings:
BFI (2017): BFI-level 2
A numerical axisymmetric collapse analysis of viscoplastic cylindrical shells under axial compression

General information
State: Published
Organisations: Department of Solid Mechanics
Authors: Mikkelsen, L. P. (Intern)
Pages: 643-668
Publication date: 1999
Main Research Area: Technical/natural sciences

Publication information
Journal: International Journal of Solids and Structures
Volume: 36
ISSN (Print): 0020-7683
Ratings:
BFI (2017): BFI-level 2
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 1.597 SNIP 1.764
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 1.703 SNIP 2.037
BFI (2013): BFI-level 2
Scopus rating (2013): SJR 1.658 SNIP 2.181
ISI indexed (2013): ISI indexed yes
A 2-D nonlocal analysis of hydroforming for thin sheets

General information
State: Published
Organisations: Department of Solid Mechanics
Authors: Mikkelsen, L. P. (Intern), Tvergaard, V. (Intern)
Pages: 249-256
Publication date: 1998
Main Research Area: Technical/natural sciences

Publication information
Journal: Journal de Physique IV
Volume: Pr8
ISSN (Print): 1155-4339
Ratings:
BFI (2008): BFI-level 1
Original language: English
Source: orbit
Source-ID: 174288
Publication: Research - peer-review › Journal article – Annual report year: 1999

Bending effects on instabilities of internally pressurized tubes modelled by a nonlocal membrane theory

General information
State: Published
Organisations: Department of Solid Mechanics
Authors: Mikkelsen, L. P. (Intern), Tvergaard, V. (Intern)
Pages: 679-686
Publication date: 1998

Host publication information
Title of host publication: Thin-Walled Structures, Research and Development
Publisher: Elsevier Science
2D Nonlocal approach to the post-necking behaviour

General information
State: Published
Organisations: Department of Solid Mechanics
Authors: Mikkelsen, L. P. (Intern)
Pages: 696-701
Publication date: 1997

Host publication information
Title of host publication: Computational plasticity, fundamentals and applications
Place of publication: Barcelona
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 166905
Publication: Research - peer-review › Article in proceedings – Annual report year: 1997

A 2-D non-local analysis of hydroforming for thin sheets

General information
State: Published
Organisations: Department of Solid Mechanics
Authors: Mikkelsen, L. P. (Intern), Tvergaard, V. (Intern)
Publication date: 1997

Publication information
Original language: English
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 166908
Publication: Research - peer-review › Report – Annual report year: 1997

A non-local two-dimensional analysis of instabilities in tubes under internal pressure

General information
State: Published
Organisations: Department of Solid Mechanics
Authors: Mikkelsen, L. P. (Intern), Tvergaard, V. (Intern)
Number of pages: 16
Publication date: 1997

Publication information
Original language: English
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 166934
Publication: Research - peer-review › Report – Annual report year: 1997

Necking of stretched sheets modelled by a 2-D nonlocal plasticity model

General information
State: Published
Organisations: Department of Solid Mechanics
Authors: Mikkelsen, L. P. (Intern)
Publication date: 1997

Host publication information
Title of host publication: Proceedings of the 2nd Euroconf. and Int. Symp.: Material instabilities in deformation and fracture
Post-necking behaviour modelled by a gradient dependent plasticity theory

Axisymmetric collapse of viscoplastic cylindrical shells under axial compression
Necking of biaxially stretched thin sheets modelled by a nonlocal plasticity theory

General information
State: Published
Organisations: Department of Solid Mechanics
Authors: Mikkelsen, L. P. (Intern)
Pages: 579-584
Publication date: 1996

Host publication information
Title of host publication: Advances in engineering plasticity and its applications. Proceedings of the 3rd Asia-Pacific Symposium on Advances in Engineering Plasticity and Its Applications
Place of publication: Hiroshima
Publisher: Pergamon Press
Editors: Abe, T., Tsuta, T.
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 166797
Publication: Research - peer-review › Article in proceedings – Annual report year: 1996

On the analysis of viscoplastic buckling
For elastic-viscoplastic structures the classical elastic-plastic bifurcation approach to inelastic buckling is not valid. Only an elastic bifurcation point exists in the el-tic-viscoplastic case, and the inelastic buckling behaviour is controlled by a strong sensitivity to small imperfections. However, in the last few years some papers have been published on an approximation that leads to a so-called viscoplastic bifurcation point. Results of accurate numerical analyses for elastic-viscoplastic columns are compared with predictions based on the approximate bifurcation approach. In some cases the bifurcation approach gives a poor approximation of the actual elastic-viscoplastic column behaviour, whereas in other cases the discrepancy is less pronounced. The simple column model gives a clear illustration of the effect, but similar results for plates are also mentioned briefly.

General information
State: Published
Organisations: Department of Solid Mechanics
Authors: Mikkelsen, L. P. (Intern)
Pages: 1461-1472
Publication date: 1993
Main Research Area: Technical/natural sciences

Publication information
Journal: International Journal of Solids and Structures
Volume: 30
Issue number: 11
ISSN (Print): 0020-7683
Ratings:
BFI (2017): BFI-level 2
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 1.597 SNIP 1.764
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 1.703 SNIP 2.037
Projects:

**Process Parameters and Fatigue Properties of High Modulus Composites**

Department of Wind Energy

Period: 01/05/2016 → 30/04/2019

Number of participants: 4

Phd Student:

Mortensen, Ulrich Andreas (Intern)

Supervisor:

Løgstrup Andersen, Tom (Intern)

Hansen, Birgitte Møller (Ekstern)

Main Supervisor:

Mikkelsen, Lars Pilgaard (Intern)

**Financing sources**

Source: Internal funding (public)

Name of research programme: Samfinansieret - Andet PhD

**Bio4Self**

Department of Wind Energy

Composites and Materials Mechanics

Period: 01/03/2016 → …

Number of participants: 5

Project ID: H2020

Project participant:

Beauson, Justine (Intern)
Improved testing methods for fibre composites used in wind turbine blades

Department of Wind Energy
Period: 01/11/2014 → 31/08/2015
Number of participants: 3
Phd Student:
Kristiansen, Morten Fogtmann (Intern)
Supervisor:
Brøndsted, Povl (Intern)
Main Supervisor:
Mikkelsen, Lars Pilgaard (Intern)

Financing sources
Source: Internal funding (public)
Name of research programme: Institut stipendie (DTU)
Project: PhD

Fatigue damage evolution in fibre composites for wind turbine blades

Department of Wind Energy
Period: 15/04/2014 → 14/04/2017
Number of participants: 7
Phd Student:
Jespersen, Kristine Munk (Intern)
Supervisor:
Hansen, Jens Zangenberg (Intern)
Mishnaevsky, Leon (Intern)
Main Supervisor:
Mikkelsen, Lars Pilgaard (Intern)
Examiner:
Niordson, Christian Frithiof (Intern)
Asp, Leif Erik (Ekstern)
Spearing, Simon Mark (Ekstern)

Financing sources
Source: Internal funding (public)
Name of research programme: Offentlig finansiering
Project: PhD

Alliance for Imaging and Modelling of Energy Applications
The CINEMA research alliance will develop unique 3D micro-structural characterization methods, which make it possible to investigate components under realistic conditions and in real time. This will enable correlation between performance and local changes in the microstructure.

Department of Energy Conversion and Storage
Imaging and Structural Analysis
Department of Physics
Neutrons and X-rays for Materials Physics
Department of Wind Energy
Composites and Materials Mechanics
Department of Applied Mathematics and Computer Science
Image Analysis & Computer Graphics
Scientific Computing
Mixed Conductors
Statistics and Data Analysis
University of Copenhagen
Northwestern University
University of Manchester
MaxLab
LM Wind Power
Haldor Topsoe AS
Xnovo Technology ApS
Rockwool International A/S
Amminex Emissions Technology A/S
Period: 01/01/2014 → 31/12/2018
Number of participants: 26
Acronym: CINEMA
Project participant:
Mikkelsen, Lars Pilgaard (Intern)
Sørensen, Bent F. (Intern)
Bowen, Jacob R. (Intern)
Kuhn, Luise Theil (Intern)
Larsen, Rasmus (Intern)
Hansen, Per Christian (Intern)
Frandsen, Henrik Lund (Intern)
Gundlach, Carsten (Intern)
Dahl, Anders Bjorholm (Intern)
Yang, Shu-Yi (Intern)
Poulsen, Stefan Othmar (Intern)
Lyckegaard, Allan (Intern)
Lauridsen, Erik Mejdal (Intern)
Sørensen, Henning Osholm (Ekstern)
Project Manager, organisational:
Sørensen, Hanne (Intern)
Phd Student:
Jespersen, Kristine Munk (Intern)
Beil, Johannes (Ekstern)
Andersen, Michael (Intern)
Emerson, Monica Jane (Intern)
De Angelis, Salvatore (Intern)
Birkeland, Klaus (Ekstern)
Jacobsen, Hjalte Sylvest (Intern)
Chapelle, Lucie (Intern)
Supervisor:
Frandsen, Henrik Lund (Intern)
Project Manager, academic:
Andreasen, Jens Wenzel (Intern)
Project Coordinator:
Poulsen, Henning Friis (Intern)

Relations
Activities:
DTU Energy Conversion 2nd International PhD Summer School

High resolution ptychographic tomography of soft matter

Publications:
- Micromechanical Time-Lapse X-ray CT Study of Fatigue Damage in Uni-Directional Fibre Composites
- Dictionary Based Segmentation in Volumes
- Micromechanical Investigation of Fatigue Damage in Uni-Directional Fibre Composites
- 3D X-Ray Computed Tomography (XCT) of Fatigue Damage Evolution in UD Glass Fibre Composite
- Enabling Flexible Polymer Tandem Solar Cells by 3D Ptychographic Imaging
- Improving organic tandem solar cells based on water-processed nanoparticles by quantitative 3D nanoimaging

Reliabilities of composite materials for wind turbine blades

Department of Wind Energy
Period: 01/04/2013 → 04/07/2016
Number of participants: 7
Phd Student:
- Pereira, Gilmar Ferreira (Intern)
Supervisor:
- McGugan, Malcolm (Intern)
- Sørensen, Bent F. (Intern)
Main Supervisor:
- Mikkelsen, Lars Pilgaard (Intern)
Examiner:
- Legarth, Brian Nyvang (Intern)
- Güemes, Alfredo (Ekstern)
- Ogin, Stephen L. (Ekstern)

Financing sources
Source: Internal funding (public)
Name of research programme: Marie Curie (EU-stipendium)

Relations
Publications:
- Multi-life-stage monitoring system based on fibre bragg grating sensors for more reliable wind turbine rotor blades:
- Experimental and numerical analysis of deformation and failure in composite materials
Project: PhD

Ultimate strength of wind turbine blade structures under multi axial loading

Department of Wind Energy
Period: 01/05/2012 → 25/02/2016
Number of participants: 7
Phd Student:
- Haselbach, Philipp Ulrich (Intern)
Supervisor:
- Berggreen, Christian (Intern)
- Bitsche, Robert (Intern)
Main Supervisor:
- Branner, Kim (Intern)
Examiner:
- Mikkelsen, Lars Pilgaard (Intern)
- Lindgaard, Esben (Ekstern)
- Trujillo, Juan-José (Intern)

Financing sources
Source: Internal funding (public)
Micro-Scale Experiments and Models for Composite Materials with Materials Research

Department of Wind Energy  
Period: 01/01/2012 → 30/10/2015  
Number of participants: 7  
Phd Student:  
Zike, Sanita (Intern)  
Supervisor:  
Sørensen, Bent F. (Intern)  
Tvergaard, Viggo (Intern)  
Main Supervisor:  
Mikkelsen, Lars Pilgaard (Intern)  
Examiner:  
Legarth, Brian Nyvang (Intern)  
Jensen, Henrik Myhre (Intern)  
Thouless, Michael (Intern)  

Financing sources  
Source: Internal funding (public)  
Name of research programme: Forskningsrådsfinansiering  
Project: PhD

Optimal Design of Composite Structures under Manufacturing Constraints

Department of Wind Energy  
Period: 01/08/2011 → 05/11/2014  
Number of participants: 7  
Phd Student:  
Marmaras, Konstantinos (Intern)  
Supervisor:  
Lund, Erik (Ekstern)  
Mikkelsen, Lars Pilgaard (Intern)  
Main Supervisor:  
Stolpe, Mathias (Intern)  
Examiner:  
Branner, Kim (Intern)  
Duysinx, Pierre (Intern)  
Klarbring, Anders (Ekstern)  

Financing sources  
Source: Internal funding (public)  
Name of research programme: Forskningsrådsfinansiering  
Project: PhD

Micro Mechanical Damage Tolerance improvements of Composites

Department of Mechanical Engineering  
Period: 01/04/2011 → 25/08/2014  
Number of participants: 8  
Phd Student:  
Ashouri Vajari, Danial (Intern)  
Supervisor:  
Berggreen, Christian (Intern)  
Niordson, Christian Frithiof (Intern)  
Sørensen, Bent F. (Intern)  
Main Supervisor:  
Legarth, Brian Nyvang (Intern)
Free Material Optimization of Wind Turbine Blades
Department of Wind Energy
Period: 15/12/2010 → 03/12/2014
Number of participants: 6
Phd Student:
Weldeyesus, Alemseged Gebrehiwot (Intern)
Supervisor:
Lund, Erik (Ekstern)
Main Supervisor:
Stolpe, Mathias (Intern)
Examiner:
Mikkelsen, Lars Pilgaard (Intern)
Kocvara, Michal (Intern)
Stingl, Michael Walter (Ekstern)

Financing sources
Source: Internal funding (public)
Name of research programme: Institut, samfinansiering
Project: PhD

The effects of fibre architecture on fatique life-time of composite materials
Department of Wind Energy
Period: 15/04/2010 → 30/09/2013
Number of participants: 6
Phd Student:
Hansen, Jens Zangenberg (Intern)
Supervisor:
Østergaard, Rasmus Christian (Intern)
Main Supervisor:
Brøndsted, Povl (Intern)
Examiner:
Mikkelsen, Lars Pilgaard (Intern)
Adolphs, Georg (Ekstern)
Varna, Janis (Ekstern)

Financing sources
Source: Internal funding (public)
Name of research programme: Forskningsrådsfinansiering
Project: PhD

Danish Centre for Composites Structures and Materials for Wind Turbines
Some of the most critical components of a wind turbine are the rotor blades, which are usually made of polymer matrix composites and are the largest rotating components of a wind turbine. Different types of damage can develop at different length scales in wind turbine rotor blades. Therefore, the Danish Centre for Composite Structures and Materials for Wind Turbines (DCCSM) aims to develop a coherent, multiscale-based understanding of the mechanical behaviour of composite materials and structures for wind turbine blades. The length scale goes from nano- and microscale (materials) to product scale (the whole blade, which currently can be more than 60 meters in length), and covers manufacturing, materials design, damage detection, modelling and prediction of damage evolution in wind turbine blades. A coherent multiscale understanding of composite materials and structures will enable full optimisation, viz., optimisation at all length scales.
The Centre aims for the creation of new knowledge (e.g. material models), new experimental methods and new modeling methods. The Centre spans wide thematically and disciplinarily. The specific PhD, Post Doc and research projects funded by DCCSM (Core and Shell activities) are focused at smaller, well-defined topics. Therefore, the Centre will coordinate the research activities in Denmark in the area of composite structures and materials for wind turbines. That includes the Core and Shell activities of DCCSM and research projects that are not funded by the DSF funds but are thematically covered by the Centre. Such projects are called "Crust" projects.

DSF Strategic Research Centre (sags. nr. 09-067212).

Department of Wind Energy
Composites and Materials Mechanics
Department of Micro- and Nanotechnology
Amphiphilic Polymers in Biological Sensing
Wind Turbines
Solid Mechanics
Department of Mechanical Engineering
Department of Civil Engineering
Section for Structural Engineering
Period: 01/04/2010 → 31/03/2017
Number of participants: 11
Acronym: DCCSM
Project participant:
Almdal, Kristoffer (Intern)
Mikkelsen, Lars Pilgaard (Intern)
Branner, Kim (Intern)
Mishnaevsky, Leon (Intern)
Legarth, Brian Nyvang (Intern)
Berggreen, Christian (Intern)
Stang, Henrik (Intern)
Phd Student:
Zike, Sanita (Intern)
Hansen, Jens Zangenberg (Intern)
Ashouri Vajari, Danial (Intern)
Approving authority:
Sørensen, Bent F. (Intern)

Relations
Publications:
The effects of fibre architecture on fatigue life-time of composite materials
Quantitative study on the statistical properties of fibre architecture of genuine and numerical composite microstructures
Methodology for characterisation of glass fibre composite architecture
Fatigue damage propagation in unidirectional glass fibre reinforced composites made of a non-crimp fabric
Micro-Scale Experiments and Models for Composite Materials with Materials Research
A numerical study of the influence of microvoids in the transverse mechanical response of unidirectional composites
Design of a fibrous composite preform for wind turbine rotor blades
Determination of the minimum size of a statistical representative volume element from a fibre-reinforced composite based on point pattern statistics
From Measurements Errors to a New Strain Gauge Design
Correction of Gauge Factor for Strain Gauges Used in Polymer Composite Testing

Project

Yield point phenomenon and formability of nanometals

Department of Wind Energy
Period: 01/01/2010 → 20/06/2014
Number of participants: 6
Phd Student:
Kidmose, Jacob (Intern)
Supervisor:
Winther, Grethe (Intern)
Main Supervisor:
Huang, Xiaoxu (Intern)
Examiner:
Mikkelsen, Lars Pilgaard (Intern)
Nielsen, Karl Brian (Ekstern)
Tsuji, Nobuhiro (Ekstern)

Financing sources
Source: Internal funding (public)
Name of research programme: Institut, samfinansiering
Project: PhD

Structure and mechanical properties of aligned natural fibre composites
Department of Wind Energy
Period: 01/04/2009 → 31/01/2013
Number of participants: 6
Phd Student:
Rask, Morten (Intern)
Supervisor:
Lauridsen, Erik Mejdal (Intern)
Madsen, Bo (Intern)
Main Supervisor:
Sørensen, Bent F. (Intern)
Examiner:
Mikkelsen, Lars Pilgaard (Intern)
Spearing, Simon Mark (Ekstern)

Financing sources
Source: Internal funding (public)
Name of research programme: Anden EU-finansiering
Project: PhD

Manufacturing related properties of thick fibre reinforced polymer composites
Risø National Laboratory for Sustainable Energy
Period: 01/11/2008 → 31/03/2010
Number of participants: 3
Phd Student:
Krishnan, Krishna Kumar (Intern)
Supervisor:
Lystrup, Aage (Intern)
Main Supervisor:
Mikkelsen, Lars Pilgaard (Intern)

Financing sources
Source: Internal funding (public)
Name of research programme: Institut/centerfinansieret
Project: PhD

Brudmekanismer i kompositmaterialer - effekt af fiber/matrix grænsefladens mekaniske egenskaber
Department of Mechanical Engineering
Period: 15/04/2004 → 11/04/2008
Number of participants: 7
Phd Student:
Østergaard, Rasmus Christian (Intern)
Supervisor:
Mikkelsen, Lars Pilgaard (Intern)
Sørensen, Bent F. (Intern)
Main Supervisor:
Tvergaard, Viggo (Intern)
Examiner:
Niordson, Christian Frithiof (Intern)
Jensen, Henrik Myhre (Intern)
Östlund, Sören (Ekstern)

Financing sources
Source: Internal funding (public)
Name of research programme: Risø (Løn)
Project: PhD

Effect of Grain Orientation on Dislocation Structures at Large Strains
Department of Management Engineering
Period: 01/09/2002 → 06/04/2006
Number of participants: 6
Phd Student:
Li, Zhengjie (Ekstern)
Supervisor:
Winther, Grethe (Intern)
Main Supervisor:
Bay, Niels Oluf (Intern)
Examiner:
Mikkelsen, Lars Pilgaard (Intern)
Barlow, Claire Y. (Ekstern)
Hutchinson, William Bevis (Ekstern)

Financing sources
Source: Internal funding (public)
Name of research programme: Risø (Løn)
Project: PhD

Application of non-local material models for the prediction of localization and formability
Project with the MUP2 programme ‘Materials Properties, Processing and Modelling’.

Department of Solid Mechanics
Period: 01/01/1996 → 30/08/1997
Number of participants: 1
Project Manager, organisational:
Mikkelsen, Lars Pilgaard (Intern)

Viskoplastisk materialeopførsels indflydelse på skallers stabilitet og kollaps
Department of Mechanical Engineering
Period: 01/02/1992 → 05/10/1995
Number of participants: 2
Phd Student:
Mikkelsen, Lars Pilgaard (Intern)
Main Supervisor:
Tvergaard, Viggo (Intern)

Financing sources
Source: Internal funding (public)
Name of research programme: DTU-stipendium
Activities:

NAFEMS Nordic Steering Committee (NNSC) (External organisation)
Period: 2015 → …
Lars Pilgaard Mikkelsen (Member)
Department of Wind Energy
Composites and Materials Mechanics
Degree of recognition: International
Links:
https://www.nafems.org/about/regional/nordic/committee/

Related external organisation

Challenges of using composite materials for large wind turbine blades
Period: 2 Nov 2015
Lars Pilgaard Mikkelsen (Lecturer)
Department of Wind Energy
Composites and Materials Mechanics
Description
Seminar at: Yamagata University, Yonezawa City, Japan
Organized by Japan Society of Mechanical Engineers
Documents:
Abstract-LPMikkelsen
Links:
http://www.jsme.or.jp/th/presen/H27/H27.html

Related event

Seminar organized by Japan Society of Mechanical Engineering
02/11/2015 → …
yonezawa city, Japan
Activity: Talks and presentations › Conference presentations

DCAMM’s Videnskabelige Råd (External organisation)
Period: 2013 → …
Lars Pilgaard Mikkelsen (Member)
Department of Wind Energy
Composites and Materials Mechanics
Links:
http://www.dcamm.dk/

Related external organisation

DCAMM’s Videnskabelige Råd
Activity: Membership › Membership in committee, council, board

DTU Wind Energy’s Board of Studies (Studienævn) (External organisation)
Period: 2012 → …
Lars Pilgaard Mikkelsen (Member)
Related external organisation

**DTU Wind Energy's Board of Studies (Studienævn)**
Activity: Membership › Membership in committee, council, board

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**Risø DTU Board of Studies (External organisation)**
Period: 2007 → 2012
Lars Pilgaard Mikkelsen (Member)
Department of Wind Energy
Composites and Materials Mechanics

Related external organisation

**Risø DTU Board of Studies**
Activity: Membership › Membership in committee, council, board