Technical University of Denmark

Annual Report 2016
DTU Wind Energy

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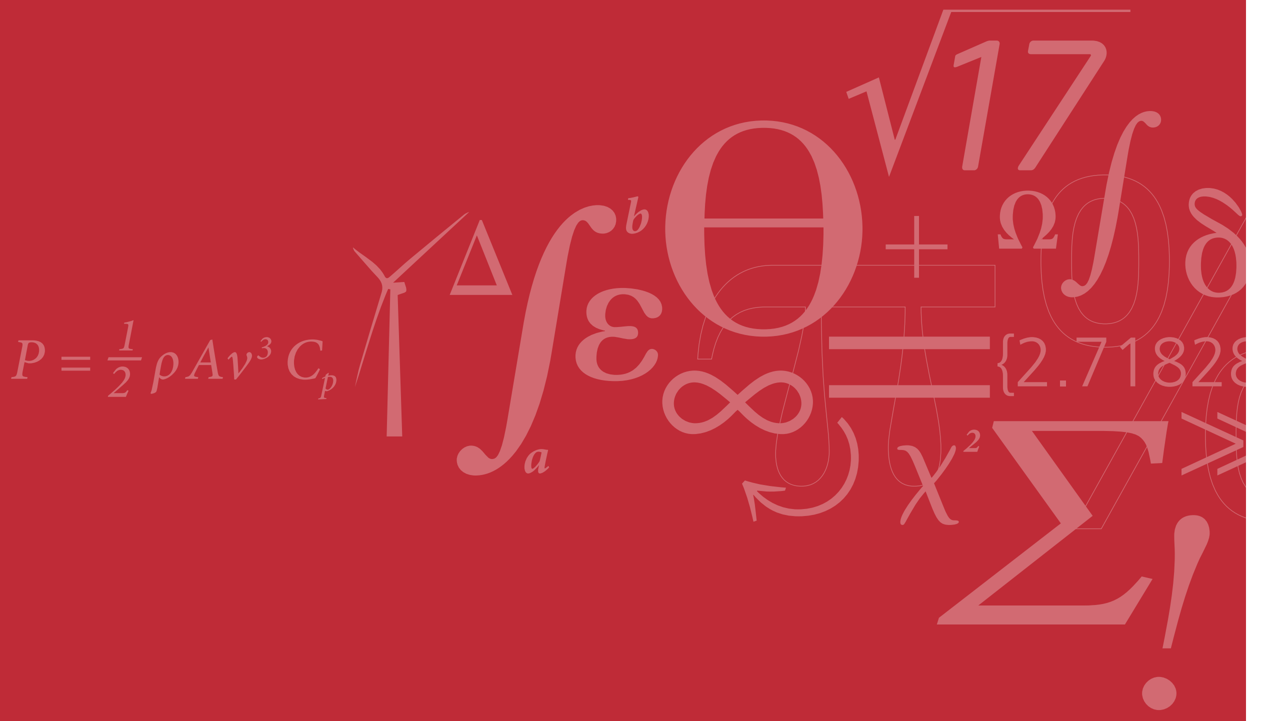
Department of Wind Energy



Annual Report 2016
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The first five years as DTU Wind Energy

The Department of Wind Energy at DTU was established on January 1, 2012 based on a merger of DTU's primary groups involved in wind energy. The decision was based on an analysis and strategy, developed during autumn 2011. The vision was that DTU Wind Energy in interaction with other departments at DTU should become a globally leading department for wind energy with globally leading technical-scientific competencies and in a unique combination of research, education, innovation and public/private sector consultancy. Furthermore, the department should be a key contributor to the realization of the vision of Denmark as a "wind power hub" and the activities should support and develop the global wind energy sector with a special effort on national industrial development and innovation.

During the departments five year history, wind energy has continued to develop. In Europe the European Commission has stated its ambition to be No. 1 in the world in renewable energy. Wind energy has been and should remain a cornerstone in Europe's ability to fulfill this ambition. With a total installed capacity of 153,7 GW, wind energy has overtaken coal as the second largest form of power generation capacity in Europe. Wind energy now covers more than 10% of EU's electricity demand. European wind energy companies are globally leading and the sector generated 330.000 jobs in 2016 in Europe; more than twice as much as solar photovoltaic.

In Denmark, the installed wind energy capacity has reached 5225 MW in 2016 (3.954MW onshore and 1.271 MW offshore) and generated what approximately amounts to 40% of the electricity demand in the last two years. The sector employs approximately 30.000 of which 14% have a higher education (compared to an average of eight in Danish industry in general). Hence, the reasons for creating the department and the vision are no less valid today.

With regard to our research, the department underwent its first international research evaluation last year. The external international panel concluded that:.

"The research at DTU Wind Energy is of high international level, and in several areas at the cutting edge….. Furthermore, the panel …..find the research at DTU Wind Energy to stand at a very high level, being one of the leading institutes in wind energy worldwide. The research output from all sections is high. The Department possesses first-class research infrastructure….."

Looking back, we can be satisfied with our role in the global wind energy research. We have also seen considerable development in our research infrastructure. The Østerild prototype test facility, the development of the Windscanner (on both the national and the ESFRI roadmaps for research infrastructure), a HPC cluster, a new V52 research wind turbine, as well as the national wind tunnel and the large scale structural test facility, which are under construction.

On education, a portfolio of wind energy specific course has been established, and the department is responsible for two wind energy master programmes resulting in 80-90 candidates a year. Especially noteworthy

2012

Department of Wind Energy **established**

BY JANUARY 1ST 2012, the Department of Wind Energy was established. The new department was based on DTU's primary groups involved in waind energy, i.e. two groups from DTU Mechanical Engineering whose core activities were fluid dynamics and composite mechanics, two groups from the Risø DTU Materials Research Division, where the research was focused on composite materials and metals and finally the former Wind Energy Division at Risø DTU.

Head of Department Peter Hauge Madsen reported on the creation of the new Department of Wind Energy, "We have gone through a rapid process in which the new department has been developed. We start from scratch building up a new department. It is a unique opportunity to create a new, strong and globally very competitive wind energy research organisation"

The new Department was organised in eight sections. By January 2016, the department was re-organised, from this point consisting of 10 sections in total.

is the use of e-learning to address the international need for continued education in wind energy. We have developed e-learning course versions of various training courses for industry, we have developed a free Coursera course on wind energy, which attracted more than 20.000 learners during the first year and have started the development of a 2-year master program, to be launched in 2017. The PhD-program has suffered somewhat from the reduction and changes in strategy of the national energy research funding during the period. However, the quality is high and the PhDs highly sought by the industry.

We see innovation and consultancy as the value creation process, whereby we transfer and implement new knowledge, methods and techniques in collaboration with commercial and public partners. The direct research collaboration and research-based test and consultancy services have grown steadily, and the income allows us to maintain a high level of research and investment in research infrastructure. The public sector consultancy or scientific advice has seen new international activities in e.g. South Africa and Mexico, and we have formed a partnership with the World Bank on global wind mapping.

The five years have also brought surprises. Wind energy has continued it growth globally beyond the first markets in Europe, the cost has come down rapidly, including offshore wind, which promises to become competitive without subsidies in a few years. The globalization of the industry is visible and the industry is consolidating into larger units; in Denmark witnessed by the Mitsubishi-Vestas joint venture on offshore wind turbines and the recent merger between Siemens Wind Power and Gamesa. Thus, we believe in the recommendation from the international research evaluation panel, namely ….We would encourage making stronger efforts to grow from a somewhat Denmark-centric model into a truly international player…. We are therefore intensifying our effort to create strong research partnerships in Europe through EERA and EAWE as well as bilateral partnerships with strong international parties.

In conclusion, the first five years of the Department of Wind Energy have been successful, and the intentions and goals for the department met, thanks to the engagement and strong effort by everyone in the department. Some of the achievements are described in the following pages, which hopefully illustrate that the Department of Wind Energy is a worthy partner for industry, policy makers and civil society, is a great place for staff and students and is well equipped to face the future and its challenges.

Peter Hauge Madsen
Head of Department

WindScanner **Preparatory Phase** project kick-off

The Department of Wind Energy hosted the kick-off meeting of the WindScanner.eu Preparatory Phase project in **OCTOBER 2012**. The project was supported by the European Commission with 4.2 M €, and nine European partners participated. The aim of the project was preparing the administrative, legal, financial and technical issues necessary for the establishment and subsequent operation of the new European WindScanner Facility, a joint European Research Infrastructure with a central node hosted by DTU Wind Energy, and with several national and regional nodes distributed in other European countries. The preparatory phase ended in September 2015 however, the construction of WindScanner equipment and software for the WindScanner nodes continues as do the daily operation of the new research infrastructure.

Read more on www.WINDSCANNER.EU

The Vestas 4-rotor concept turbine at DTU Risø Campus.

Opening of Østerild Test Centre for **Large Turbines**

ON OCTOBER 6TH 2012, Østerild National Test Centre for Large Turbines opened with a public event. One of the aims of the event was to invite neighbours, industry etc. in order to present the centre and explain the use of it. The test centre was established to create the necessary framework conditions in order to maintain the Danish leading position within the field of wind energy. The centre opened with seven test stands allowing for turbines with a height of up to 250 meters.

Read more about Østerild on page 16-17.

New Vestas 4-rotor Concept Turbine being tested at Risø

During April 2016, a new turbine was installed at the test centre situated at the DTU Wind Energy Risø Campus. Having not only one but a total of four rotors, the turbine differs from wind turbines as we have known them until now.

BY METTE BISCHOFF KRISTIANSEN

In 2016 a new wind turbine was built at DTU Risø Campus. It is not just a wind turbine, as we have known them before. This new turbine has four rotors, thus it was given the name the 4-rotor Concept Turbine.

This 4-rotor Concept Turbine is a part of research into whether the cost of wind energy can be more competitive by delivering a larger production of electricity and reducing the weight concurrently. The motivation behind the turbine is thus reducing the cost of electricity. This is to be done by reducing the consumption of materials and using smaller components for the turbine. The smaller parts are visible at the small blades of the turbine.

In general, through the last decades, turbines have grown larger resulting in bigger challenges regarding logistics and handling of the components. The larger the turbines are the more materials are being used. In spite of the height of the concept turbine of just 74 meters, it has got a capacity of 900 kW due to the four rotors.

The future?

Even though the wind turbine is geographically placed at Risø, it is Vestas, who owns the turbine. President of DTU, Anders Bjarklev welcomes the collaboration with Vestas and states that:

"We're very pleased to make our expertise available in this research partnership with Vestas. It's promising if it's possible to boost output in new and unconventional ways, and we hope that this exciting concept will contribute to making wind turbine technology even more efficient."

When doubling the size of a turbine, the area, which the rotating blades are covering, will get four times as big. In this way, the electricity generation will increase fourfold. However, there is another side of the coin: The total weight of the blades is increasing as well as the weight of the other mechanical components. The increased weight comes from an increased material consumption resulting in higher total costs of the turbine. By constructing a turbine like the 4-rotor Concept Turbine with more and smaller components, a lower weight is achieved, just as it gets easier to handle the turbine and the components. This is an advantage e.g. when the components of the turbine are to be transported to markets where the necessary infrastructure has not been developed yet.

At spring 2017, a number of tests are going to be conducted at DTU's test site at DTU Risø Campus. These tests will contribute to deciding whether turbines like the 4-rotor Concept Turbine are considered cost-effective at a future turbine market. The vision is to further strengthen the competitiveness of wind power compared to other sources of energy.

The beginning of **INNWIND.EU**

IN NOVEMBER 2012, DTU Wind Energy hosted the kick-off meeting for the EU Framework Programme 7 supported INNWIND.EU project. The aim of the project is to create innovation that enable the realisation of a giant 20MW offshore wind turbine. Approximately 65 people from twenty-seven partners across different European organisations participated in the kick-off meeting.

The project will end in 2017 and has developed several innovative concepts of offshore wind turbines at the 10 MW - 20 MW capacities to lower the Levelized Cost of Energy (LCOE). The conceptual designs have been extensively analyzed and prioritized in terms of their potential impact in reducing LCOE. Examples of key innovative concepts developed are blades with advanced bend-twist coupled structure, pseudo magnetic direct drive generators and low cost fixed and floating support structures. Based on a developed LCOE model, a 14% reduction in LCOE due to the advanced concepts researched in INNWIND.EU is possible, which also corresponds to an overall reduction of more than 30% in LCOE compared to the European Wind Industrial Initiative (EWII) 2012 estimate .

For further information please visit www.INNWIND.EU

Kasper Sandal wins PhD poster award

BY BETINA BRINK LAURSEN WINTHER

Kasper Sandal, PhD at DTU Wind Energy, won the PhD poster award at the Wind Energy Denmark 2016 conference in Odense during the 26th and 27th of October 2016.

Kasper Sandal won the price for his PhD project "Design Optimization of Jacket Structures for Mass Production". In order to achieve the optimum design for the jacket structures, he has developed a software for calculating e.g. the optimal spacing between the legs of the jacket structures to achieve the most cost effective design.

Kasper Sandal started his presentation with the words "Math is more effective than people," a statement that is supported by the functionality of the software, which will make it possible to calculate the effects of different designs within a short period of time, leading to significant cost reductions.

Chief Engineer wins award after lecture series

BY CHARLOTTE BOMAN HEDE

"I am extremely proud and happy that I received the award. We are a lot of people who have spent a great amount of time on the course and to have it acknowledged is simply amazing," says Malcolm McGugan, Chief Engineer at DTU Wind Energy.

In 2016, he received the AVT Panel Excellence Award from NATO. For several years, he had been teaching a series of lectures all over the world, with the name "Structural Health Monitoring of Military Vehicles".

In 2014, Malcolm McGugan and some of his colleagues from other European Universities held free lecture series in Berlin and Madrid planned by the Science and Technology Organization (STO), which is a NATO subsidiary body. In 2015, the course was held in Vancouver as well. Approximately 140 participants represented fifteen different NATO Nations from industry, government and academia during the lectures in Berlin, Madrid and Vancouver.

Due to popularity, STO ordered an extra lecture series, this time in Bilbao in 2016. During that course, NATO presented Malcolm McGugan from DTU Wind Energy with the AVT Panel Excellence Award.

In 2017, the same group of lecturers will present "Highlights and Challenges in Diagnosis of Structural Integrity and Failures", but this time as part of the CISM (Centre International des Sciences Méchaniques) organized Advanced Professional Training at Udine, Italy. The lectures take place from the 2nd to 6th October this year and a book will be published in 2018.

2013

The start of **IRPWind**

The European Commission decided in **DECEMBER 2013** to fund the Integrated Research Programme on Wind Energy (IRPWIND), which was one of the final projects allocated in Framework Programme 7. The project is coordinated by DTU Wind Energy and addresses coordination and networking elements as well as research activities. The ambition is to create a joint European Wind Energy Research Programme with strategy and planning including a secretariat to support this. The budget is 10M EURO for 4 years. The programme will finish in 2017.

DTU **WinDTUrbineracer** sets world record

BY BETINA BRINK LAURSEN WINTHER

The DTU-built WinDTUrbineracer set a new world record in 2016, while winning the Racing Aeolus competition in Den Helder, the Netherlands.

In 2016, the WinDTUrbineracer won the Racing Aeolus competition for the second year running. The team did not only ensure the third victory out of nine Racing Aeolus competitions, but it also managed to break the world record in racing against the wind, when the car reached a speed of 101.8% of the wind speed. This was the first time in the history of the competition that one of the competing cars went faster than the speed of the wind.

The DTU team at the 2016 Racing Aeolus competition

New team every year

At DTU, it is a new team racing the WinDTUrbineracer every year. In 2016, the team consisted of Joachim Holm Knudsen and Joakim Sehested Sie from DTU Mechanical Engineering, as well as Mathias Kirk from Environmental Engineering at at DTU.

After setting a new world record, Joakim Sehested expressed to Andreas Johansen: "This means that we have to learn a lot of new skills at once when we start, but it is also really cool since it allows one to use the theory from the classes in real life, which provides one with a greater understanding".

Accreditation of the **Master's programme** in wind energy (MSc in Wind Energy)

Several months of work to get the graduate programme in Wind Energy accredited culminated on **21 FEBRUARY 2013**. It was accredited last time in 2007 and accreditation must be renewed every 6. years. At the accreditation meeting with the Accreditation Agency ACE Denmark, various groups were invited to share their experiences concerning the education and the interviews in conjunction with the submitted report of more than 300 pages. The accreditation for MSc in Wind Energy was given with the highest mark in all categories and lasts for the next 6 years.

Poul la Cour Wind Tunnel in the making

In 2016, President for DTU Anders Bjarklev, Head of Department at DTU Wind Energy Peter Hauge Madsen and Lars Christensen, Head of Division for Research Infrastructures at Danish Agency for Science and Higher Education cut the first sod for the new wind tunnel at DTU Risø Campus.

BY CHARLOTTE BOMAN HEDE

In 2017, the new wind tunnel at DTU Risø Campus will open. The wind tunnel, which is called the Poul la Cour Wind Tunnel, is a unique masterpiece due to the size of the test section. The wind tunnel will be among the biggest university owned tunnels in the world, and the combination of test possibilities makes the wind tunnel one of a kind, not just nationally but globally. This is due to the size of the wind tunnel and high flow speed as well as the possibility to combine measurements of aerodynamics and noise.

Peter Hauge Madsen, Head of Department at DTU Wind Energy looks forward to opening the new facility:

"The Poul la Cour Wind Tunnel is not only going to be a wind tunnel. It is going to be the best wind tunnel in the world," he said while cutting the first sod in June.

A great investment

President at DTU, Anders Bjarklev also praised the the new facility "I and the rest of the world have great expectations to what we can achieve by the use of the wind tunnel. The society will benefit from the new facility, which also brings Denmark and DTU Wind Energy even further out into the world," he said.

The size of the wind tunnel will make it possible to not only test parts of turbine blades but also other products, e.g. downscaled models of houses, vehicles and entire wind turbines.

Henrik Stiesdal became affiliated professor

BY CHARLOTTE BOMAN HEDE

During the fall of 2016, Henrik Stiesdal, one of the most influential professors within the field of wind energy, became affiliate professor at DTU Wind Energy.

On October 28th he gave his inaugural lecture. The title of the lecture was 'Research with impact – how to foster innovation'.

Built one of the first wind turbines

Henrik Stiesdal is well known within the field of wind energy. He built one of the first wind turbines attached to the power grid back in 1978 on a field owned by his parents. It was the beginning of the wind turbine adventure at Vestas, which Henrik Stiesdal was a part of until 1987.

After his stay at Vestas, Henrik Steisdal was employed by Bonus Energy A/S, a wind turbine manufacturer, that later became a part of Siemens, where Henrik Stiesdal worked for many years and made it all the way to the top by becoming Head of Technology in Siemens Wind Power.

175 inventions and 650 patents

Besides his impressive career, Henrik Stiesdal has also made 175 inventions and has more than 650 wind related patents.

As affiliated professor at DTU Wind Energy, Henrik Steisdal can now pass on his knowledge and innovative understanding to new generations of enthusiasts within the field of wind energy.

2014

Inauguration of
Computer cluster

The new PC cluster for high-performance computing within computational fluid dynamics, fluid structure interaction and structural optimization was inaugurated on **18 MARCH 2014**. At the official opening, DTU's President Anders Bjarklev and mayor of Roskilde, Joy Mogensen cut the red ribbon, held by Head of Department Peter Hauge Madsen.

Model of the new Large Scale Facility

Building Large Scale Facility

During the fall of 2016, work started on a new building at DTU Risø Campus. The building with the name 'Large Scale Facility,' will accommodate a unique test facility of the highest international standards for research in strength and fatigue of large structures.

BY BETINA BRINK LAURSEN WINTHER

"Large Scale Facility will provide research projects and companies with possibilities to perform tests at very large scale. In addition to the testing facilities, DTU Wind Energy will offer cooperation with a dedicated team of leading scientists and techniques that can deliver state of the art analysis. The vision is to establish a unique facility of the highest international standard for research in strength and fatigue of large structures exposed to complex loading. At the facility, new advanced test methods will be developed and the research will help to gain a better understanding of failure in large structures.

The new facility consists of a 1560 square metre test hall with three test stands capable of testing 45 m, 25 m and 15 m blades, as well as other slender structures. Inside the test hall, a 460 square meter staff building is constructed. The staff building is two stories high and contains the control room, workshop, depots, visitor centre and various service facilities. The new test facility will be well suited for static and dynamic tests of wind turbine blades, while it will also be possible to test other large structures.

The Danish Building and Property Agency is the developer and owner of 'Large Scale Facility', which is built by Dansk Halbyggeri A/S and is a part of the Villum Centre for Advanced Structural and Material Testing (CASMaT).

Large Scale Facility will be ready for use during the summer of 2017.

Floating test rig inaugurated at DTU Risø Campus

JUNE 26, 2014 the INDUFLAP project inaugurated the rotating test rig site at DTU Risø Campus. The inaguration took place at the row of wind turbines and participants could take a closer look at the test rig and prototype flaps. The rotating tests have served as proof of the concept of the flap system working on operational loading corresponding to full-scale conditions on a MW turbine.

The DTU Risø Campus site in the 1980's and 2017

Coursera was a major success

DTU Wind Energy launched a course on the online education platform Coursera in 2016. The course is a major success with more than 20.000 participants so far.

BY ALMA SALNAJA

The use of E-learning increases day-by-day, making material accessible from any place in the world. Coursera is one of leading platforms for massive open online courses.

Thus, DTU Wind Energy initiated an online course about wind energy on the American platform in 2016. The course gives an overview of key aspects of wind energy engineering.

There has been a mix of scientists, professors and researchers involved to create material through the most fundamental disciplines of wind energy research, such as wind measurements and resource assessment, aerodynamics, wind turbine technology, structural mechanics, materials, financial and electrical systems.

Several thousand participants

Merete Badger, senior researcher at DTU Wind Energy has been in charge of the Coursera course, which she calls a major success:

"We had been talking about the course for several years but now we wanted to put it into action," she says and continues:

"We hoped that the public would welcome the course, but we only dreamed that it would be such a success."

A year after the launch of the course, the enrollment for the course reached 21,752 people, of which 5 % bought the course certificate.

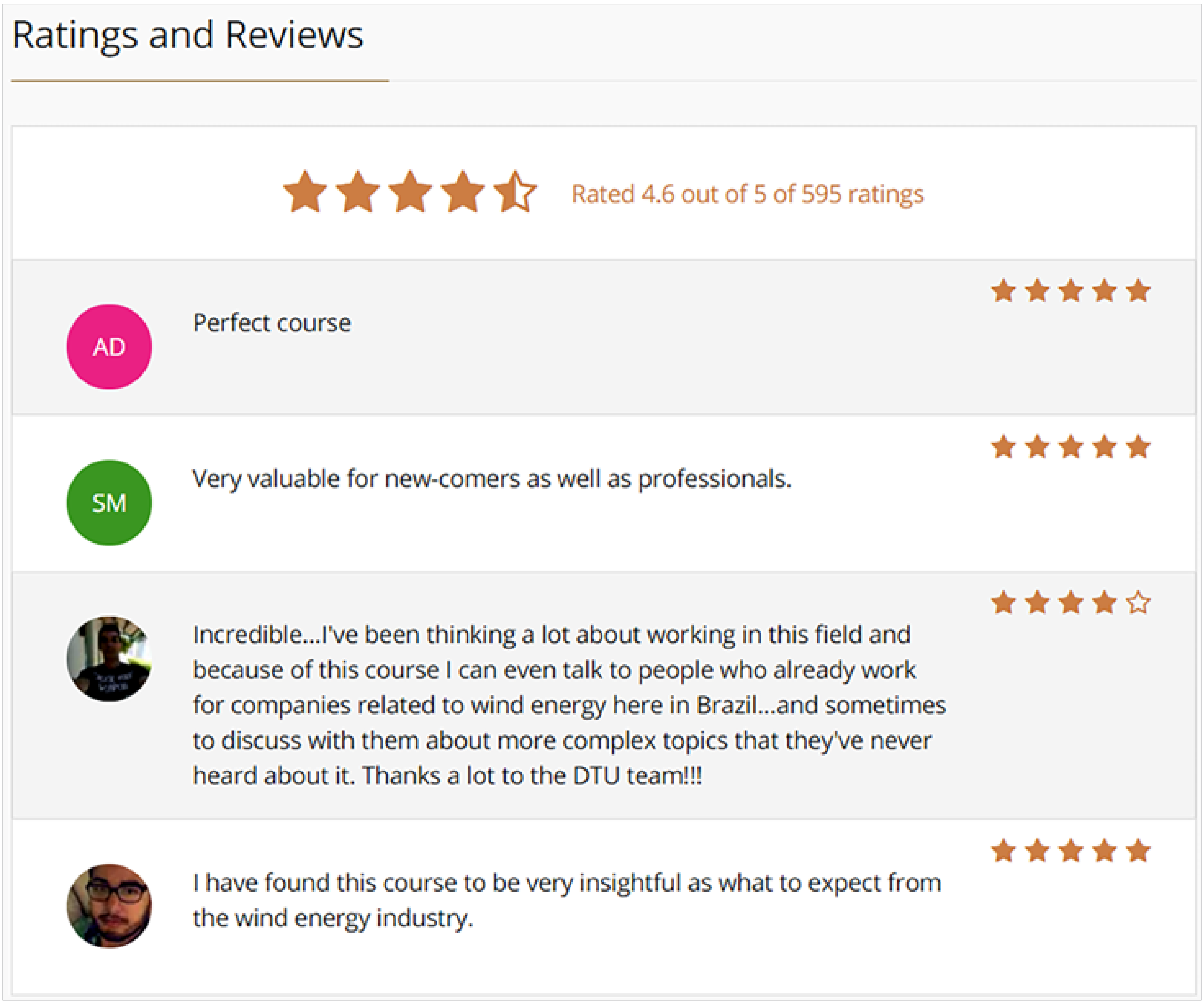
Participants in the course are grateful for this new opportunity to study wind energy online. Of the people, who have left feedback, 97 procent were positive. Among them is Rafael León from Venezuela. He writes: "I loved that the course was very clear in its objectives, and it was very focused on the principal considerations that should be taken to extract energy from the wind."

The Coursera course continues in 2017.

21.752 PARTICIPANTS ENROLLED
36% OF THE PARTICIPANTS HAVE A BACHELOR DEGREE
32% OF THE PARTICIPANTS HAVE A MASTER'S DEGREE
49% OF THE PARTICIPANTS HAVE A FULL-TIME JOB AND PARTICIPATED IN THE COURSE WHILE WORKING

South Africa **Wind Atlas** Finalized

The finalization of the Wind Atlas for South Africa (WASA) Project for the Western Cape and parts of the Northern and Eastern Cape marked an important milestone in South Africa's renewable energy efforts. WASA is implemented as a research and capacity building project with SANEDI as the Executing Agency and DTU Wind Energy as a main partner, providing the methods for calculating wind and extreme wind atlases. Other partners included CSIR, SAWS and UCT (CSAG).



Ratings and Reviews

Rated 4.6 out of 5 of 595 ratings

AD Perfect course

SM Very valuable for new-comers as well as professionals.

Incredible...I've been thinking a lot about working in this field and because of this course I can even talk to people who already work for companies related to wind energy here in Brazil...and sometimes to discuss with them about more complex topics that they've never heard about it. Thanks a lot to the DTU team!!!

I have found this course to be very insightful as what to expect from the wind energy industry.

An excerpt of the reviews of the DTU Wind Energy Coursera course

2015

PhD-student wins award in renewable energy

PhD-student at DTU Wind Energy, Nikola Vasiljevic, won the PhD Annual Award in Renewable Energy. The theme was 'Innovation and cost saving' and DNV-GL announced Nikola Vasiljevic from DTU Wind Energy as winner of the award for his PhD thesis: 'A Time-space Synchronization of Coherent Doppler Scanning Lidars for 3D Measurements of Wind Fields', during the EWEA Conference in **MARCH 2015**. With the award came a 5000-euro cash prize.

HERE YOU WILL FIND TWO EXAMPLES OF PROJECTS LED BY THE DEPARTMENT AND FUNDED BY EUDP IN 2016

Blatigue
- Fast and efficient fatigue test of large wind turbine blades

Kick-off meeting 7-8 December 2016

Failure of trailing edge in full-scale blade test

BY PROJECT LEAD, KIM BRANNER

DTU Wind Energy, Siemens Wind Power, Blade Test Centre A/S (BLAEST), R&D A/S, Olsen Wings A/S, DNV GL Denmark, DONG Energy Wind Power A/S and Zebicon A/S have therefore joined forces in a project named BLATIGUE. The objective of BLATIGUE is to develop fast and efficient fatigue test methods for large wind turbine blades and to develop equipment to excite the blades under such tests.

"The tests that have been used until today are not representing the real world sufficiently. In reality, blades are exposed to torsion and bending in different directions at the same time. That is some of the things that BLATIGUE will deal with," says Peter Hauge Madsen, Head of Department at DTU Wind Energy.

An important development

As blades become larger, the time needed to perform the necessary certification tests becomes longer. This is converting into a challenge for the industry as 100m blades may take more than a year to test. There is a need to shorten the test time and multi-axis test methods can do that as flap and edgewise loads can be tested at the same time.

The business partner Siemens were never in doubt whether to participate in the project. Rasmus Ladevig, Head of Blade Test at Siemens Wind Power says:

"Siemens has been part of developing the wind industry to the current level, including blade design and test. By joining representatives from certifying bodies, clients, other test centers and the research capacity of DTU Wind, we expect to be part of developing the next generation of structural blade test."

The BLATIGUE project is the first project that will use the Large Scale Facility. Read more on page 9.

FUNDING: EUDP
PROJECT PERIOD: NOVEMBER 1ST 2016 – MAY 31ST 2020

New V52 turbine at Risø Campus

In **APRIL 2015**, a new addition was made to the distinctive row of wind turbines on DTU Risø Campus. DTU started seeking out a new turbine back in 2010, but it was not until 2014 that a stalled project in Italy presented the University with the chance to purchase a Vestas V52 turbine, that was 'small' enough to be added to Risø's row of turbines, and large enough to match the commercial models.

"First and foremost, we are delighted to have a modern turbine here, close to our workplace, where we can decide for ourselves which experiments to run, when, and for how long. This is crucial to our ability to verify our models and hypotheses," said Thomas Buhl, Head of Section at DTU Wind Energy at the time.

Lidar detection of wakes for wind Turbine optimization

**BY PROJECT LEAD FOR DTU,
EBBA DELLWIK**

Since 2008, Windar Photonics A/S (Windar), DTU Photonics and DTU Wind Energy have successfully developed and marketed a two-beam lidar sensor "WindEye" for wind turbine optimization. The collaborative efforts resulted in the WindEye (Fig 1, left), now commercially sold by Windar, and the new four-beam sensor (Fig 1, right). In the "Lidar detection of wakes for wind turbine optimization" project, the engineers at Windar will collaborate closely with the DTU researchers on wind analysis and software development for wake detection, and to estimate the effects of using Windar's lidars on wind turbine performance in wake and half-wake situations. At DTU Wind Energy, the project participants are a good mix of lidar experts, wind turbine control specialists and wind farm researchers.

Measures incoming wind

In standard operation, the lidar sensor measures the incoming wind to the turbine along the two or four line-of-sight directions. By comparing the line of sight wind speed from the right and the left beam, it can be determined whether the turbine is correctly aligned to the wind field or not. The sensor directly quantifies how much the turbine should be yawed in order to maximize its energy production. However, this operation is only successful when the incoming wind field is homogeneous. In the case when wind turbines are located in clusters, upstream wind turbine wake makes the wind field approaching the turbine inhomogeneous.

The first aim of the current project is therefore to introduce wake detection into the software of the lidar signals, such that a distinction between the two situations becomes evident. A second aim of the project is to use all the information in the detected wake and introduce wake compensation algorithms to make the turbine yaw in the correct direction also in wake situations. If successful, this would mean that the WindEye sensor's applicability would be significantly enhanced. The third aim of the project is to demonstrate different turbine control strategies for minimizing the loads on the turbine, while still keeping the energy production high.

FUNDING: EUDP
PROJECT PERIOD: OCTOBER 1ST 2016 – SEPTEMBER 30TH 2018

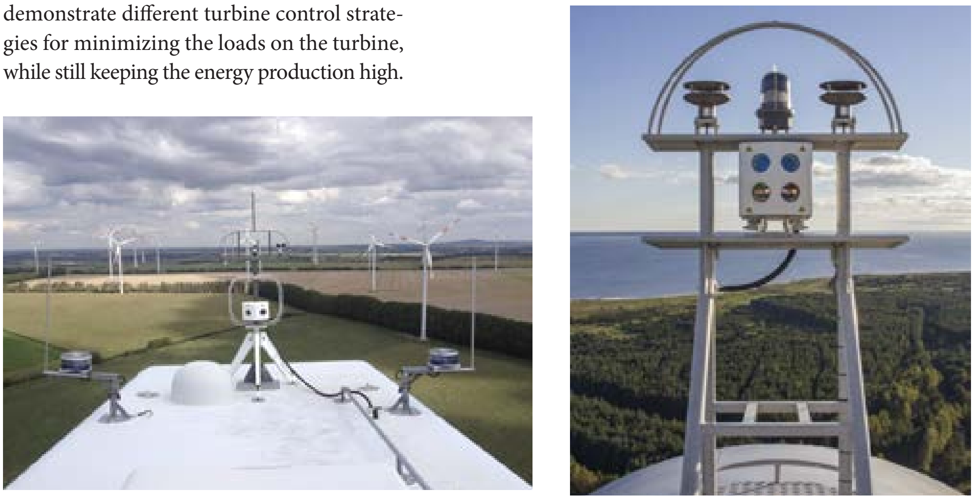
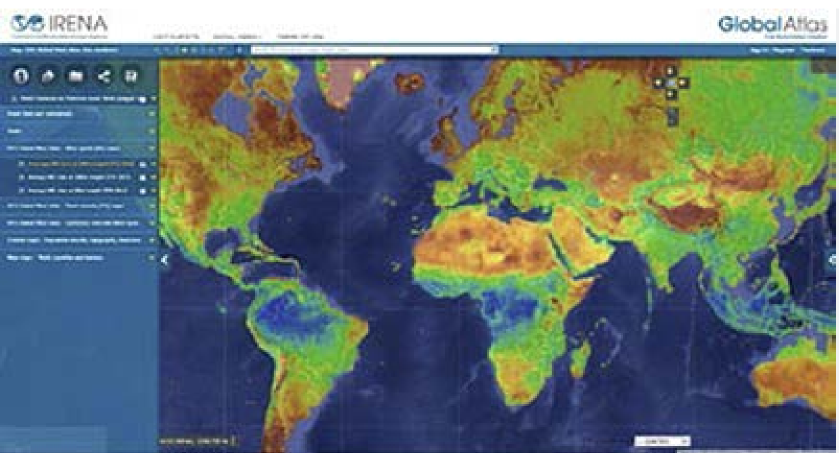


Fig. 1 The core instruments used in the project are the commercial sensors sold by Windar Photonics.



Launch of **Global Wind Atlas**

A global wind atlas for improving global wind power utilization was launched in **OCTOBER 2015**. DTU Wind Energy played a key role in developing the wind atlas, a free tool for world energy planners. The global wind atlas is a tremendous asset for all nations looking to explore the possibilities for wind energy."

Two test sites evolving

BY POUL HUMMELSHØJ

At the two full-scale test sites in Høvsøre and Østerild, DTU Wind Energy performs research projects in cooperation with the wind turbine industry. Innovations and computer models of the turbines as well as wind flow and turbulence around the turbines are studied in detail. Researchers use measurements from tall towers up to 250 m and lidars (measuring wind speed with laser light) to understand and improve the quality of the turbines – in order to reduce the cost of electricity.

The Test Station for Large Wind Turbines in Høvsøre has been operative since 2003. The purpose of the test site is to perform the final full-scale test of the complete wind turbine. All of the individual sub components are tested individually to prove they interact in a full-scale wind turbine.

A typical test program consists of measuring power curves, loads on the construction, noise emission, electrical grid integration and other sub component tests. These are the last steps for the final product before the installation at wind farms worldwide, onshore as well as offshore.

The test station in Høvsøre can host five prototype wind turbines, each having a max-

imum total blade tip height of 165 m above ground level. All of the five stands have been in use from 2003 until today.

Østerild – National Test Centre for Large Wind Turbines

The National Test Centre in Østerild opened in 2012. The purpose of the test centre was to meet the increasing requirements for testing full-scale prototype turbines. Concurrently, the size of the turbines installed has outgrown the test station in Høvsøre. Consequently seven larger test sites were installed in Østerild, each with a maximum effect of 16 MW and a maximum tip height of 250 m above ground level.

At Østerild, focus is mainly on wind turbines for the global offshore marked, as the size of the wind turbines fulfil the call for reducing the cost of energy from offshore wind farms.

A visitor centre at Østerild is going to open in 2017.

The National Test Centre in Østerild opened in 2012. The purpose of the test centre was to meet the increasing requirements for testing full-scale prototype turbines. Concurrently, the size of the turbines installed has outgrown the test station in Høvsøre. Consequently seven larger test sites were installed in Østerild, each with a maximum effect of 16 MW and a maximum tip height of 250 m above ground level.

At Østerild, focus is mainly on wind turbines for the global offshore marked, as the size of the wind turbines fulfil the call for reducing the cost of energy from offshore wind farms.

A visitor centre at Østerild is going to open in 2017.

TEST CENTRE FOR LARGE WIND TURBINES AT HØVSØRE

§ 5 WIND TURBINES

§ THE TALLEST TURBINE AT THE TEST SITE IS CURRENTLY THE SIEMENS SWT-3,6 130, WHICH HAS A TIP HEIGHT OF 164.5 METERS

ØSTERILD NATIONAL TEST CENTRE FOR LARGE WIND TURBINES

§ 7 WIND TURBINES

§ THE TALLEST TURBINE AT THE TEST SITE IS CURRENTLY THE VESTAS V164-9.0 MW, WHICH HAS A TIP HEIGHT OF 222 METERS

PhDs finished in 2017

Name: Christian Pavese
Nationality: Italian

Project Title:
Light Weight Rotor Design – Combined Passive and Active Control Methods

Supervision: Taeseong Kim

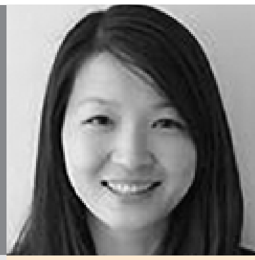
Abstract:
In the last two decades, several studies have been conducted to show the potentials of both passive and active control techniques. The research within wind energy field has been focused on the development of blade designs that employs only a single passive or active control strategy at a time. The current work aims at studying the load alleviation potential for a combination of passive and active control methodologies with the final goal of proposing new and innovative concepts for lightweight and lifeendurin g wind turbine blade designs. The idea is to find and exploit synergies between the control methods analyzed, alleviating their negative characteristics where possible. Due to the high complexity of the constraints and the design problem itself, which touches many different disciplines, such as aerodynamics, structural dynamics, control theory, etc., a multidicisplinary optimization framework is used.

Name:
Juan Pablo Murcia Leon
Nationality:
Colombian

Project Title:
Uncertainty Quantification of Wind Farm Flow Models

Supervision: Pierre-Elouan Mikael Rethore

Abstract:
There is a need for estimating the uncertainty of the predictions of wind farm performance. Investors and financial institutions are interested in receiving information that could help them make better decisions about investing in a particular wind energy project. Modern methods for uncertainty quantification estimate the probability distributions of the input uncertain variables and study how they propagate through the model chain. Realistic distribution of the parameters that describe the turbulent inflow field have been used to determine their effect in the lifetime performance of a wind turbine aeroelastic model. Stationary wake models have been calibrated and validated with respect to operational data of large offshore wind farms, from which the uncertainty in the model parameters and model prediction error can be estimated. A complete estimation of the uncertainty in the lifetime performance of a wind turbine inside a power plant can be estimated by combining the realistic distributions of the uncertain input variables with the resulting distribution of model parameters and historical model prediction errors. The uncertainty in the lifetime performance can be used to estimate the uncertainty in the levelized cost of energy or to estimate the risk for a particular investor of a new wind energy project



Name:
Chaoling Xu
Nationality:
Chinese

Project Title:
Nucleation of Recrystallization at Selected Sites in Deformed FCC Metals

Supervision: Dorte Juul Jensen

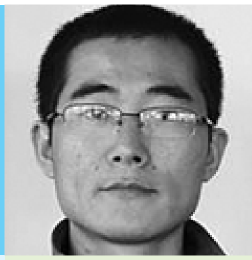
Abstract:
The nucleation process strongly affects the development of recrystallization texture and microstructure development of metals and alloys, and is thus of significant importance for the final properties of these materials. In the present study, nucleation of recrystallization at selected sites in deformed fcc metals is explored.
In the cold rolled columnar grained nickel samples, the preference of TJs and GBs as nucleation sites is observed. The majorities of the nuclei have the same orientations as the surrounding matrix or are twin-related to a surrounding deformed grain. Only a few nuclei are observed with orientations different from the surrounding matrix. Hardness measurements at TJs in the deformed sample indicate a weak correlation between the difference in hardness of the three grains at the TJs and the potentials of the junctions to form nuclei: the higher the difference, the more likely is nucleation.
In the weakly rolled and indented aluminium samples, it is found that hardness indentations lead to large orientation rotations near indentations tips. In initial grains of different crystallographic orientations, the grains with higher SE in the rolled microstructures have higher average hardness values and higher nucleation probabilities. In general, indentations with higher hardness values have higher nucleation potentials. The orientations of the nuclei from different indentations in a given grain are observed not to be randomly distributed, but clustered in limited orientation spaces. The orientation spread observed near the indentation tips in the deformed state covers the orientations of the nuclei observed in the annealed state.

Name:
Jayachandra Naidu Sakamuri
Nationality: Indian

Project Title:
Coordinated Control of Wind Power Plants in Offshore HVDC Grids

Supervision: Nikolaos A. Koutouloulis

Abstract:
The objective of this project is to develop, implement, and test control strategies for offshore wind power plants connected through multi terminal HVDC grid to provide ancillary services such as frequency support, voltage, power oscillation damping, and fault ride through capability. More specifically, the objectives of the project are focused on the investigation of the technical capabilities and control characteristics of large offshore wind farms connected to HVDC grid and on the development of control strategies that will allow the effective delivery of ancillary services from HVDC grid with large amounts of wind power.
North Sea has created additional market for HVDC connection between onshore AC Grid across borders and WPPs, loads at offshore platforms for the exchange of power and balancing services. This project will provide the technical solutions to provide ancillary services from offshore WPP to onshore AC Grid which will enhance the penetration of wind power in power systems.



Name:
Jianting Du
Nationality: Chinese

Project Title:
Coupling Atmospheric and Wave Models for Storm Cinditions

Supervision: Xiaoli Guo Larsen

Abstract:
My PhD project is to couple the atmospheric model and the ocean wave model for storm simulations, especially for the coastal areas in the North Sea. For this particular purpose, an offline coupled wind-wave modelling system: WRFMIKE 21 SW is developed for the coastal areas, and an online coupled wind-wave modelling system: WRF-SWAN is implemented for North Sea storm simulations. In the coupling, the atmospheric model provides 10 meter wind speed to the wave model and the wave model feeds back the sea surface roughness length (z0). Sensitivity study shows that the state-of-the-art z0 parameterization approaches cannot represent the complicity of the sea state in storm conditions and in coastal areas. We developed a dynamical coupled interface, namely, a wave boundary layer model (WBLM) based on the momentum and kinetic energy conservation in the air-sea interface. The WBLM is imbedded in SWAN as a new wind-input source function for the calculation of the wave growth and the estimation of the sea surface stress. The new WBLM approach is proved to be able to improve both the wind and wave simulations through idealized fetch-limited study and real storm simulations.

Name:
Kristine Munk Jespersen
Nationality: Danish

Project Title:
Fatigue Damage Evolution in Fibre Composites for Wind Turbine Blades

Supervision: Lars Pilgaard Mikkelsen

Abstract:
This PhD project experimentally examines fatigue damage evolution in a uni-directional non-crimp fabric based glass fibre composite used for the main load carrying parts of a wind turbine blade. X-ray computed tomography is used to study the damage initiation and progression in 3D by intially examining the damage and one damage state, and later at several states by time-lapse X-ray CT experiments. From the experimental results, both initiation and progression of the damage has been observed. It has given important knowledge required to improve the fatigue properties of the material and also in relation to how the mechanisms can be modelled to predict the fatigue life in future studies.

Name:
Kaya Onur Dag
Nationality: Turkish

Project Title:
Development of Large Eddy Simulation Tools for Simulation of Atmospheric Boundary Layers in Wind Farms

Supervision: Jens Nørkær Sørensen

Abstract:
The general scope of the project is to develop a high-order accurate Navier-Stokes/ Actuator Line technique for Large Eddy Simulations of turbulent boundary layers around and inside wind farms. The numerical approach is anticipated to combine high-order finite-difference schemes with a Fourier-decomposed spectral method where horizontal axes will be represented by Fourier modes and the vertical will be treated with a high-order finite-difference approach. Various sub-grid scale turbulence models will be considered and tested, and the code will be validated against in-house EllipSys code and full-scale experimental data. Additionally, the code will be parallelized and optimized for CPU/GPU heterogeneous computing.

Name:
Antoine Borraccino
Nationality: French

Project Title:
Using Nacelle-mounted Lidars in Wind Turbine Power and Load Measurements

Supervision: Michael Stephen Courtney

Abstract:
Profiling nacelle lidars probe the wind at several heights and several distances upstream the rotor. Yet, it is still unclear how to condense the lidar raw measurements into useful wind field characteristics such as speed, direction, vertical and longitudinal gradients (wind shear). In this paper, we demonstrate an innovative method to estimate wind field characteristics using nacelle lidar measurements taken within the induction zone. Model-fitting wind field reconstruction techniques are applied to nacelle lidar measurements taken at multiple distances close to the rotor, where a wind model is combined with a simple induction model. The method allows robust determination of free stream wind characteristics. The method was applied to experimental data obtained with two different types of nacelle lidar (5-beam Demonstrator and ZephIR Dual-Mode). The reconstructed wind speed was within 0.5% of the wind speed measured with a mast top-mounted cup anemometer at 2.5 rotor diameters upstream of the turbine. The technique described in this paper overcomes measurement range limitations of the currently available nacelle lidar technology.

Name:
Harald Debertshäuser
Nationality:
German

Project Title:
Modelling of Low Frequency Noise from Wind Turbines

Supervision: Wen Zhong Shen

Abstract:
Our approach to simulate low frequency noise of wind turbines is to combine two different methods. First, we calculate the fluctuating incompressible flow field around a wind turbine with the Actuator Line Model and Large Eddy Simulation (LES).
Then we take the incompressible solution as an input for solving perturbation equations. These equations are derived by subtracting compressible from incompressible NavierStokes equations, with a decomposition of flow variables. This twostep approach is referred as Flow Acoustic Splitting Technique. Since we solve compressible NavierStokes equations, reflection, diffraction, and other nonlinear effects are included in the model. This is not the case for acoustic analogies such as Lighthill, which are based on linearized wave equations combined with predefined sound sources.

Name:
Kasper Sandal
Nationality:
Norwegian

Project Title:
Design Optimisation of Jacket Structures for Mass Production

Supervision: Jesper Mathias Stolpe

Abstract:
Offshore wind turbines are mounted on costly bottom-fixed support structures such as monopiles and jackets. Design optimization of offshore wind turbine support structures is a complex engineering task. The newly funded Danish strategic research project ABYSS at DTU Wind Energu develops novel mathematical models, reliable numerical optimization techniques and software for optimal structural design of cost effective bottom-fixed offshore wind turbine support structures for all relevant water depths including deep waters in excess of 50m. The particular responsibility of my PhD project is to include mass manufacturing considerations in the optimization process.

Name:
Alexander Raul Meyer Forsting
Nationality: German

Project Title:
Scholarship Associated with DSF Project UniTTe

Supervision: Niels Troldborg

Abstract:
Lidars (wind speed measuring lasers) will change the way wind turbines sense the wind. Instead of measuring far away from the turbine, they will measure within one rotor diameter of the turbine. This will enhance the correlation between the measured wind field and the one ultimately interacting with the turbine. It will lower the uncertainty in power curve assessment and allow better individual as well as communal turbine control. Our inflow models are essential to these measurements close to the turbine rotor, as they will offset the measurement uncertainty from rotor effects. We use a multi-fidelity modelling approach in combination with extensive validation through field measurements. We validated of our high fidelity model and have derived a simple engineering model, which can be used for commercial purposes. Furthermore, our findings might channel into future IEC standards on power curve assessment.

Name:
Jeppe Bjørn Jørgensen
Nationality: Danish

Project Title:
Adhesive Joints in Wind Turbine Blades

Supervision: Bent Fruergaard Sørensen

Abstract:
The overall business objective of the project is to reduce the cost of energy by enabling manufacturing of longer and more cost efficient wind turbine blades. More specifically, this project will develop and improve analysis tools for adhesive joints in wind turbine blades. This will enable the industry to design closer to the actual structural limits.
The main research objective is, based on fracture mechanics, to develop a generic analytical model which can predict the crack initiation and propagation of both the transverse and longitudinal cracks. The state of the art theory will be used together with modern experimental methods to generate generic models, which can be applicable on the family of joints. It will be beneficial if a single generic model can be applicable to all members of the joint family. The mathematical models and analytical methods should be integrated into design rules, which are suitable for improving the joint design for large wind turbine blades. The generic model of the joints must be developed using more detailed (e.g. cohesive zone) models, which are not yet available.

PhDs finished in 2016

Name: Giorgio Demurtas
Nationality: Italian

Project Title:
Performance Measurements with the use of Spinner Anemometry

Supervision: Troels Friis Pedersen

Abstract:
The goal of this PhD project was to investigate the feasibility of use of spinner anemometry for power performance measurements. First development of spinner anemometer was related to calibration of yaw misalignment measurements. Here the first innovation was made in the spinner anemometer mathematical model, introducing a new calibration constant, kα =k1/k2. This constant was found to be directly related to measurements of inflow angle (yaw misalignment and flow inclination). The calibration of the constant was based on yawing the stopped turbine several times in and out of the wind comparing the varying inflow angle measurement with the yaw position sensor. The calibration for inflow angle measurements was further improved with an innovation step to calibrate without use of the yaw position sensor, saving cost and time of installing the additional yaw sensor. The so called "wind speed response method" was validated by comparing 27 different calibration tests to the fist methods. This method is now used as default in commercial calibrations.

Name: Matias Sessarego
Nationality: Canadian

Project Title:
Design of Large Wind Turbines using Fluid-Structure Coupling Technique

Supervision: Wen Zhong Shen, Néstor Ramos-García, Jens Nørkær Sørensen

Abstract:
Aerodynamic and structural dynamic performance of modern wind turbines are routinely carried out in the wind energy field using computational tools known as aero-elastic codes. Most aero-elastic codes use the blade element momentum (BEM) technique to model the rotor aerodynamics and a modal, multi-body, or finite-element approach to model the turbine structural dynamics. A novel aero-elastic code has been developed called MIRAS-FLEX. MIRAS-FLEX is advantageous to standard aero-elastic codes because it uses a more advanced aerodynamic model than BEM and is still computationally efficient. MIRAS-FLEX combines the three-dimensional viscous-inviscid interactive flow method, MIRAS, with the structural dynamics model used in the aero-elastic code FLEX5.
Following the development of MIRAS-FLEX, a surrogate optimization methodology using MIRAS alone was developed for the aerodynamic design of wind-turbine rotors. Designing a rotor using a computationally expensive MIRAS instead of an inexpensive BEM code represents a challenge, which is resolved by using the proposed surrogate-based approach. Results demonstrate that the methodology is effective for the aerodynamic design of wind-turbine rotors.

Name: Alexander Rudolf Stäblein
Nationality: German

Project Title:
Optimal Design of Adaptive Wind Turbine Blades

Supervision: Morten Hartvig Hansen

Abstract:
The effects of bend-twist coupling on the aeroelastic response and stability limits of wind turbine blades are investigated in this thesis. Bend-twist coupling creates a feedback loop between the aerodynamic forces and the blade geometry which can be utilised to tailor the aeroelastic response of the blade, for example to reduce fatigue loads. The coupling arises from the blade geometry (e.g. pre-bending, sweep, or bending under loading), or from the anisotropic properties of the blade material (material coupling). The research in this thesis focuses on material coupling which is modelled by varying the coupling term of bending and twist in the cross-section stiffness matrix.
The effects of anisotropic material on the structural response of wind turbine blades are reviewed and an analysis framework for coupled blades is proposed. For the analysis of elastically coupled blades, an existing Timoshenko beam element formulation is extended to allow for anisotropic cross-sectional properties.

Name: Jun Sun
Nationality: Chinese

Project Title:
Statistical Characterization of Metal Microstructures

Supervision: Dorte Juul Jensen

Abstract:
The boundary migration during recrystallization is by nature a heterogeneous process and local structural variations form on recrystallization boundaries. The local structural variations, in the form of protrusions and retrusions, can provide a dragging/driving force due to the local boundary curvature and affect the further migration of recrystallization boundaries. In order to develop new understandings and models for boundary migration that take the heterogeneous local structural aspects into account, a detailed characterization is essential of partly recrystallized microstructures focusing on the local shapes of the boundaries, in particular on whether protrusions and retrusions are formed or not. Quantification of the "amount" of boundary roughness in the form of protrusions and retrusions is of importance for statistical investigations into the factors that potentially influence the recrystallization boundary roughening.
A method is developed for quantitative characterization of 2-D line features. The area integral invariant (AII) is employed as a morphological variable to obtain information of local structural variations. The AII value is direction-independent allowing unbiased characterization of morphological irregularities with both closed and non-closed boundary profiles.

Name: Lucie Chapelle
Nationality: French

Project Title:
Mechanical Properties of Stone Wool Products after Chemical and Mechanical Ageing

Supervision: Povl Brøndsted

Abstract:
Mineral wool designates a highly porous network of fibres drawn by spinning molten minerals. Traditionally, mineral wool products have found application as thermal and acoustic insulation of buildings. Recent concepts where mineral wool products are subjected to higher structural loads have emerged and as a consequence focus on the mechanical properties of mineral wool has intensified. Also understanding the deformation mechanisms during compression of low density mineral wool is crucial since better thickness recovery after compression will result in significant savings on transport costs.
In this PhD thesis, a methodology based on image analysis to characterize the 3D structure of mineral wool materials in terms of fibre orientation, fibre diameter, contacts and pore size is proposed. The method uses 3D data obtained by X-ray tomography. The measured data are fitted to probability distributions in order to facilitate the comparison of individual characteristics of different mineral wool materials and provide simple descriptors of the 3D structure. All the methods described here are applied to glass wool and stone wool. By developing a FEM model including the real characteristic of the mineral wool fibre structure, the effect of the structure on mechanical properties can be explored.

Name: Julia Lange
Nationality: German

Project Title:
PhD Scholarship in Turbulent Atomspheric Flow with Relevance for Wind Energy

Supervision: Jakob Mann Sørensen

Abstract:
The work presented in this thesis contains two diverse approaches to help understand the flow behaviour over a complex terrain site, in this case the Bolund peninsula. The first approach investigates the wake and recirculation zone downstream of the Bolund escarpment with help of a continuous-wave Doppler lidar. The instrument measures the line-of-sight windspeed 390 times per second in highly resolved 7-m tall profiles by rapidly changing the focus distance and beam direction.
Although the presented full-scale experiments around the Bolund escarpment has been performed with great success, experiments in controlled environments such as wind tunnels provide the opportunity to study problems systematically in greater detail. This large-scale wind laboratory investigation of the flow field over a large-scale model of the Bolund peninsula shows that the mean wind, wind shear and turbulence level are extremely sensitive to the exact details of the terrain.

Name: Gilmar Ferreira Pereira
Nationality: Portuguese

Project Title:
Reliabilities of Composite Materials for Wind Turbine Blades

Supervision: Lars Pilgaard Mikkelsen

Abstract:
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 co-simulation, 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.

Name: Kaushik Das
Nationality: Indian

Project Title:
Integration of Wind Power and other Renewables in Power System Defence Plans

Supervision: Poul Ejnar Sommer Sørensen

Abstract:
Increasing levels of penetration of wind power and other renewable generations in European power systems pose challenges to power system security. The power system operators are continuously challenged especially when generations from renewables are high thereby reducing online capacity of conventional controllable generations to minimum. In such operation hours, the system is typically more vulnerable to disturbances in general and major disturbances in particular.
The aim of this study is to investigate how renewable generations like wind power can contribute to the power system defence plans. This PhD project develops a new methodology to analyse the adequacy of reserves for future power systems with high penetration of wind power generation. This methodology assesses the requirements of frequency restoration reserves in order to contain the power imbalance caused by forecast errors within the designed frequency containment reserves.
This work has been done as a part of EU-FP7 iTesla project.

Name: Henrik Alsing Friberg
Nationality: Danish

Project Title:
Combinatorial Optimization over Second-Order and Industrial Applications

Supervision: Jesper Mathias Stolpe

Abstract:
Mixed-integer second-order cone optimization is a powerful mathematical framework capable of representing both logical conditions and nonlinear relationships in mathematical models of industrial optimization problems. Solution methods are already part of many major commercial solvers including that of MOSEK [73] as well as XPRESS [31], GUROBI [46] and CPLEX [50]. This thesis concerns the performance and reliability of these solvers and makes two contributions; a theoretical one and a practical one.
In the theoretical part of the thesis a fundamental issue with reliability, affecting both continuous and mixed-integer conic optimization in general, is discovered and treated. An important distinction to make between continuous and mixed-integer optimization, is that the reliability issues occurring in mixed-integer optimization cannot be blamed on the practitioner's formulation of the problem. Finally, a branch-and-bound method utilizing these mechanisms is established. In the practical part of the thesis, a lack of consensus regarding basic definitions, representations and file formats is found, thereby increasing barriers for benchmarking with decreased market transparency as result.

Load-transfer region performing an uni-axial tensile testing of a fiber reinforced composite material used in the load carrying part of wind turbine blade

DTU Wind Energy

Head of Department:
Peter Hauge Madsen

Advisory Board

Education Committee

RAM
Resource Assessment Modelling

Resource Assessment Modelling - RAM, Jake Badger

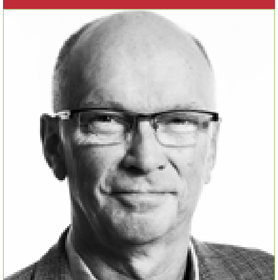
The section's research focuses on the modelling of wind flow over terrain for wind resource assessment and siting of wind farms. The research also applies both micro and meso-scale modelling of wind conditions for the purposes of wind energy, i.e. resources, turbulence, extremes, variability and other relevant qualities.

MES
Meterology and Remote Sensing

Meteorology and Remote Sensing - MES, Hans Ejsing Jørgensen

The section's research focuses on experimental, theoretical and metrological issues in wind energy related to boundary-layer meteorology, turbulence and wind turbine power performance. The research also includes atmospheric boundary layer and coastal zones as well as wind measurement techniques, including Short and Long-range WindScanner methodologies.

INP
Integration and Planning



Integration and Planning - INP, Jens Carsten Hansen

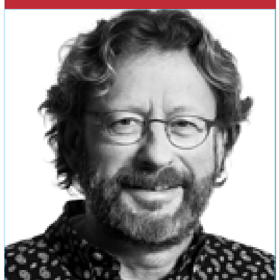
The section's research focuses on integration, control and planning of wind power. The research also includes wind farm operation and system support functionality, modelling of variability, electrical concepts for wind power plants and new control solutions and planning aspects aimed at authorities' needs.

LAC
Loads and Control

Wind Turbine Loads and Control - LAC, Kenneth Thomsen

The section's research focuses on modelling and analysis of loads and dynamics, aero-elastic stability, and control of wind turbines. Research also includes aero-hydro-servo-elastic modeling, analysis and optimization of wind turbine response and loads under real operational conditions for different wind turbine concepts.

FLU
Fluid Mechanics



Fluid Mechanics - FLU, Jens Nørkær Sørensen

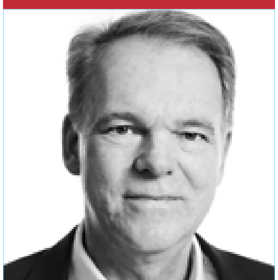
The section's research focuses on fluid dynamics applied for wind turbine aerodynamics, hydrodynamics, aero-acoustics, aero-elasticity and turbulence in wind farms. Furthermore, research is done in laminar-turbulent transition, wave propagation and flow control, numerical prediction of wave loads and wake flows in wind farms as well as in wind tunnel experiments.

Deputy Head of Department:
Peter Hjuler Jensen

AMS - Administrative Secretariat

LES - Management Secretariat

AER
Aerodynamic Design



Aerodynamic Design - AER,
Flemming Rasmussen

The section's research focuses on aerodynamic and aero-acoustic modelling and experimental research for air foil, blade design, and optimization. Research also includes CFD and fluid-structure coupling for aero-elastic design of wind turbines in wind farms including effects from wakes and terrain, experimental investigations in wind tunnels, full-scale and aerodynamic noise modelling.

SAC
Wind Turbine Structures and Components

Wind Turbine Structures and Component Design - SAC,Ignacio Martí,
Head of Section

The section's research focuses on the design and prediction of structural response of the turbine and its components and deals with structural design and optimization, reliability and loads. The research also includes advanced models and efficient numerical optimization methods used for rational structural design of wind turbine components, offshore design conditions and validation etc.

TEM
Test and Measurements

Test and Measurements - TEM,
Poul Hummelshøj

The section's research focuses on full scale tests on wind turbines at test stations in Høvsøre and Østerild where implementation of experimental research projects take place. The section's core activities are accredited power curves, load measurements, lidar calibration and wind and turbine measurements within research projects.

MAC
Material Science and Characterization

Material Science & Characterization - MAC,
Dorte Juul Jensen

The section's research focuses on processing, structural characterization and mechanical properties of metallic materials with wind energy applications. The research also includes nanometals, surface engineering and performance, effects of microstructural variations and technical advancement of wind turbine components.

COM
Composits and Materials Mechanics

Composites & Materials Mechanics - COM,
Bent Fruergaard Sørensen

The section's research focuses on manufacturing of new types of composite materials with aligned, continuous fibers, and improved description of existing composite materials, with respect to strength, fatigue, fracture, durability and resistance to damage. The research also includes manufacturing and machining, microstructure characterization, phenomenological and micromechanical models etc.

Research Programmes at DTU Wind Energy

Research at DTU Wind Energy is organized in 10 sections and three cross sectional programmes. Each programme forms a platform for developing, aligning and coordinating research and innovation efforts – from the generation of research ideas to the effective execution of projects and ultimately providing added value to the wind energy sector and society.

Siting and Integration

The overall focus is on the challenges that are associated with development of knowledge and tools for a more cost-effective siting and integration of wind power as well as electrical design and control aspects of wind turbine technology.

Offshore Wind Energy

The purpose is to provide the research-based knowledge aiming at safe and cost-optimal offshore turbine and wind farm design, including operations.

Wind Turbine Technology

The objective of this programme is to ensure the establishment, extension and application of knowledge, competences and capability basis for optimal and sustainable wind turbine design, manufacturing and operation.

Education

The programme for education is the umbrella for all educational activities at DTU Wind Energy, and is implemented by the Educational Committee. The programme coordinates and plan new teaching initiatives and ensures the pedagogical quality of the various teaching activities.

Research-based consultancy and testing

The programme coordinates test and measurements for the industry and research-based consultancy related to national and international authorities on technical requirements, strategies, project development, capacity building and planning for the wind power sector.

Study Programmes

Study Committee,
Dr. Niels-Erik Clausen,
chairman

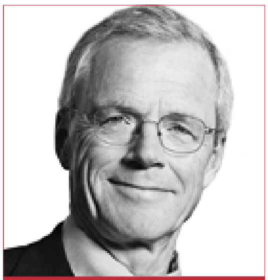
Erasmus Mundus
European Wind
Energy Master,
Professor
Jens Nørkær Sørensen

Master Programme
in Wind Energy,
Ass. Professor
Martin L. Hansen

Advisory Board

Henrik Stiesdal: Wind power pioneer and the former CTO at Siemens Wind Power A/S

"I would like to contribute to DTU Wind Energy to be able to keep and also preferably develop its long-standing status as the leading research institution in the world within wind energy."



Anders Eldrup: Former CEO at DONG Energy, Head of Board at LORC

"Denmark has for years held a leading position in developing wind energy. By joining forces from first class universities, a strong industry with a unique supply chain and with world class test facilities, I hope we can continue to contribute to develop wind industry."

Tove Felt: Vice President for Engineering Solutions, Siemens Wind Power A/S, Ballerup

"To bring industry experience and aspiration to DTU Wind Energy on the journey to become a preferred partner in a sustainable wind marked."

Michael Høgedal: Head of DX Platform, Siemens Wind Power A/S

"DTU Wind Energy is the most significant player in wind energy research and represents state-of-the-art in its field. Coming from the industry joining the Advisory Board gives me the opportunity through an outside-in perspective to contribute to the strategy of DTU Wind and thereby in a broader context help shaping the future of wind energy."

Carl Erik Skjøldstrup: Vice President for Engineering Integration, Vestas

"As member of DTU Wind Energy's advisory board I will be able to influence that the knowledge produced by DTU - through close cooperation - results in ground breaking innovations in the wind industry and that DTU ensures a pipeline of good open-minded candidates."

Education Advisory Board

Per Lauridsen
CTO
Siemens WInd Power

Søren Niebuhr
Board Director
NIEBUHR Gears

Hans G. Rømer
Senior Manager
Wind Farm
DONG Energy

Nete Bechmann
Executive HR Business
Partner
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Peter Winfeld Rasmussen
R&D system-
component-simulation
Fritz Schur Gruppen A/S

Joachim Holbøll
Professor and Deputy
Head of Centre
DTU Elektro

Jens Nørkær Sørensen
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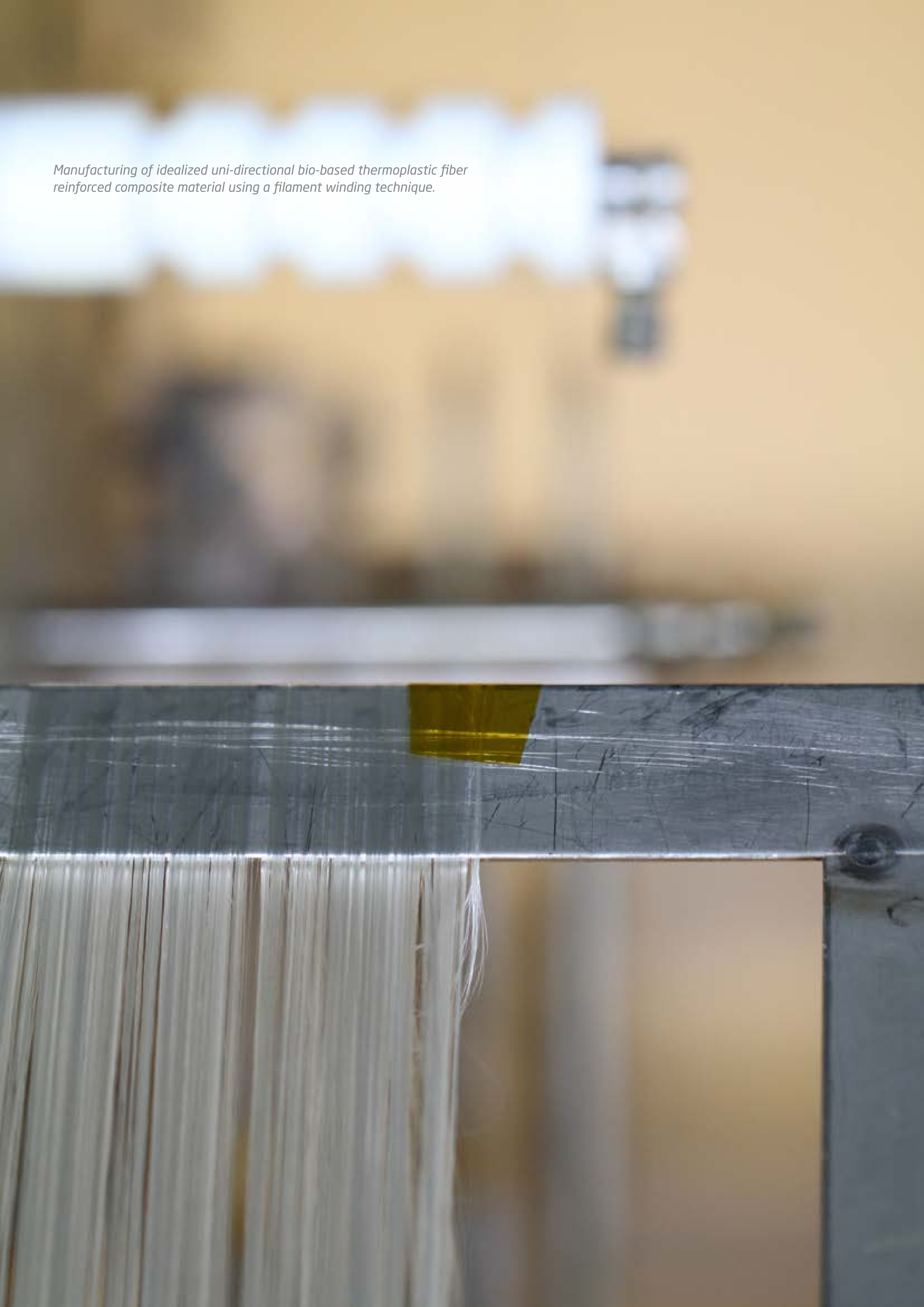

Manufacturing of idealized uni-directional bio-based thermoplastic fiber reinforced composite material using a filament winding technique.

Publications

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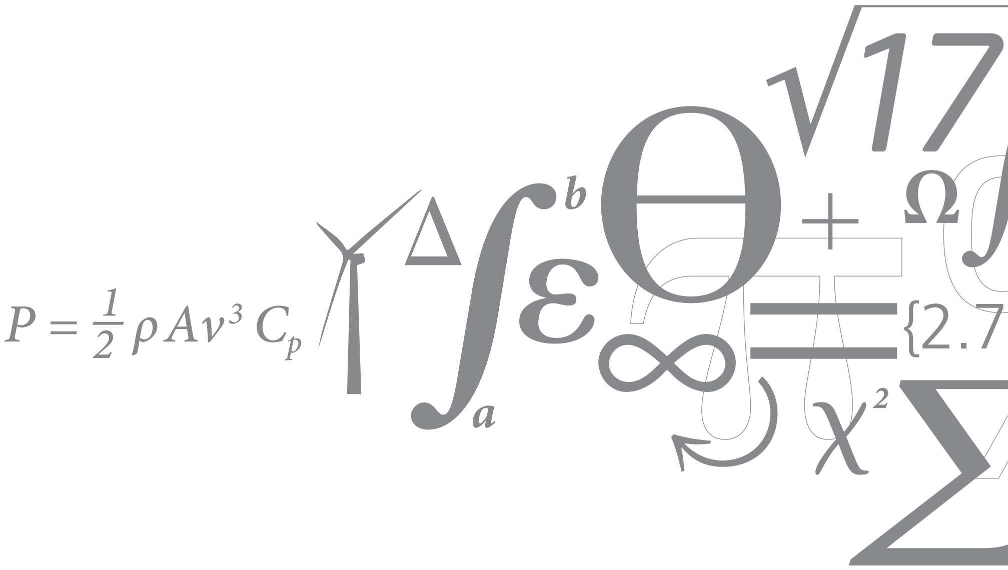
$P = \frac{1}{2}\rho A v^3 C_p$